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Substantiation of the indicators' system for assessing the state's energy security

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Abstract. The relevance of the article is due to the need to develop a indicators' system for assessing the state's energy security, which is important in the context of the aggressor's deliberate attempts to destroy Ukraine's energy systems.

The article is aimed at presenting a indicators' hierarchy that comprehensively characterise the main factors affecting energy security. The indicators development system is based on a systematic analysis of these factors.

The article presents the proposed indicators' hierarchy for assessing energy security, which are divided into two groups – military and non-military, and allow assessing both the condition of main energy's system elements (nuclear energy system, electricity system and fuel supply system), energy supply of the Armed Forces of Ukraine, and general indicators – energy independence, diversification of ways and energy's resources supply volumes, critical infrastructure condition and energy efficiency of the national economy.

A possible generalised approach to the calculation of these indicators based on aggregates of

lower-level partial indicators is also proposed.

In general, the proposed indicators' system allows to consistently assess the contribution of the energy factor to the to the meaning of overall state's defence security importance; to obtain unified energy's security level integrated indicators (provision), which will allow an unambiguous state affairs' assessment in this sphere; to determine the dynamics of changes in significant indicators when the factors on which they depend change, and, accordingly, to assess the measures' effectiveness the taken to strengthen the condition of state's energy and military security; to identify sources of possible dangers that could lead to the condition of the military (energy) state's security aggravation.

Directions for further research may include the procedure development for determining the energy supply integral indicators of the Armed Forces, energy security and their impact on the state's economic, defence and national security.

Keywords: military security, energy security, energy sector, energy carriers, electricity, energy supply, energy independence.

Introduction

As a result of the russian federation's aggression, the issue of national and, in particular, military security has become particularly important. In this context, it should be noted that the state's military security largely depends on the military-economic component, which implies a condidion of the defence sector economy that guarantees a sufficient level of military consumption during armed confrontation.

It is quite clear that military-economic security directly depends on the state's economic capabilities to maintain the military security system, i.e., on economic security.

Economic security is the main indicator of economic walfare and is determined by the contribution of all its components: social, environmental, military, legal, energy, information and other spheres of life.

At present, economic development has reached a level where the energy sphere plays a key role in terms of its impact on other economic components. Therefore, determining the energy factor contribution to economic security is crucial for analysing economic security and determining the military security condition.

At the same time, a prerequisite for the existence and state's development is to create conditions for neutralising or eliminating threats to both the energy system and the state's economy, i.e., to ensure the state's energy security.

Energy security is one of the national security most important components, a prerequisite for ensuring sustainable state's development. Energy security envisages ensuring the national interests' protection in the access area to reliable, sustainable, affordable and modern energy sources for all consumers in a technically reliable, safe, cost-effective and environmentally acceptable manner in normal conditions and crisis situations (On approval of the Energy Security Strategy, 2021).

Since the beginning of the russian aggression in 2014, a number of problems have arisen related to energy carriers supplies, loss of energy generating enterprises, etc., which has significantly worsened the difficult situation in the Ukraine's energy sector, which has hardly developed during the independence years.

In such a situation, an urgent scientific task is to assess the energy security condition, determine its impact on military and national security, which will further allow to substantiate ways to overcome the emerging problems.

Methodological Framework

The proposed system of indicators was developed on the factors' analysis basis that affect the state's energy security.

Recently, Ukraine has paid considerable attention to the military security problems, for example, (Bohdanovych, 2019) and (Bohdanovych, 2020), (Bocharnikov, 2019), (Hohoniants, 2019), as well as its important component – energy security (Sukhodolia, 2020), (Ilienko, 2019), (Matviichuk, 2018), (Topalov, 2022), (Pavlenko, 2022). However, most studies consider only one energy security aspect – political or technological. Often, energy security is understood only as the condition of the state's energy resources (oil, gas, coal). The issue of developing a methodological apparatus for substantiating measures to ensure military security by improving the state's energy security has not been sufficiently studied.

A significant drawback in this regard is the lack of a systematic approach to the study of the relationship between the state's energy security and its military security, which would allow taking into account the entire range of energy security threats, assessing their impact and justifying a list of measures aimed at improving the energy security level and, accordingly, ensuring the required level of military security.

At the same time, this complication creates a contradiction between the state's economic capabilities to improve its own energy security (in order to achieve a certain economic and military security level) on the one hand, and the need to maintain the military security system in constant readiness to counter threats on the other. This is especially important in a period when the energy sector components can be physically destroyed in a very short time.

Results and Discussions

Assessing the effectiveness of the state's energy security and measures to improve it is important for determining rational ways to ensure (increase) military security. This is especially important in the case when reaching the required level of military security cannot be achieved only by building up military power.

Military security, as a structural element of national security, characterises the ability of a state and its armed forces to confront or prevent damage to its national security by armed violence means. This is its main specificity.

In order to assess the contribution of energy security to military security, the author proposes an approach that provides its consistent assessment. To implement such an approach, we propose an appropriate indicators' system, the general structure of which is shown in Fig. 1. The proposed system contains only indicators that take into account the impact of the military security energy component.

The **military** sphere indicators characterise the energy supply condition of the Armed Forces of Ukraine.

It is proposed to use the following indicators:

Fuel supply (diesel, petrol and aviation kerosene);

electricity supply condition (mobile equipment and stationary system condition, electricity supply needs of the armed forces).

The general approach is to calculate these indicators as (Semenenko, 2021):

$$E_r = f(m_r) = 1 - e^{-m_r}; \quad (1)$$

$$m_r = \frac{S_{rn}}{S_{rp}},$$

where m_r – indicator characterising the supply of the *r*-th type resources;

S_{rn} – available stocks of the r-th type resources;

S_{rp} –demand for the r-th type resources;

E_r – supply condition of the r-th type resources.

In the **non-military** sphere, a number of indicators are used to determine the energy security condition, which characterise the electric power systems' condition, fuel supply system and nuclear

power system. In addition, indicators are proposed to assess the state's energy independence, the energy supply diversification degree, and the energy efficiency of the national economy, which, as experience has shown, has become important since the beginning of the confrontation with russia and the disruption of traditional energy and energy carriers supply routes.

The partial indicators' convolution for all non-military sphere indicators is carried out similarly to the formula (1).

The electricity systems condition indicator (except for nuclear power enterprises) is calculated using a number of known partial indicators that are calculated or determined on the statistical data basis:

share of TPSs capable to operate on two or more interchangeable fuel types;

depreciation of main production funds of fuel and energy sector enterprises;

the total income share of fuel and energy sector enterprises allocated to their modernisation and technological upgrading of main funds;

main production capacities' utilisation level of fuel and energy sector enterprises;

reserve capacity - the total established capacity ratio of power plants to the maximum actual load in the power system;

energy conversion efficiency of power generating capacities.

The fuel supply system condition is calculated using the following partial indicators:

ensuring reserve volumes and storage tanks for fuel and energy resources (oil, oil products, including fuel oil, gas, coal, etc.);

ratio of underground gas storage facilities employment to meet domestic and export needs;

level of energy transmission capacities load (oil, gas and electricity transmission systems);

unproductive losses of energy resources' main types (natural gas, oil, coal, heat and electricity) during their transportation, conversion, distribution and transmission (percentage of their final consumption).

The nuclear energy system condition is calculated using the following partial indicators:

share of energy produced by nuclear power plants in the total consumption;

depreciation of nuclear power enterprises' main production funds;

share of the total income of nuclear power enterprises allocated for their modernisation and technological renewal of main funds;

load level of the nuclear power enterprises' main production capacities;

reservation – the total installed capacity ratio of nuclear power enterprises to the maximum actual load in the power system;

energy conversion efficiency of nuclear power enterprises generating capacities.

To assess energy independence, a mono-criterion approach was chosen, based on the one indicator employment – the share of own energy resources in total consumption. This approach is justified within the framework of this study from the point of view of the need to determine an integral indicator, which is impossible when using the approaches set out in (Sobolevskyi, 2003).

Critical infrastructure's condition. Critical infrastructures of the state's energy system mean systems and resources so vital to the energy system's functioning that their incapacitation or destruction has a significant (critical) impact on national (military) security.

The study considered only those impacts on critical infrastructure related to military threats (disabling, destruction, capture). Natural and man-made threats were not taken into account. In practice, it is sufficient to consider only a limited number of attack types and object types on which they can be carried out.

At the same time, since the threat value determination implies a dependence on parameters, it should be taken into account that the threat can be represented in the format of a probability distribution, rather than a single indicator.

The critical infrastructure threat indicator is calculated using a number of partial indicators:

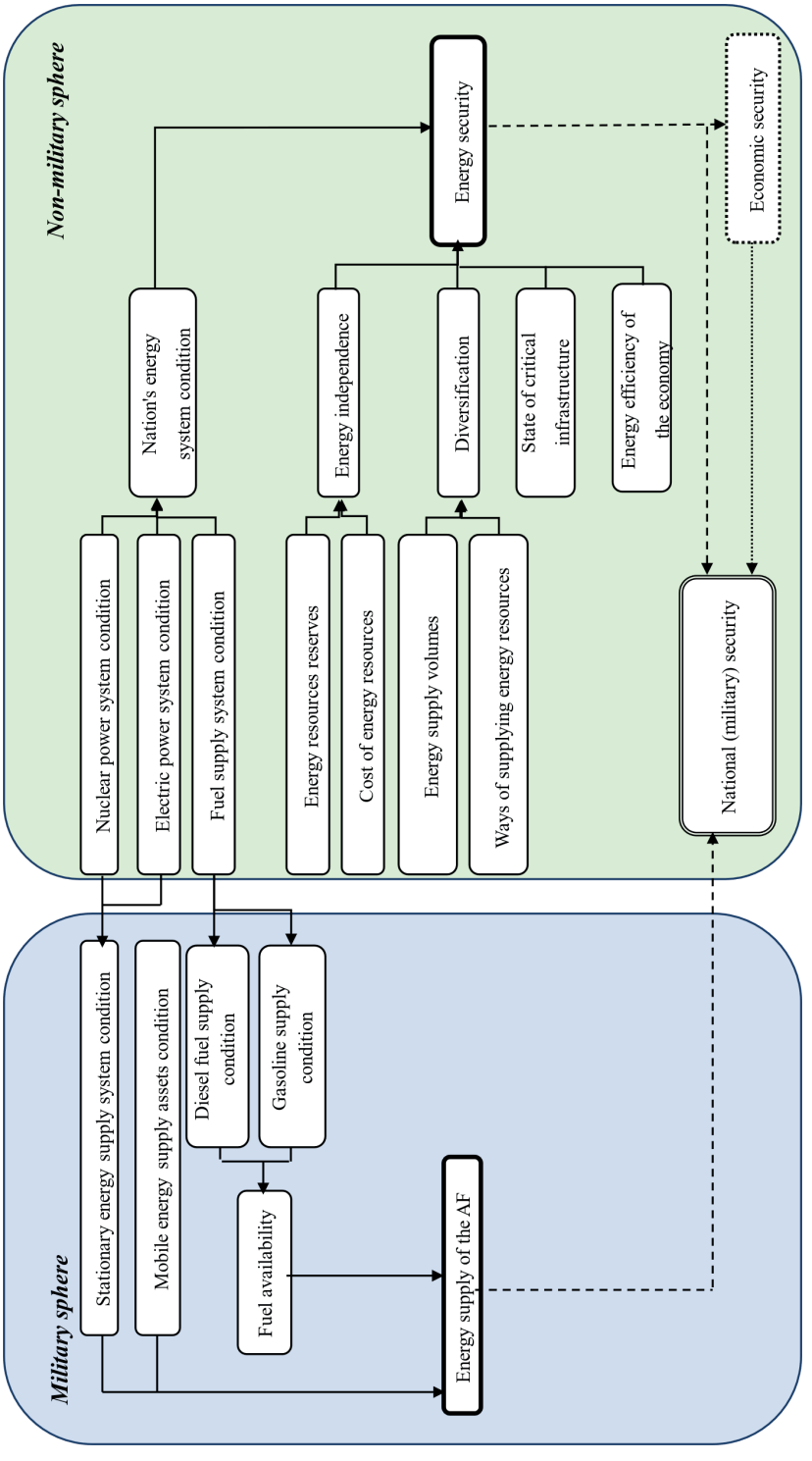


Figure 1. Indicators' system for assessing the state's energy security

threat – the probability that a certain target may be attacked in a certain way over a certain period of time;

vulnerability – the probability that an attack of a certain type appears to be successful if it is carried out;

consequences – the amount and type of damage caused by a successful attack.

The consequence magnitude is determined by the expected amount of damage over a specific period of time for a defined type of attack that results to damage to a certain target. It varies from "0" - no consequences, to "1" - complete destruction (capture) of an object or system.

The concept of the national economy energy efficiency refers to the qualitative economy condition that ensures rational and efficient employment of fuel and energy resourses in accordance with the existing level of economic and cultural development of the society, equipment and technology development, the prevailing type of society's worldview and the state's development priorities. At the same time, GDP energy efficiency is the inverse of GDP energy capacity, and the lower the energy capacity is, the higher the energy efficiency of the state's economy (Sukhodolia, 2003).

It's necessary to note that although GDP energy capacity reflects the relative efficiency of a state's employment of energy resources, it is not considered to be an absolutely accurate criterion. The GDP energy capacity indicator reflects only the trends in the national economy development in terms of energy usage, and its dynamics tracks the chosen type (energy-saving, extensive) and trends in the state's economic development.

It is proposed to calculate the value of economy energy efficiency using a number of partial indicators that comprehensively characterise the economy condition, its energy resources usage and environmental impact.

To calculate the indicators, the values of such primary indicators as the the total amount of energy consumption for production (V), the output volume (Pr) and the emissions volume into the environment (Br) are used. It should be noted that the calculations do not use the gross (extensive) values of these indicators, but rather partial efficiency indicators, which are determined by their ratio:

energy efficiency (in the general sense it is the efficiency ratio)

$$m_{en} = \frac{Pr}{V};$$

technological efficiency (reflects the internal characteristics of production processes and is the inverse share volume of harmful emissions to the environment)

$$m_{teh} = \frac{V}{Br};$$

environmental efficiency (characterises the environmental friendliness of a final product unit)

$$m_{eco} = \frac{Pr}{Br};$$

energy wastefulness (high values of this indicator by its meaning reflect environmentally efficient systems that are characterised by significant energy consumption)

$$m_{rast} = \frac{VPr}{Br};$$

environmental wastefulness (high values of this indicator reflect energy efficient systems that have a significant impact on the environment)

$$m_{prir} = \frac{BrPr}{V};$$

innovativeness (high values of this indicator indicate the production advantage over energy consumption)

$$m_{inn} = \frac{Pr}{VBr};$$

Conclusion

Thus, the proposed indicators' system allows:

to consistently assess the contribution of the energy factor to the importance of the overall state's military security;

to obtain unified integrated indicators of energy security level (provision), which will allow an unambiguous assessment of the affairs condition in this sphere;

to determine the dynamics of changes in significant indicators when the factors on which they depend change, and, accordingly, to assess the effectiveness of the measures taken to strengthen the state's energy and military security;

to identify sources of possible dangers that may lead to aggravation of the state's military (energy) security by determining critical values of indicators and to determine their importance (priorities).

The proposed indicators of the Armed Forces of Ukraine enegy supply, energy independence and energy efficiency of the state's economy, as well as diversification of fuel and energy resources supplies allow for a more complete consideration of the factors that have decisive impact on the state of military (energy) security of the country.

A direction for further research could be the development of a procedure for determining the integral indicators of energy supply of the Armed Forces, energy security and their impact on the economic, military and national security of the state.

Recommendations

The materials of the article can be used in the methodological approach development to assessing the energy security condition, modelling and predicting processes in the energy sector. The article may also be useful for information and analytical services' specialists, scientists and analysts involved in the development and justification of state decisions in the energy sector.

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Сценарії розвитку воєнного конфлікту російської федерації та України: воєнно-економічний аспект

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Анотація. Актуальність цієї статті полягає у тому, що в умовах війни, яка триває, важливо розуміти, як різні види ресурсів – фінансові, матеріальні та людські – впливають на розвиток російсько-українського конфлікту і формують основу для подальшого ефективного

протистояння. Аналіз сценаріїв розвитку цього конфлікту дає можливість оцінити вплив ресурсів на ефективність військових дій, стійкість оборонних систем, стійкість національної економіки, здатність до тривалого протистояння. Вивчення цих аспектів допомагає не тільки краще зрозуміти поточну ситуацію, а й розробити стратегії, що можуть сприяти більш ефективному використанню наявних ресурсів для досягнення бажаних результатів. Тому головною метою статті є формування комплексного уявлення про можливі сценарії розвитку воєнного конфлікту між росією та Україною з урахуванням воєнно-економічних наслідків за кожного сценарію, що допоможе у розробленні стратегій для забезпечення національної безпеки та стійкості України в умовах тривалого збройного конфлікту. Основними методами досліджень є методи: воєнно-економічного аналізу, експертного опитування та порівняння, методи математичної статистики, метод мозкового штурму, методи дедукції та формалізації. Основними результатами статті є те, що в ній: запропоновано методи проведення досліджень щодо ідентифікації сценаріїв розвитку воєнного конфлікту російської федерації проти України; визначено складові забезпечення ресурсами розвитку держави та розраховано їхні оцінки впливу на стан розвитку національної економіки до початку широкомасштабного вторгнення росії в Україну та нині; сформовано сценарії розвитку російсько-українського конфлікту та їхні характеристики; проведено аналіз результатів експертного опитування на основі прогнозованих статистичних даних щодо розвитку України протягом наступного періоду у разі розвитку подій за тим чи іншим сценарієм війни; спрогнозовано наслідки для національної економіки України та для сил оборони (Збройних Сил України) за кожного сценарію. Матеріали статті можуть бути корисними спеціалістам оборонного менеджменту та управління оборонними ресурсами, представникам керівництва Збройних Сил України та Міністерства оборони України, а також науковцям і дослідникам за воєнно-економічним напрямом.

Ключові слова: воєнно-економічні дослідження, військові витрати, макроекономічні показники, Збройні Сили України, збройний конфлікт, військові операції, людські, фінансові, матеріальні ресурси, збройна агресія, гібридна війна, національна безпека, оборонний бюджет, сценарії розвитку воєнного конфлікту, сили оборони держави.

“Якби людина вміла задовольнятися тим, що має, а не зазіхати на надбання сусіда, вона б завжди насолоджувалась світом і свободою”.
Жан де Лабрюєр

Introduction (Вступ)

Актуальність проведення досліджень щодо аналізу сценаріїв розвитку російсько-українського конфлікту полягає в тому, що дуже важливо зрозуміти, як різні види ресурсів – фінансові, матеріальні та людські – відіграють вирішальну роль у формуванні бази протистояння між росією та Україною (Оцінка KSE Institute станом на січень 2024 року, 2024; Підсумки роботи із запитами на інформацію, 2024; Василенко, 2017; Сікачинський, 2018; Гончар, 2019; Коваленко, 2020; Сидоренко, 2021; Зорін, 2022; Тарасов, 2023; Семененко, Коверга, Остапенко, Кравченко, Митченко, Тарасов, 2022; Семененко, Воронченко, Москаленко, Абрамова, Харитонов, 2021; Соломицький, Семененко, Онофрійчук, Слюсаренко, Баранов, Мітченко, 2022; Петров, 2023; Galeotti, 2018; Aslund, 2015; House, 2020; Wilson, 2014; Menon, Rumer, 2015; Kuzio, 2022; Pifer, 2017). Фінансові ресурси необхідні для фінансування військових операцій і підтримки економічної стабільності під час конфлікту. Значні економічні ресурси росії дозволяли їй фінансувати військові інтервенції та надавати фінансову підтримку сепаратистським групам на території України. З іншого боку, Україні довелося мобілізувати свої обмежені фінансові ресурси для посилення

обороноздатності та підтримки економіки в умовах конфлікту. Матеріальні ресурси, зокрема зброя, обладнання та інфраструктура, є життєво важливими для ведення війни і застосування сили в конфлікті. Наявність і якість матеріальних ресурсів часто визначають ефективність військової сили в конфлікті, як це можна побачити в російсько-українському конфлікті, де сторони з переважаючими матеріальними ресурсами мали перевагу на полі бою. Людські ресурси є критично важливими в ухваленні рішень як на полі бою, так і в управлінні (Зорін, 2022; Семененко, Коверга, Остапенко, Кравченко, Митченко, Тарасов, 2022). Вони впливають на ефективність військових операцій, управлінські процеси та загальну стабільність держави.

Materials and Methods (Матеріали та методи)

Методологія досліджень щодо визначення сценаріїв розвитку воєнного конфлікту російської федерації проти України передбачає комплексний підхід до аналізу можливих сценаріїв розвитку конфлікту з урахуванням воєнних та економічних факторів. Це, зокрема, моделювання різних варіантів розвитку подій, оцінювання їхніх наслідків, а також розроблення стратегій для мінімізації ризиків та підвищення стійкості України за різних сценаріїв продовження війни. Основні методи проведення таких досліджень та їхню характеристику наведено у табл. 1 (Оцінка KSE Institute станом на січень 2024 року, 2024; Підсумки роботи із запитами на інформацію, 2024; Василенко, 2017; Сікачинський, 2018; Гончар, 2019; Коваленко, 2020; Сидоренко, 2021; Зорін, 2022; Тарасов, 2023; Семененко, Коверга, Остапенко, Кравченко, Митченко, Тарасов, 2022; Семененко, Воронченко, Москаленко, Абрамова, Харитонов, 2021; Соломицький, Семененко, Онофрійчук, Слюсаренко, Баранов, Мітченко, 2022; Петров, 2023; Galeotti, 2018; Aslund, 2015; House, 2020; Wilson, 2014).

Таблиця 1. Основні методи проведення досліджень щодо визначення сценаріїв розвитку воєнного конфлікту російської федерації проти України

№	Метод	Характеристика	Напрям застосування
1	Сценарний аналіз	Метод передбачає створення декількох можливих сценаріїв розвитку конфлікту на основі різних вихідних умов та факторів. Сценарії передбачають як оптимістичні, так і песимістичні варіанти, а також проміжні.	Для прогнозування можливих напрямів розвитку конфлікту, оцінювання наслідків кожного сценарію та розроблення відповідних стратегій подальших дій.
2	Економічне моделювання	Використання математичних моделей для аналізу економічних показників, що впливають на конфлікт та залежать від нього. Це може передбачати моделі економічного зростання, інфляції, ринку праці тощо.	Для оцінювання економічних наслідків війни, зокрема впливу на ВВП, бюджетні витрати, рівень життя населення та інвестиційну привабливість країни.
3	Аналіз воєнних стратегій	Вивчення військових доктрин, стратегій і тактик, що можуть бути застосовані у конфлікті. Це передбачає аналіз військових ресурсів, техніки, чисельності армій, а також можливих стратегічних та тактичних ходів обох сторін.	Для розроблення оптимальних військових стратегій, що можуть мінімізувати втрати та забезпечити ефективний захист країни.
4	SWOT-аналіз	Метод оцінювання сильних (Strengths), слабких (Weaknesses) сторін, можливостей (Opportunities) та загроз (Threats), пов'язаних із розвитком конфлікту.	Для ідентифікації ключових факторів, що впливають на конфлікт, та розроблення стратегій для максимізації переваг і мінімізації ризиків.
5	Системний аналіз	Комплексний підхід, що передбачає вивчення конфлікту як системи з урахуванням взаємозв'язків між різними елементами (військовими, економічними, соціальними та політичними).	Для глибокого розуміння структури та динаміки конфлікту, що допомагає у розробленні більш ефективних стратегій управління конфліктом.
6	Аналіз чутливості	Метод, що дозволяє визначити, як зміни в певних ключових параметрах впливають на результати дослідження.	Для виявлення найбільш критичних факторів, що можуть змінити перебіг конфлікту, та розроблення відповідних адаптивних стратегій.

Застосувавши зазначені вище методи, можна отримати комплексне уявлення про можливі сценарії розвитку воєнного конфлікту між росією та Україною з урахуванням воєнно-економічних аспектів їхнього розвитку, що допоможе у розробленні стратегій для забезпечення національної безпеки та стійкості України в умовах тривалого збройного конфлікту.

Results (Результати)

Безперервні дослідження за напрямом визначення, вивчення та прогнозування воєнно-економічних особливостей сценаріїв розвитку воєнного конфлікту російської федерації проти України потрібні у зв'язку із динамічністю ситуації на фронті, постійними змінами у воєнно-політичній обстановці, а також необхідністю оперативного реагування на нові виклики і загрози. Це дає можливість ухвалювати обґрунтовані рішення, забезпечувати ефективне використання ресурсів та знижувати ризики для національної безпеки і економічної стабільності України. Важливими також є адаптація та розроблення довгострокових стратегій, що передбачають урахування міжнародної підтримки, внутрішньої соціально-економічної стійкості та модернізацію Сил оборони України. Безперервні дослідження сприяють підвищенню готовності до непередбачуваних змін у ході конфлікту, вдосконаленню системи мобілізації, підготовці до можливих ескалацій та ефективному управлінню ресурсами, що в кінцевому підсумку забезпечує стійкість держави в умовах тривалої війни.

Російсько-українська війна є безперервним конфліктом з 2014 року, коли росія анексувала Крим і підтримала сепаратистські рухи на сході України. У майбутньому може розгорнутися кілька сценаріїв щодо фінансових, матеріальних і людських ресурсів залучених до цього конфлікту (табл. 2, рис. 1).

Розглядаючи оптимістичний сценарій розвитку російсько-української війни до кінця 2024 року (табл. 2, рис. 1), ми мусимо насамперед визнати складну динаміку цього конфлікту. З фінансової точки зору, російська економіка зазнала напруги в останні роки через міжнародні санкції та низькі ціни на нафту.

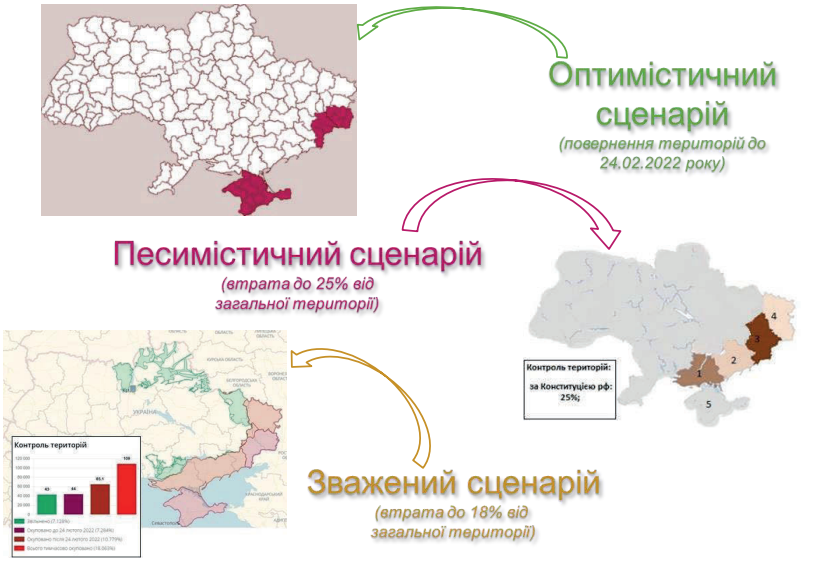


Рисунок 1. Ілюстрація сценаріїв розвитку російсько-українського конфлікту на 2024–2026 роки

Таблиця 2. Визначення та характеристики сценаріїв розвитку російсько-українського конфлікту на 2024–2026 роки

Сценарій	Зміст	Характеристики
Оптимістичний сценарій (війна закінчиться у 2024 році)	Війна завершується у 2024 році успішними переговорами або перемогою на полі бою.	Швидке економічне відновлення. Швидке скорочення витрат на військові потреби та перенаправлення ресурсів на відновлення економіки. Інфраструктурні проєкти. Масштабні програми з відновлення та модернізації інфраструктури. Зростання інвестицій. Швидке повернення довіри інвесторів, зростання внутрішніх та зовнішніх інвестицій. Реформи. Проведення необхідних економічних та соціальних реформ для прискорення відновлення. Міжнародне співробітництво. Значна підтримка міжнародної спільноти, зокрема фінансова допомога та інвестиції в реконструкцію.
Зважений сценарій (війна закінчиться у 2025 році)	Війна закінчується у 2025 році завдяки досягненню домовленостей або вирішенню конфлікту військовим шляхом.	Економічна стабілізація. Початок відновлення економіки після завершення війни, скорочення витрат на військові потреби. Реконструкція. Першочергові заходи з відновлення зруйнованої інфраструктури та житлового фонду. Інвестиції. Поступове повернення внутрішніх та зовнішніх інвестицій. Ринок праці. Повільне відновлення ринку праці, створення нових робочих місць, зниження рівня безробіття. Міжнародна підтримка. Активна участь міжнародної спільноти у відновленні країни, збільшення обсягів допомоги.
Песимістичний сценарій (війна триватиме до 2026 року включно)	За цього сценарію війна триває без перерви до кінця 2026 року. Військові дії інтенсивні, а переговори про мир не дають стійких результатів.	Економічне виснаження. Продовження витрат на військові потреби, висока інфляція, дефіцит бюджету. Інфраструктурні втрати. Значні руйнування критичної інфраструктури (мости, дороги, енергетичні об'єкти). Соціальна напруженість. Високий рівень безробіття, зростання бідності, міграція населення. Політична нестабільність. Постійна загроза військових дій, напруженість у відносинах із сусідніми державами та міжнародною спільнотою. Зовнішня допомога. Залежність від міжнародної гуманітарної та військової допомоги, але її обсяги можуть бути обмежені.
Деструктивний сценарій (війна триватиме після 2026 року протягом декількох років)	За цього сценарію відбуватиметься подальша ескалація конфлікту з великими втратами як серед військових, так і серед цивільного населення. Війна триватиме на кількох фронтах, зокрема, вестимуться постійні бойові дії, здійснюватимуться артилерійські та ракетні обстріли, а також можливі нові спроби територіальних захоплень з боку росії. Крім цього, існуватиме високий ризик втягнення у конфлікт інших країн та розширення географії війни.	Значні людські втрати. Зростання кількості загиблих та поранених серед військових і цивільних, а також подальше зростання кількості внутрішньо переміщених осіб та біженців. Економічні наслідки. Значне погіршення економічної ситуації через руйнування інфраструктури та зниження інвестиційної привабливості. Посилення інфляції, зростання безробіття та зниження рівня життя населення. Соціальні наслідки. Погіршення соціальної згуртованості та зростання психологічного навантаження на населення. Збільшення кількості соціальних проблем, таких як злочинність, безпритульність і зловживання наркотиками. Політичні наслідки. Посилення політичної нестабільності та можливість виникнення внутрішніх конфліктів. Зміна зовнішньополітичних пріоритетів та залежність від міжнародної допомоги. Гуманітарні наслідки. Збільшення гуманітарної кризи, необхідність міжнародної допомоги для забезпечення базових потреб населення. Погіршення доступу до медичних послуг, освіти та інших соціальних послуг. Міжнародні наслідки. Подальше погіршення відносин між Україною та росією, а також можливість втягнення інших країн у конфлікт. Збільшення санкційного тиску на росію та можливе посилення міжнародної підтримки України. Деструктивний сценарій продовження російсько-української війни після 2026 року матиме катастрофічні наслідки для України в усіх сферах життя. Для мінімізації цих ризиків необхідно шукати шляхи до мирного врегулювання конфлікту та зміцнення внутрішньої стійкості країни.

Основними сценаріями визначено такі: оптимістичний сценарій (війна закінчиться у 2024 році); зважений сценарій (війна закінчиться у 2025 році); песимістичний сценарій (війна триватиме до 2026 року включно); деструктивний сценарій (війна триватиме після 2026 року протягом декількох років). Кожен із цих сценаріїв має особливості та наслідки.

Проте країна все ще підтримує значний оборонний бюджет і володіє значними військовими технологіями. З іншого боку, Україна отримала суттєву фінансову підтримку від західних союзників, що дозволило їй модернізувати свої збройні сили та покращити обороноздатність.

Під час російсько-української війни Україна стикнулася зі значними фінансовими, матеріальними та людськими труднощами. Однак, незважаючи на ці перешкоди, є декілька

стратегій, які можна було б застосувати, щоб мінімізувати втрати та пом'якшити вплив війни на Україну. З фінансової точки зору, Україна могла б зосередитися на отриманні міжнародної фінансової допомоги та позик для підтримки своєї економіки під час конфлікту. Використовуючи свої відносини з міжнародними організаціями, такими як Міжнародний валютний фонд і Світовий банк, Україна могла б отримати доступ до вкрай необхідних коштів для зміцнення своєї фінансової стабільності та підтримки військових зусиль. З точки зору матеріальних ресурсів, Україна могла б визначити пріоритетним стратегічний розподіл ресурсів, щоб забезпечити безперешкодний доступ до основних засобів, таких як продовольство, пальне та боєприпаси, для її військових сил. Завдяки оптимізації логістики та ланцюгів постачання Україна могла б мінімізувати збої та підтримувати міцний захист від російської агресії, а також залучити свої людські ресурси, мобілізувавши населення для підтримки військових зусиль.

Якби війна в Україні закінчилася в середньостроковій перспективі (рис. 1) це, ймовірно, мало б значні наслідки для країни з точки зору фінансових, матеріальних і людських ресурсів. По-перше, через конфлікт, що триває, Україна зазнала серйозної економічної кризи, коли ВВП країни скорочувався, а інфляція зростала. Припинення війни прокладе шлях до економічного відновлення, потенційно залучивши іноземні інвестиції й допомогу для відновлення зруйнованих війною регіонів та інфраструктури. Більше того, матеріальні ресурси, які були спожиті під час конфлікту, такі як будівлі, дороги та заводи, слід реконструювати. Це потребуватиме значного фінансування та ресурсів, що може завдати шкоди державному бюджету. Однак після відновлення миру Україна матиме можливість зосередити свої ресурси на розвитку та відбудові, а не на військових витратах. З точки зору людських ресурсів, війна призвела до значних втрат і переміщення людей. Багато українців були змушені покинути свої домівки та шукати притулку в інших частинах країни чи за кордоном.

Щоб зрозуміти зважений сценарій цього конфлікту (рис. 1), важливо проаналізувати ресурси і те, як вони, ймовірно, будуть використані в найближчі роки. З фінансової точки зору, росія, як відомо, має більший оборонний бюджет порівняно з Україною. Ця фінансова перевага дозволяє росії інвестувати в озброєння, технології та військову інфраструктуру, надаючи їй значну перевагу щодо вогневої потужності та можливостей. З іншого боку, Україна отримувала підтримку від Заходу у формі фінансової та військової допомоги, що дало змогу зміцнити її оборону та модернізувати її збройні сили.

У фінансовому плані конфлікт, що триває, створив величезне навантаження на бюджет України. Уряд був змушений виділити значну частину своїх ресурсів на військові витрати, зокрема на закупівлю зброї, амуніції та обладнання для боротьби із сепаратистськими силами у східних регіонах країни. Це призвело до зменшення фінансування соціальних програм, розвитку інфраструктури та інших важливих напрямів інвестування. У матеріальному плані війна сильно вдарила по інфраструктурі України. У результаті бойових дій було пошкоджено або знищено важливу інфраструктуру, таку як дороги, мости та будівлі. Це не тільки перешкоджало здатності країни ефективно функціонувати, а й створювало значні проблеми для відновлення та економічного розвитку постраждалих територій. Людські ресурси також зазнали великих втрат унаслідок конфлікту.

Якщо війна в Україні закінчиться в довгостроковій перспективі, країна стикнеться з багатьма проблемами, що стосуватимуться фінансових, матеріальних і людських ресурсів. На фінансовому фронті Україна була обтяжена високими витратами внаслідок конфлікту, зокрема військовими витратами, витратами через пошкодження інфраструктури та навантаження на соціальні служби. По завершенні війни виникне потенціал для зменшення військових витрат, що дозволить уряду перерозподілити кошти на відновлення економіки, стимулювання соціальних програм та інвестування в довгострокові проєкти розвитку. Міжнародна допомога та інвестиції також можуть збільшитися, коли повернеться

стабільність, що ще більше зміцнить фінансові ресурси України. Що стосується матеріальних ресурсів, то основним пріоритетом буде відновлення та реконструкція інфраструктури. Війна залишила багато міст і селищ у руїнах, з пошкодженими дорогами, будівлями та комунікаціями. Відбудова цих важливих структур вимагатиме значних інвестицій у будівельні матеріали, обладнання та технології. Уряд муситиме координувати зусилля з міжнародними організаціями та партнерами, щоб забезпечити швидкий та ефективний процес відновлення.

Російсько-українська війна є тривалим і руйнівним конфліктом, який має далекосяжні наслідки для обох країн і регіону в цілому. Заглядаючи в песимістичний сценарій розвитку цієї війни (рис. 1), можна передбачити збереження поточного статус-кво або навіть ескалацію бойових дій. З фінансової точки зору, і росія, і Україна і далі вкладатимуть значні ресурси у свої військові зусилля. Витрати на підтримку та розширення їхніх військових можливостей, а також фінансування самої війни створили б значне навантаження на економіки обох країн. Це може призвести до економічної стагнації, інфляції та зниження рівня життя населення. З точки зору матеріальних ресурсів, конфлікт ще більше виснажить арсенали та інфраструктуру обох країн. Продовження бойових дій призведе до руйнування критичної інфраструктури, такої як дороги, мости та комунікаційні мережі, що зробить для обох країн ще більш складним завдання відновлення після закінчення війни. Конфлікт порушив роботу основних служб і спричинив масові руйнування, зокрема в східних регіонах.

Війна не лише мала руйнівні гуманітарні наслідки, а й завдала значного тиску на фінансові, матеріальні та людські ресурси обох залучених країн (рис. 2). Конфлікт, що триває, призвів до виснаження економічних ресурсів обох країн, оскільки вони змушені відволікати кошти, які можуть бути використані для розвитку та інфраструктури, на військові витрати. З точки зору фінансових ресурсів, як росії, так і Україні довелося виділити значну частину своїх бюджетів на військові витрати для підтримки своїх сил у конфлікті. Це мало негативний вплив на інші сфери економіки, такі як охорона здоров'я, освіта та соціальні послуги, оскільки кошти перенаправлялися на військові потреби.

Економічні санкції, запроваджені проти росії західними країнами, ще більше посилили фінансовий тиск на країну, що остаточно ускладнило для них довготривалу підтримку конфлікту. Крім фінансових ресурсів, війна завдала значного навантаження на матеріальні ресурси обох країн. Конфлікт, що триває, призвів до руйнування інфраструктури, будинків, об'єктів промисловості тощо.

Кореляція між зростанням ВВП і національними економічними показниками є критично важливим аспектом розуміння фінансового стану країни (рис. 2). Наприклад, зростання ВВП свідчить про те, що країна переживає економічне зростання, яке часто пов'язане зі збільшенням можливостей працевлаштування, вищими рівнями доходів і покращенням промислової діяльності. І навпаки, падіння ВВП свідчить про економічний спад, який може сигналізувати про загрозливі проблеми, такі як зростання безробіття та зменшення споживчих витрат. По суті, зв'язок між зростанням ВВП і національними економічними показниками підкреслює важливість ВВП як інструменту для вимірювання здоров'я та траєкторії розвитку економіки.

На рис. 2 відображено спади у темпах приростів ВВП у 2014 році та під час повномасштабного вторгнення, а також наведено його прогноз за трьома сценаріями з 2024-го по 2026 роки відповідно.

Коливання торговельного балансу мають далекосяжні наслідки для загальної економічної стабільності, слугуючи барометром здоров'я національної економіки. Позитивний торговельний баланс, або позитивне сальдо торговельного балансу, вказує на те, що країна експортує більше, ніж імпортує, що сприяє економічному зростанню та стабільності. І навпаки, торговельний дефіцит може сигналізувати про потенційні економічні проблеми, що потребує запозичень або використання резервів для збалансування платежів.

Досвід України з 2012-го по 2024 роки, деталізований у фактичних змінах торговельного балансу, ілюструє його коливання й під час воєнних дій. Ці коливання можуть впливати на: наявність валютних резервів, стабільність обмінного курсу, що, у свою чергу, позначається на інфляції та купівельній спроможності, здатності країни залучати іноземні інвестиції. Розуміння та управління факторами, що впливають на торговельний баланс, такими як обмінні курси, глобальні економічні умови та внутрішні виробничі можливості, мають вирішальне значення для підтримки економічної стабільності та сприяння сталому зростанню. Кореляція між зростанням державного боргу та темпами зростання ВВП в Україні розкриває складну динаміку, яка є вирішальною для розуміння економічного здоров'я країни. Цей зв'язок свідчить про те, що зі зростанням ВВП України зростає і її державний борг, нібито для фінансування збільшення державних витрат, спричинених економічною експансією. Однак природа цього співвідношення може бути різною, причому такі фактори, як призначення боргу та ефективність його використання, відіграють вирішальну роль.

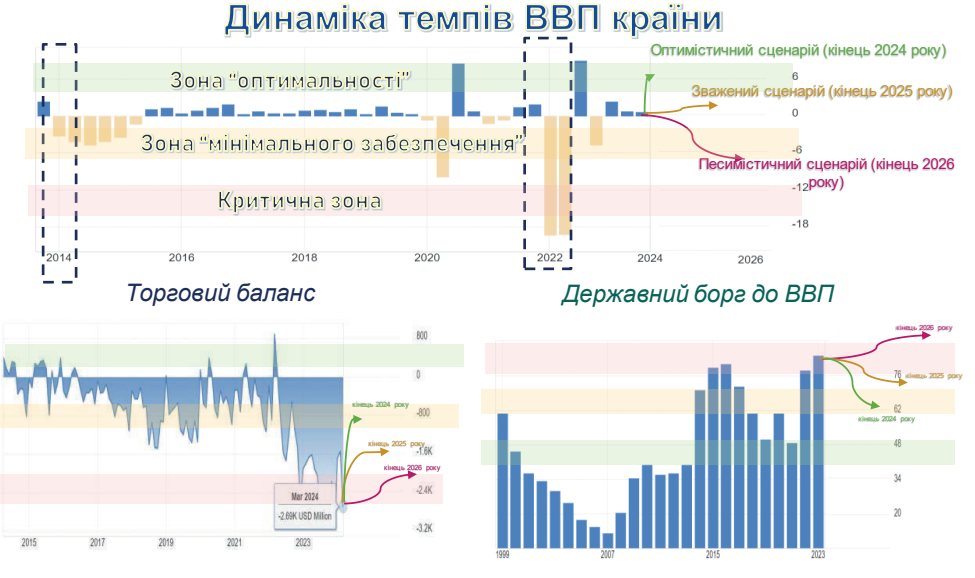


Рисунок 2. Фінансові ресурси: макроефект (ВВП, торгівельний баланс, відношення державного боргу до ВВП)

Обслуговування високого рівня державного боргу суттєво впливає на державні інвестиції та ВВП в Україні. Високий рівень боргу зумовлює необхідність виділення значної частини бюджету на обслуговування боргу, що, у свою чергу, обмежує доступні кошти для державних інвестицій. Цей сценарій може призвести до замкненого кола, коли скорочення інвестицій перешкоджатиме економічному зростанню, ще більше ускладнюючи здатність держави керувати своїм боргом і виплачувати його. У період з 2013-го по 2024 роки спостерігалися різні видатки на погашення та обслуговування державного боргу, що відображало його безпосередній вплив на державний бюджет і, як наслідок, на ВВП України. Складний баланс між залученням зовнішнього боргу для економічного розвитку та управлінням його наслідками для економічної стабільності, таким чином, є ключовим питанням для економічної політики України. Виділення значної частини державного бюджету на витрати на ЗС України має істотний вплив на доступність і якість державних послуг (рис. 3).

В умовах загострення оборонних потреб, подібних до тих, які відчуває Україна через російську агресію, фінансові ресурси держави значною мірою спрямовуються на підтримку та нарощування військового потенціалу.

Такий перерозподіл коштів може призвести до зменшення інвестицій у такі сектори, як охорона здоров'я, освіта та інфраструктура. Природа цих видатків вимагає ретельного пошуку балансу, щоб гарантувати, що в той час як потреби оборони задовольняються, загальний добробут громадян не постраждає. Завдання полягає в оптимізації видатків на оборону без шкоди для якості державних послуг, необхідних для розвитку країни та добробуту її громадян.

Фінансування оборонних операцій безпосередньо впливає на податкові ставки та державні інвестиції, позначаючись на економічному кліматі держави. В Україні імператив зміцнення обороноздатності в умовах конфліктів, що тривають, зумовив коригування фіскальної політики, включно з потенційно більшим податковим навантаженням на громадян і бізнес.



Рисунок 3. Фінансові ресурси: характеристики військових витрат

Така перебудова пріоритетів може призвести до скорочення асигнувань на інші критичні сфери державних інвестицій, такі як інфраструктура, технології та соціальні послуги, які є важливими для довгострокового економічного зростання та розвитку. Завдання, яке стоїть перед урядом, полягає в тому, щоб провести ці фіскальні коригування таким чином, аби підтримувати потреби оборони, мінімізуючи негативний вплив на економіку та забезпечуючи сприятливе середовище для інвестицій і зростання.

Фінансові потреби українських військовослужбовців під час війни у 2024 році охоплюють широкий спектр речей першої необхідності – від їжі та одягу до житла. Розподіл витрат на предмети першої необхідності є критично важливим аспектом належного забезпечення військ на всіх фронтах. Зокрема, першочерговим є виділення коштів на щоденне

харчування, як-от їжа та вода, одяг, що підходить для різних погодних умов, і житло, яке пропонує хоч якийсь комфорт у такі тяжкі часи.

Крім базових витрат, витрати на спорядження та амуніцію становлять значну частину фінансових потреб українських військовослужбовців у 2024 році. Закупівля сучасного озброєння, захисного спорядження та необхідних боєприпасів для підтримки операцій є критично важливою інвестицією в ефективність та безпеку військових сил. Основна увага приділяється оснащенню військовослужбовців: зброєю, що підвищує їхні бойові можливості; засобами індивідуального захисту, що відповідають найвищим стандартам безпеки; достатньою кількістю боєприпасів для забезпечення готовності до тривалих боїв. Цей розподіл має вирішальне значення для підтримки міцної позиції в обороні та наступі, що дозволяє військовослужбовцям упевнено та ефективно виконувати свої обов'язки.

Добробут українських військовослужбовців під час війни у 2023 році виходить за межі фізичних потреб і передбачає значні інвестиції в медичну та психологічну підтримку. Усвідомлюючи важкий вплив бойових дій і стресів, пов'язаних із війною, реалізовано комплексний підхід до охорони здоров'я та психологічного здоров'я. Це передбачає: негайний доступ до медичної допомоги у разі травм і захворювань, що забезпечує швидке відновлення здоров'я або лікування захворювань; послуги психологічної підтримки для подолання психічних та емоційних проблем, з якими стикаються військовослужбовці, виховання стійкості та допомогу у відновленні після травми; програми, спрямовані на довгострокове здоров'я та благополуччя військовослужбовців.

Заниження витрат у військових діях суттєво підриває бойовий потенціал ЗС України. Це явище не тільки впливає на безпосередні оперативні можливості, а й має довгострокові стратегічні наслідки. Розбіжність між фактичними витратами та бюджетними асигнуваннями (рис. 4, рис. 5) може призвести до дефіциту найважливіших матеріалів, затримки технічного обслуговування та неможливості інвестувати в необхідні технології й інфраструктуру. Цей розрив перешкоджає розвитку та готовності збройних сил, створюючи серйозну загрозу національній безпеці. Наслідком фінансових прорахунків можуть стати оперативні невдачі, оскільки сили можуть бути недостатньо оснащені або готові реагувати на нові загрози. Таким чином, важливість точного оцінювання витрат має першочергове значення для забезпечення ефективності та сталості військового потенціалу. Мобілізація українського ділового співтовариства для захисту країни стала ключовим аспектом стійкості країни в російсько-українському конфлікті. Вона виходить за рамки традиційних оборонних секторів, залучаючи підприємства та організації в різних галузях. Міністерство стратегії окреслило конкретні суб'єкти, які відіграють вирішальну роль у цій мобілізаційній роботі, наголошуючи на важливості військовозобов'язаних у зміцненні національної безпеки та оборони (рис. 6). Ця стратегія спрямована на відсіч і стримування збройної агресії, демонструючи єдиний фронт проти зовнішніх загроз. Залучення приватного сектора до національної оборони посилює не тільки військовий потенціал України, а й загальну стійкість суспільства на тлі військових дій, що тривають.

Неможливо недооцінити внесок аграрного сектора в продовольчу безпеку України під час конфлікту. Ця стійкість має вирішальне значення не лише для внутрішніх потреб, а й для збереження позиції України на світовому продовольчому ринку.

Пристосованість цього сектора та його внесок у продовольчу безпеку підкреслюють стратегічну важливість сільського господарства для підтримки нації, його роль у підтримці загальної стійкості та стабільності під час конфлікту. Однак на рис. 4 наведено динаміку індексу промислового виробництва, що більшою мірою відображає стан підприємств України (-44,7% на початок I кв. 2024 року лише у промисловому секторі).

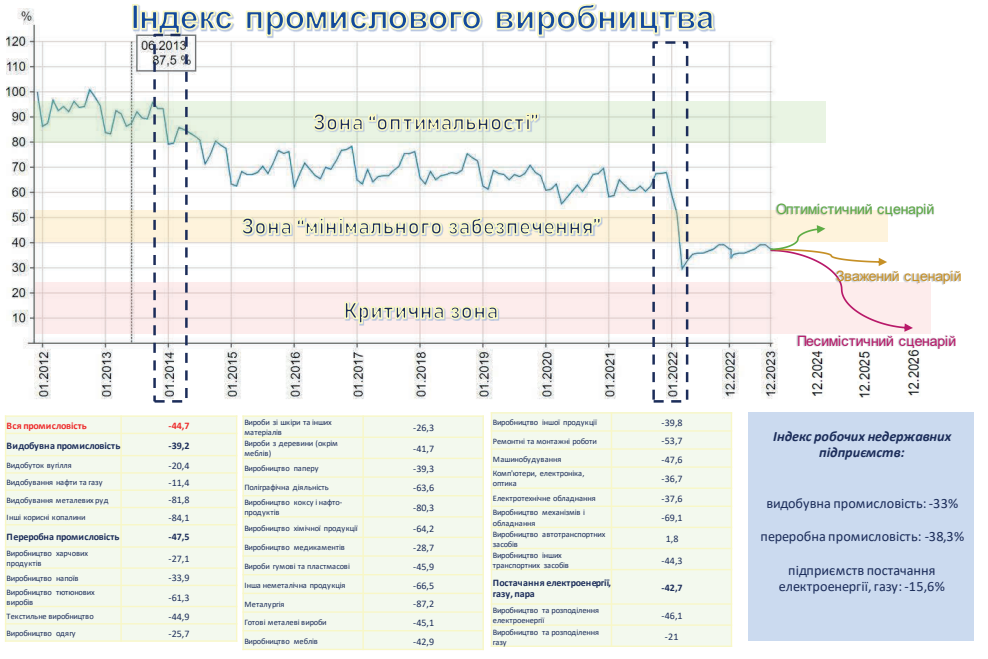
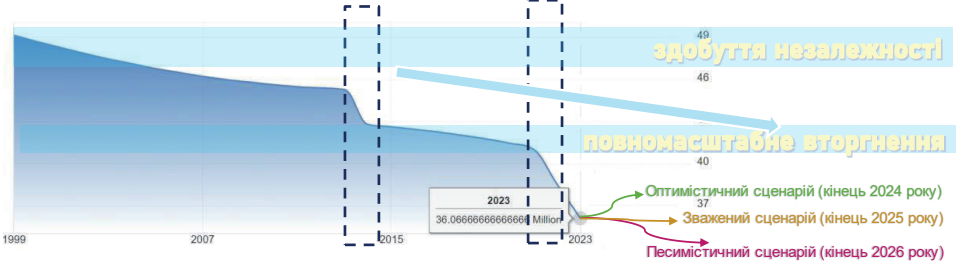
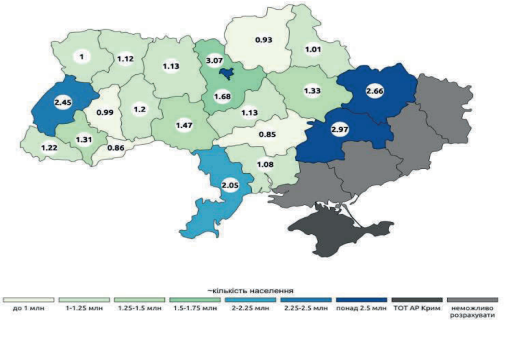


Рисунок 4. Матеріальні ресурси: динаміка індексу промислового виробництва в Україні під час війни



Розрахункова кількість жителів по регіонах (І кв. 2024 року)



Міграційний чинник (І кв. 2024 року)

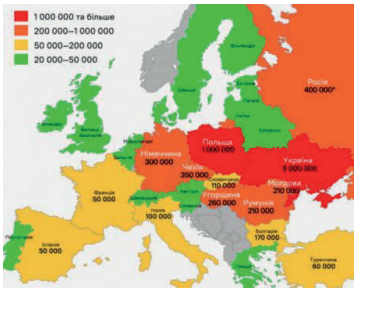


Рисунок 5. Людські ресурси: динаміка та географія населення України

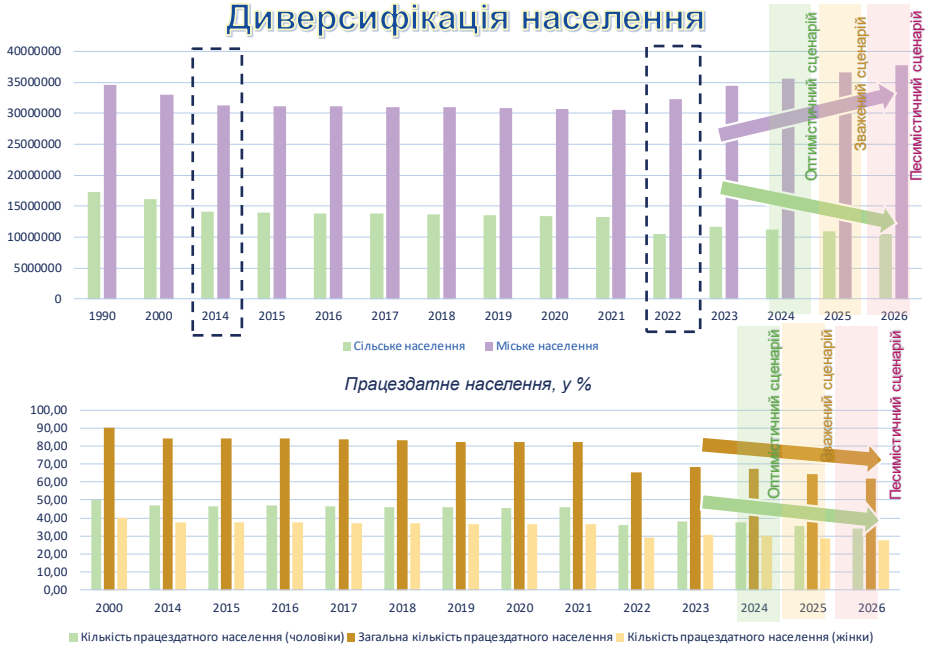


Рисунок 6. Людські ресурси: диверсифікація населення

Чисельність населення відіграє вирішальну роль у формуванні військового комплекту та резерву України, особливо в контексті російсько-українського конфлікту, що триває. Через значне скорочення чисельності населення з 51,6 млн до 36,16 млн станом на 1 січня 2024 року внаслідок різних факторів, зокрема міграції та безпосереднього впливу війни, потенційний пул, з якого можна залучати солдатів і резерви, помітно скоротився (рис. 5). Ця демографічна зміна потребує стратегічного коригування того, як Україна підходить до свого оборонного планування, наголошуючи не лише на кількості військ, а й на якості та універсальності сил, які їй вдається зібрати. Скорочення чисельності населення безпосередньо впливає на здатність країни підтримувати тривалі військові дії та вимагає зосередитися на ефективній підготовці та використанні ефективних технологій для компенсації скорочення людської сили.

Географічний розподіл населення України суттєво впливає на тактику партизанської боротьби проти російської навали (рис. 5). Міські та густонаселені райони пропонують інші виклики та можливості для опору порівняно із сільськими та малонаселеними регіонами.

У міських умовах щільна інфраструктура може забезпечити прикриття та маскування для партизанських дій, ускладнюючи окупаційним силам утримання контролю. Навпаки, сільська місцевість пропонує партизанським силам величезні ландшафти для маневру, хоча матеріально-технічне забезпечення може бути більш складним. Розуміння регіональних особливостей розподілу населення має важливе значення для планування ефективних стратегій опору, які використовують місцеві географічні та демографічні особливості.

Демографічний склад України, зокрема вікові, етнічні та культурні фактори, значною мірою впливає на національну мораль і рух опору. Велика частина населення України виявляє сильні патріотичні почуття, які сприяють вихованню стійкого національного духу. Цей патріотизм є не лише джерелом волонтерів, які бажають захищати свою країну, а й сприяє

ширшій суспільній підтримці зусиль опору. Мобілізація кваліфікованої робочої сили є критично важливою для відновлення економіки України під час війни. Крім того, перед початком повномасштабного вторгнення Україна мала дефіцит робочої сили, але зараз, коли понад 6 млн українців були змушені залишити країну, цей дефіцит став ще більш гострим (рис. 7). Для забезпечення економічного відновлення у воєнний час необхідно активно залучати та утримувати кваліфіковану робочу силу, яка має достатньо навичок та знань для відновлення економіки.

Реалізація політики підтримки та використання потенціалу працездатного населення також відіграє важливу роль у відновленні економіки під час війни. Набуття досвіду, навичок та знань працездатним населенням у період конфлікту підвищує продуктивність праці та створює умови для стійкого економічного зростання. Заходи з підтримки працездатного населення, зокрема надання допомоги та інвестицій у підтримку співробітників, є необхідними для успішного економічного відновлення України в умовах війни.

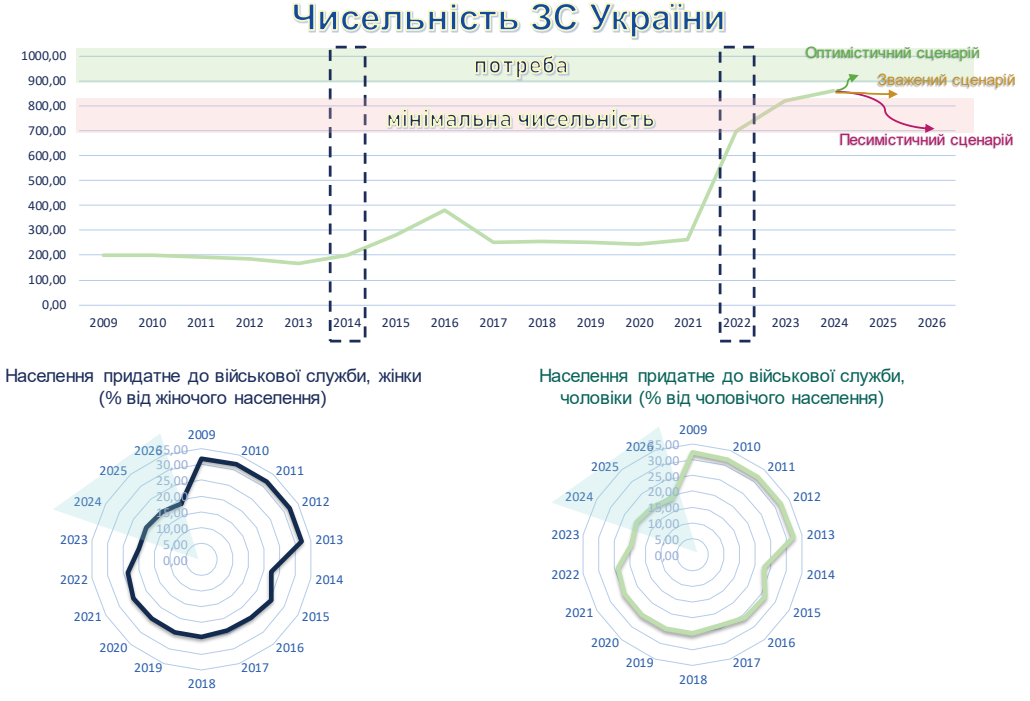


Рисунок 7. Людські ресурси: чисельність ЗС України

Чисельність збройних сил істотно впливає на стратегічну гнучкість і оперативні можливості. Цей вплив особливо відчутний у контексті розгортання важкої бронетехніки, яка відіграє вирішальну роль у забезпеченні мобільності військ під час безпосереднього зіткнення з противником. Здатність маневрувати та пристосовуватися до мінливих умов на полі бою безпосередньо залежить від кількості наявних підрозділів і типів техніки, що є в їхньому розпорядженні. Більші сили володіють спроможністю виконувати більш широкий спектр стратегій, від наступу на широкому фронті до цілеспрямованих спеціальних операцій, підвищуючи їхню загальну ефективність у сценаріях конфлікту. Крім того, чисельність збройних сил значною мірою сприяє стримуванню та психологічному впливу на противника.

Психологічний аспект війни, важливість якого все більше визнається, залежить від сприйманої сили та готовності військової сили. Більша, добре оснащена сила може діяти як потужний стримуючий фактор для потенційних агресорів, сигналізуючи про здатність і готовність ефективно захищатися від нападів.

Обговорення (Discussions)

Ще раз зазначимо, що кожен із цих сценаріїв має свої виклики та можливості, і напрями впливу конфлікту на економіку будуть різнитися залежно від тривалості та інтенсивності військових дій, а також від ефективності заходів з відновлення та підтримки економіки. Динаміка забезпечення ресурсами значно залежить від того за яким сценарієм будуть розвиватися події.

Recommendations (Рекомендації)

У табл. 3 розкрито наслідки для національної економіки України та для сил оборони (ЗС України) за умов розвитку кожного можливого сценарію (воєнно-економічний аспект).

Нині треба зрозуміти, що тривала війна матиме руйнівні наслідки як для економіки України, так і для її збройних сил та сил оборони в цілому, а також негативно відіб'ється на рівні національної безпеки України. Зниження рівня національної безпеки країни неминуче вплине на рівень конкурентоспроможності України на міжнародній арені. Щоб мінімізувати ці наслідки, необхідно шукати можливості для політичного врегулювання конфлікту та продовжувати реформування і модернізацію економіки й збройних сил, а також забезпечувати підтримку міжнародних партнерів.

Висновок (Conclusion)

За результатами дослідження сценаріїв розвитку воєнного конфлікту російської федерації проти України за воєнно-економічним напрямом можна зробити різні висновки про можливі шляхи розвитку подій та їхні наслідки для України. Дослідження розглянуло чотири основних сценарії: оптимістичний, зважений, песимістичний та деструктивний, кожен з яких має свої особливості та виклики.

Оптимістичний сценарій передбачає швидке завершення конфлікту за допомогою дипломатичних зусиль та мирних переговорів. У цьому випадку Україна може розраховувати на поступове відновлення економіки та інфраструктури, збільшення інвестицій та повернення до стабільного зростання ВВП. Скорочення військових витрат дозволить направити бюджетні ресурси на соціальні програми та розвиток інфраструктури. Проте для реалізації цього сценарію необхідно забезпечити стійку підтримку з боку міжнародної спільноти та ефективне впровадження реформ. У разі оптимістичного сценарію розвитку російсько-українського конфлікту Україна за умови допомоги країн-партнерів зможе за 2–3 роки досягти певного ступеня стабільності функціонування національної економіки, але для відновлення (особливо тимчасово окупованих територій) необхідний більш тривалий період.

Зважений сценарій передбачає тривалість конфлікту ще на кілька років, але з поступовим зменшенням інтенсивності бойових дій. У цьому випадку економіка України і далі функціонуватиме у стані постійної загрози, що стримуватиме інвестиції та економічне зростання. Водночас, поступове відновлення територій, що постраждали від війни, та стабілізація фінансової системи можуть дати можливість для поступового економічного відновлення. ЗС України потребуватимуть постійної підтримки для забезпечення обороноздатності країни, тобто військові витрати ще достатньо тривалий час будуть залишатися підвищеними, що буде знижувати темпи відновлення національної економіки. За такого сценарію відбувається втрата території, що негативно відіб'ється на макроекономічних показниках країни та стані її розвитку взагалі.

Таблиця 3. Наслідки для національної економіки України та для сил оборони (ЗС України) для кожного сценарію

Сценарії	Для національної економіки	Для сил оборони (ЗС України)
Оптимістичний сценарій (війна закінчиться у 2024 році)	Швидке економічне відновлення. Скорочення військових витрат та спрямування ресурсів на відновлення економіки. Реконструкція. Інтенсивні програми відновлення та модернізації інфраструктури, залучення іноземних інвестицій. Інвестиційний клімат. Покращення інвестиційного клімату, швидке зростання внутрішніх та зовнішніх інвестицій. Реформи. Проведення економічних реформ для стимулювання зростання та покращення бізнес-середовища. Соціальні програми. Зменшення рівня безробіття та реалізація програм соціальної підтримки для населення.	Переоснащення та модернізація. Швидка модернізація техніки та озброєння, впровадження нових технологій. Реабілітація військових. Масштабні програми реабілітації та соціальної адаптації для ветеранів війни. Підвищення кваліфікації. Проведення навчальних програм та підвищення кваліфікації військовослужбовців у мирних умовах. Реформи та інтеграція. Упровадження реформ, спрямованих на інтеграцію збройних сил до європейських та натівських стандартів. Міжнародна співпраця. Розширення міжнародної військової співпраці та участь у миротворчих місіях.
Зважений сценарій (війна закінчиться в 2025 році)	Стабілізація бюджету. Зменшення витрат на оборону після завершення війни, перерозподіл ресурсів на відновлення економіки. Реконструкція інфраструктури. Активні проєкти з відновлення зруйнованих об'єктів інфраструктури. Економічне зростання. Поступове відновлення економічного зростання, залучення інвестицій. Зниження інфляції. Стабілізація цінового рівня та зниження інфляційних очікувань. Ринок праці. Відновлення ринку праці, зменшення рівня безробіття, повернення мігрантів.	Переоснащення. Можливість модернізації та переоснащення техніки та озброєння після завершення активних бойових дій. Соціальна підтримка. Упровадження програм соціальної адаптації для ветеранів війни. Навчання та підготовка. Проведення навчань та перепідготовки військових в умовах мирного часу. Реформи. Проведення структурних реформ у збройних силах з метою підвищення ефективності та готовності до нових викликів. Міжнародне співробітництво. Посилення співпраці з міжнародними партнерами у військовій сфері, обмін досвідом.
Песимістичний сценарій (війна триватиме по 2026 рік включно)	Витрати на оборону. Зберігається високе навантаження на бюджет через безперервні витрати на військові дії. Економічний спад. Постійне виснаження економіки через руйнування інфраструктури та виробничих потужностей, низький рівень інвестицій. Інфляція. Високий рівень інфляції через збільшення дефіциту бюджету та постійні військові витрати. Бідність та безробіття. Зростання рівня бідності та безробіття, відтік працездатного населення за кордон. Зовнішні борги. Збільшення державного боргу через необхідність зовнішнього фінансування військових потреб.	Високе навантаження. Постійна необхідність підтримання високої бойової готовності та збільшення чисельності особового складу. Матеріально-технічне забезпечення. Потреба у постійних постачаннях зброї, боєприпасів та іншого обладнання від партнерів. Втрати та моральний стан. Високі втрати особового складу, моральне виснаження військових. Навчання та підготовка. Постійна потреба у підготовці нових солдатів та підвищенні кваліфікації діючих військовослужбовців. Міжнародна підтримка. Залежність від міжнародної допомоги в озброєнні та техніці.
Деструктивний сценарій (війна продовжиться після 2026 року та буде тривати ще декілька років)	Зниження ВВП та економічний спад. Постійні бойові дії та нестабільність призведуть до значного скорочення економічної активності, що спричинить падіння ВВП. Інвестиційний клімат погіршиться, що зменшить обсяги прямих іноземних інвестицій. Погіршення інфраструктури. Руйнування критичної інфраструктури (дороги, мости, залізничні колії, електромережі тощо) зменшить ефективність економічних зв'язків та збільшить витрати на їх відновлення. Відсутність доступу до ключових транспортних маршрутів ускладнить логістику і зменшить експортні можливості. Зниження життєвого рівня населення. Зростання безробіття та зниження заробітної плати. Погіршення умов життя через підвищення цін на товари та послуги, зокрема через інфляцію. Збільшення числа внутрішньо переміщених осіб, що створить додаткове навантаження на соціальні служби. Фіскальні труднощі. Зростання дефіциту державного бюджету через збільшення витрат на оборону та соціальні виплати. Необхідність залучення зовнішніх позик, що призведе до зростання державного боргу. Енергетична криза. Руйнування або захоплення енергетичної інфраструктури, що може призвести до дефіциту енергії. Залежність від імпорту енергоресурсів з інших країн, що може бути дорожчим та менш стабільним.	Виснаження ресурсів. Постійні бойові дії вимагають значних матеріальних та фінансових ресурсів, що призводить до виснаження запасів озброєння та амуніції. Потреба в постійному поповненні техніки та озброєння може перевищувати можливості вітчизняного ВПК. Людські втрати. Високі втрати серед військовослужбовців можуть призвести до зниження морального духу та боєздатності військ. Потреба у регулярному поповненні людських ресурсів, що може вимагати додаткової мобілізації. Логістичні проблеми. Руйнування транспортної інфраструктури ускладнює забезпечення військових підрозділів необхідними ресурсами. Проблеми з постачанням продовольства, медичних засобів та інших важливих ресурсів на фронт. Психологічний та моральний тиск. Тривала війна негативно впливає на психологічний стан військовослужбовців та цивільного населення. Підвищення рівня стресу, вигорання та посттравматичні стресові розлади серед військових. Міжнародна підтримка. Потреба у постійній міжнародній підтримці (як військовій, так і фінансовій) для забезпечення стійкості ЗС України. Можливе зменшення міжнародної допомоги у разі затяжного конфлікту, що може залежати від політичних змін у країнах-партнерах.

Песимістичний сценарій передбачає подальшу ескалацію конфлікту із залученням додаткових військових сил та ресурсів, що може призвести до значних людських втрат та

руйнування інфраструктури. Економіка України зазнає значних збитків через руйнування промислових об'єктів, транспортної інфраструктури та енергетичної системи.

Витрати на оборону значно зростуть, що створить додаткове навантаження на державний бюджет. Ситуація потребуватиме значної міжнародної допомоги для стабілізації економіки та підтримки військових зусиль. За такого сценарію Україна буде повністю залежна від допомоги країн-партнерів у війні з росією, а економічна та політична ситуація в країні буде мати постійний коефіцієнт напруженості.

Деструктивний сценарій є найгіршим можливим розвитком подій, передбачаючи тривалу війну (понад три роки) без чіткої перспективи завершення. У цьому випадку Україна стикнеться зі значним падінням ВВП, масовим безробіттям та високим рівнем інфляції.

Руйнування критичної інфраструктури та зростання числа внутрішньо переміщених осіб ще більше ускладнить економічну ситуацію. ЗС України будуть змушені постійно мобілізувати нові ресурси для підтримки обороноздатності, що призведе до виснаження людських і матеріальних резервів та занепаду економіки. Потреба у міжнародній підтримці буде критичною, але її забезпечення може ускладнитися через втому міжнародної спільноти від тривалого конфлікту, а для України це дефолт, значна втрата територій та повна залежність від волі інших країн, які ще будуть залишатися з нею.

Таким чином, дослідження сценаріїв розвитку воєнного конфлікту російської федерації проти України показує, що кожен з можливих шляхів розвитку подій має значний вплив на воєнно-економічну ситуацію в нашій державі. Кожен сценарій – від швидкого й успішного завершення конфлікту до тривалої та руйнівної війни – вимагає відповідних стратегій і ресурсів для забезпечення стійкості країни. Вирішальними факторами залишається ефективність державної політики, міжнародна підтримка та здатність України адаптуватися до змінних умов воєнного конфлікту.

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Military Conflict Development Scenarios of the russian federation and Ukraine: military-economic aspect

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Abstract. The article is relevant due to the fact that in the ongoing war conditions, it is important to understand how different types of resources - financial, material and human - influence on the russian-Ukrainian conflict development and form the basis for further effective resistance. The scenario analysis of this conflict makes it possible to assess the resources‘ impact on the military operations’ effectiveness, the defence systems' resilience, the national economy's sustainability, and the ability to sustain a long-range confrontation. The study of these aspects helps not only to better understand the current situation, but also to develop strategies that can contribute to a more efficient use of available resources to achieve the desired results. Therefore, the article main goal is to form a comprehensive view of possible military conflict scenarios between russia and Ukraine, considering the military and economic consequences of each scenario, which will help in developing strategies to ensure national security and stability of Ukraine in the long term armed conflict conditions. The main research methods used are: military-economic analysis, expert survey and comparison, mathematical statistics, brainstorming, deduction and formalisation methods. The article's main results are as follows: the author proposes methods for conducting research to identify scenarios for the russian federation's military conflict against Ukraine's development; identifies the components of providing resources for the state's development and calculates their impact on the national economy development before the beginning of russia's full-scale invasion of Ukraine and now; formulates

scenarios for the russian-Ukrainian conflict development and their characteristics; analyses the expert survey results based on the projected statistical indicators. The article's materials may be useful for specialists in defence management and defence resource management, the leadership representatives of the Armed Forces of Ukraine and the Ministry of Defence of Ukraine, as well as for scientists and researchers in the military-economic field.

Keywords: military economic research, military expenditures, macroeconomic indicators, the Armed Forces of Ukraine, armed conflict, military operations, human, financial, material resources, armed aggression, hybrid warfare, national security, defence budget, military conflict scenarios, state defence forces.

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Mobilization and recruitment in Ukraine: challenges and solultions

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Abstract. This paper considers open-source information to consider the challenge of military recruitment in Ukraine. It then considers U.S. law and practice before and after the U.S. shifted from conscription to an all-volunteer force in 1973 for insights on methods to increase and sustain recruitment. Finally, it identifies potential methods to increase voluntary recruitment and decrease draft evasion, two sides of the same coin. Consideration is given to the impact that perceptions (and realities) about military justice and discipline have on recruitment and how to address and mitigate that impact; the relative role and impact of positive (e.g., benefits) versus negative (e.g., punishment) incentives in recruitment; the relative advantages and disadvantages of fixed enlistment terms, and whether there are alternatives to fixed terms, such as the use of combat exposure points to determine the length of service, or the implementation of mandatory unit rotations; the relative impact that recruitment age limitations play in meeting recruitment goals; the policy pros and cons of extending conscription by age and gender; and the potential role that benefits play in recruitment and how benefits might be adjusted to increase recruitment. If there was an easy or obvious recruiting solution, the Government of Ukraine would have adopted it. Marginal changes and adjustments over time can in their cumulative effect significantly change and improve the recruiting landscape. Given the long-

term nature of this war, the status of the war, and the continuous nature of the Russian threat, changes in military recruitment and culture are needed and will pay future security dividends.

Keywords: armed forces, rotation experience, human mobilisation resource, military reserve, recruitment.

Introduction

Introduction: The Challenge. Media reports indicate that the Ukrainian Armed Forces (UAF) face personnel shortages. In December 2023, former Commander in Chief of the Ukrainian Armed Forces General Zaluzhnyi is reported to have requested a call-up of an additional 500,000 persons. Media reports indicate that his successor, General Syrskyi, has called for a similar recruitment effort but with an overall reduced figure. President Zelensky stated in March 2024 that Ukrainian forces might need to shorten their lines because of manpower and munitions shortages, tactically ceding territory to Russia (Samya Kullab, 2024). The personnel challenge was addressed, in part, on April 2, 2024, when President Zelensky signed a law lowering the conscription age in Ukraine from 27 years to 25 years. The Ukrainian Parliament subsequently passed additional legislation in April 2024 providing incentives to recruitment, including a front line bonus and death benefit (Marc Santora, 2024).

However, for reasons considered below, a conscription age-change alone may not meet Ukraine's manpower needs or do so in a sustainable manner. Moreover, conscription and training will take time and the Government of Ukraine (GOU) will in all scenarios need to determine how best to implement the introduction of new personnel to maximize unit cohesion and combat effectiveness. Therefore, and critically, Ukraine should consider longer term conscription, recruitment, retention, and rotation options and solutions to meet the ongoing and persistent threat from Russia.

Roadmap. Section One of this article briefly addresses the manpower needs and challenges facing Ukraine in responding to Russian aggression (This paper is based on media reports, publicly available data, conversations, and anecdotal input. The goal of the paper is not to document data or trends but to provide relevant actors an external and comparative perspective on options to increase military recruitment and retention.). Section Two considers the U.S. experience with conscription and registration identifying decision points for GOU consideration, such as the method of conscription implementation. Considering Ukraine's recent conscription and recruitment changes, emphasis is placed on identifying "lessons" from the U.S. experience implementing conscription. Section Three considers recruitment incentives and disincentives that in U.S. experience are thought to impact voluntary recruitment and retention. Command climate, for example, as a recruiting incentive or disincentive is often overlooked, neglected, or viewed as too difficult to address in wartime; however, the U.S. experience suggests otherwise. Section Four addresses the U.S. experience with individual and unit rotation in Vietnam, post-Vietnam, and during the wars in Iraq and Afghanistan. One way to increase combat efficacy, with or without an increase in personnel, is with policies of unit rotation that allow units and individuals to rest and reset.

Methodological Framework

Assumptions and Caveats. This paper incorporates six underlying assumptions and caveats.

First, decisions about recruitment and mobilization in Ukraine are for Ukraine to make based on Ukraine's context and war experience.

Second, to meet its personnel needs, Ukraine will need to expand its conscription base. It has done so, lowering the draft age to 25 from 27. However, it may need to do so again, by lowering the draft age further, including women in the draft pool, or both.

Third, U.S. experience suggests that there are additional mechanisms that might increase voluntary recruitment and decrease conscription evasion.

Fourth, although a rebuttable presumption, while enlistment incentives may only provide marginal gains in recruitment in the short run, they may help create a steady and thus sustainable flow of recruitment in future years and thus a military capable of deterring, and if necessary, resisting ongoing Russian aggression. They are also likely to address specific recruitment needs, such as drone operators, Explosive Ordinance Disposal (EOD) experts, and medical personnel and may help to sustain a cadre of enlisted leadership.

Fifth, the paper does not presume to espouse a policy perspective or preference but rather seeks to identify options in neutral and academic manner. However, we are not neutral as to outcome. As scholars, we believe the outcome of Russia's war of aggression against Ukraine will help to define the 21st Century, including whether it is a law and rules-based century, or one defined by force and power alone. We also believe that if Russia is not stopped by Ukraine, NATO inevitably will need to stop Russia elsewhere and elsewhere will likely lead to the introduction of United State armed forces. In short, Ukraine is on the front line of freedom and law.

Finally, we approach this paper with humility and respect. Humility comes from knowing that the U.S. model and U.S. lessons are not necessarily the correct policy analogies for Ukraine. Therefore, we offer a U.S. perspective, not "the U.S. answer," so that Ukraine can draw from the U.S. experience, adopting what is apt and worked, and avoid repeating what was less successful. Respect comes from observing a nation and a military that has withstood a war of aggression while outnumbered and out equipped but not out-couraged.

Results and Discussions

The Need. Ukraine is facing a military manpower shortage. In any sustained war, the capacity to recruit and sustain an army matter. They matter more in a war of attrition. Since the full-scale invasion, U.S. estimates place Ukrainian casualties as of August 2023 at 70,000 killed and 120,000 wounded (Cooper, Gibbons-Neff, Schmitt and Barnes, 2023). The figures are certainly higher. Up to 50,000 Ukrainian combatants are estimated to have lost one or more limb due to combat wounds. Manpower matters for at least four reasons: (1) Russia has adopted attrition as a method of warfare and possesses numeric advantages; (2) offensive operations, e.g., to retake occupied territory are generally more manpower intensive than defensive operations; (3) a manpower reserve will improve combat effectiveness and recruitment by allowing for unit rotation, rest, and training cycles; and, (4) Ukraine will face an ongoing security threat from Russia after victory, as well as before.

I. Current Law, Practice, and Challenges. Under current law and practice Ukrainian men ages 25-60 are eligible for conscription into the Ukrainian Armed Forces (UAF) and are required to register with local military draft commissions. In theory, persons who volunteer or are conscripted are required to serve up to three years on active duty; however, pursuant to Martial Law declared February 24, 2022, and most recently extended a tenth time by vote of the Rada until May 14, 2024, the term of service has been extended until "the end of the special period." Therefore, persons who volunteer or are conscripted into the UAF do not in practice know how long they will be required to serve, neither do their families or employers. It is a common understanding (received wisdom) that military service will continue indefinitely until a military member is wounded or killed. There is no public data that verifies this understanding. However, from the standpoint of recruiting it does not matter. So long as this is received wisdom in Ukraine, it will have a corresponding impact on morale and recruiting.

Ukraine faces at least eight recruiting challenges.

A Diminishing Population Base. By some estimates, Ukraine's population has fallen from fifty-one million at the time of independence in 1991 to a projected population of from twenty-four to thirty-three million by 2040 (Baker, 2023). The projection varies depending on predictions about

the further demographic impact of Russia's war of aggression and the predicted rate of refugee return. Alarmingly, the younger generation, Gen Z, is the smallest generation in Ukrainian history. This reflects a number of factors reported on elsewhere, including a low birth rate following the economic depression following independence (Kramer, Holder, Letherby, 2024). The situation is compounded by the departure of an estimated 6 million women since the full-scale invasion. Although we have not identified specific legislative text or history indicating so, former Rada staff, scholars, and media indicate that the public policy reason for limiting conscription to older males is based on Ukraine's demography, to preserve the capacity of Gen Z to sustain or regenerate Ukraine's population; older conscripts are more likely to have had the opportunity to have children and start families. There are, of course, also "political" reasons to limit the age of conscription rooted in opposition to any expansion of conscription eligibility.

Exemptions. Under Ukrainian law, as amended by martial law decree, there are exemptions to conscription. These include an exemption for "critical war work." Critical war work includes, for example, railroad workers, truck drivers, and firefighters. However, the term is subject to interpretation and thus inconsistent application as well as abuse when applied by the local commissions that serve as "draft boards," in American parlance. Media reports indicate that the Rada is considering further delimiting the qualifications for the "critical war work" exemption. Full-time undergraduate students and professors holding PhDs are also exempt from conscription. This has resulted in some draft eligible men who already hold undergraduate degrees returning to university for additional undergraduate degrees, apparently finding lawful exemption from conscription while doing so.

Corruption. Any conscription process that includes exemptions, and especially interpretive exemptions adjudicated by local recruiters and commissions is subject to inconsistent application and corruption. In August 2023, media reports indicate President Zelensky fired all thirty-three Chiefs of the regional military recruiting offices on grounds of corruption (David Stern, 2023). We were told that in one oblast, fifty percent of the draft eligible men received a medical exemption for having one kidney. Whether apocryphal or verifiable, such stories become received wisdom impacting recruiting by undermining confidence in the integrity and equity of the conscription process and opening the door to a permissive - if others do it, why shouldn't I - attitude about avoiding and evading conscription.

Evasion. There is also outright evasion. At the outset of the full-scale invasion there was a mass flow of refugees into Central Europe. Most refugees were women and children, but conscription-aged men exited as well. Others were already overseas at university or working and stayed. Media reports indicate that there is an illegal market for exit papers that allow conscription-eligible men to exit the country. Media reports also indicate there is a market for guides to escort conscription eligible men across the Ukrainian border into Central Europe. These same reports indicate that approximately twenty-five men have drowned seeking to swim the Tysa River between Ukraine and Romania. Over sixteen thousand men have been captured seeking to exit Ukraine to evade conscription (Kramer, Holder, Letherby, 2024). We have been told that as many as 100,000-600,000 conscription-aged men have left the country.

Stigmatization. Some veterans and veterans groups refer to the stigma of veterans status in a manner akin to how Afghan veterans in Soviet era Ukraine and Vietnam veterans in the U.S. were perceived and treated by some. This seems extraordinary in a country that owes its survival to the UAF. The stigmatization of veterans status is an obvious deterrent to recruitment.

Impressment. Impressment also deters voluntary recruitment. Credible stories abound in Ukraine about conscription-aged males being grabbed off the street and placed directly in military training without opportunity to put their personal affairs in order and communicate with loved ones. Persons with lawful conscription exemptions are known to carry proof of exemption in public lest

recruiters seize them. Such conduct lowers trust in recruiters and the process of military recruitment and may encourage families to send conscription eligible men out of the country or in hiding.

Conflict and Ambiguity of Laws. From an outsider's perspective, Ukraine does not have clear law or regulations regarding recruitment and conscription. For example, there is an apparent conflict between Soviet era statutory law and the martial law declared following the full-scale invasion. Lack of clarity opens the door to the perception that the application of conscription rules and practices are inconsistent and unfair, including the perception that wealthy and connected persons are more likely to avoid service. This may change with the implementation of the April 2024 conscription and mobilization changes; however, it is wise to recall that in U.S. experience, clear law was implemented in inconsistent ways across draft districts leading to the impression that the law was applied unevenly and thus was unfair, an impression that often proved well founded.

Benefits – Scope and Reliability. Benefits available to wounded veterans or the survivors of servicemembers killed in the line of duty are perceived as (and likely are) inadequate to meet the actual and legitimate needs of surviving members and their families. This is illustrated by adoption of the moniker "invisible women" to describe the spouses of servicemembers killed in action. To state the obvious, it is a deterrent to recruiting, if recruits lack confidence that surviving loved ones will be cared for if they are wounded or killed in the line of duty.

II. Options and Solutions. There are no panaceas. If there was an easy or obvious solution, the Government of Ukraine (GOU) would have adopted it. The three primary mechanisms to meet military personnel requirements are conscription, voluntary recruitment, and retention. We address each in turn.

A. Conscription. As noted, in April 2024, the age of conscription in Ukraine was lowered from 27 to 25, making men ages 25-60 conscription eligible. The current draft band has resulted in an average UAF age of approximately 40. An age reduction to 25 creates a potential manpower pool of approximately 467,000. Of course, not every age-eligible man is medically qualified for military service; others may have legitimate conscription exemptions. In U.S. experience, approximately 23% of the age-eligible population meet the health and background criteria for military service without a waiver and without regard to whether these qualified persons are interested in military service (FY20 Qualified Military Available Key Findings, 2022). Weight is the leading disqualification factor; however, many disqualified persons present multiple factors, also including a criminal history, or educational deficits. Therefore, depending on accession standards established by the UAF, one can extrapolate that not all of the new band of conscription eligible men, ages 25 and 26, will be fit for military service.

No doubt, the health and background of Ukrainian men will vary in profile from their U.S. counterparts. Nonetheless, one can reasonably assess that a conscription pool of 450,000 will not produce an enlistment yield of 450,000. Applying U.S. accession standards, i.e., a qualified for service percentage of 23%, in a pool of 450,000, would likely yield 103,500 personnel. Therefore, consideration of additional changes to conscription criteria are possible, and should be framed on a contingency basis. Reference to other state practice, especially U.S./NATO practice may be helpful.

U.S. and NATO Conscription Practice. According to the Pew Research Center, fewer than a third of countries (60) have some form of an active conscription program. Twenty-three nations have conscription laws in place but do not currently engage in conscription, including the United States (Drew Desilver, 2019). Eight-five countries have no laws authorizing conscription and 23 nations have no regularly constituted military. Eight NATO countries have active conscription programs.

A. Denmark
   a. Military Conscription Stipulations: 4-12 months of military training
   b. Demographic: Men at the age of 18

B. Estonia

a. Military Conscription Stipulations: 8-11 months of military service (Some work in government services)
b. Demographic: Men ages 18-27

C. Greece
a. Military Conscription Stipulations: 9-12 months of service
b. Demographic: Men ages 19-45

D. Lithuania
a. Military Conscription Stipulations: 9 months of service obligation
b. Demographic: Men ages 19-26

E. Norway
a. Military Conscription Stipulations: 12-19 months of service obligation
b. Demographic: Both Men and Women ages 19-35

F. Sweden
a. Military Conscription Stipulations: 7-15 Months of Service, employs selective conscription.
b. Demographic: Both Men and Women ages 18-47

G. Turkey
a. Military Conscription Stipulations: 6-12 Months of Service
b. Demographic: Mandatory for Men at age 20 (Some exemptions Apply)

H. Finland
a. Military Conscription Stipulations: 5.5-12 months service with military or border guard
b. Demographic: Men must serve at age 18.

However, these programs are selective rather than universal in their application. For example, in Norway, conscription eligible persons are required to register but given the option of performing alternative public service or military service. In many cases, eligible persons do not perform any service. Thus, in practical effect, conscription results in limiting military service to true volunteers, or at least persons who have voluntarily chosen between methods of public service.

Under U.S. law and regulation, in the event of a draft, men aged 18 and six months and older "shall be liable for training and service in the Armed Forces of the United States." (See 50 U.S.C.A. §§ 3801-3820.). If the military's requirements were not met by the 19-year-old cohort, the law permits the induction of 20-year-old men, and so forth up the step ladder to age 26. The law does not specify the manner in which draftees will be called to service, i.e., whether by lottery or selection based on criteria. However, selection of persons for training and service "shall be made in an impartial manner, under such rules and regulations as the President may prescribe." The Selective Service System, as used in Vietnam, specified any lottery selection method shall use 366 days of sequence numbers to represent the birthday of all registrants 18 through 26 to create a random and impartial selection protocol (Vietnam Lotteries, 2024). The law limits inducted service to no more than 24 months ("Each person inducted into the Armed Forces…shall serve on active training and service for a period of twenty-four consecutive months, unless sooner released, transferred, or discharged…").

The United States Experience. The United States has relied on an All-Volunteer Force (AVF) since 1973. Prior to 1973, the United States employed conscription during the Civil War, the World Wars, and during the Cold War/Vietnam era, 1948-1973, as briefly described below (Kristy N. Kamarck, 2021).

The Civil War: The first U.S. draft was instituted pursuant to the 1863 Enrollment Act. Prior to that time, including during the Revolutionary War, War of 1812, and Mexican-American War, the U.S. relied on a volunteer federal force augmented by state militia as needed. Men ages 20 to 45 were eligible for the Civil War draft in both the U.S. Army and Confederate States Arms. There were

exemptions for family care dependency and employment in official positions. In addition, draftees could pay a substitute to take their place or a "commutation" fee of up to $300 ($7,388 in 2024 dollars) to avoid service, mechanisms that privileged wealthy persons. For example, one future U.S. president, Benjamin Harrison, paid for a substitute to take his place as a draftee. The Army also for the first time offered bounties (i.e. bonuses) to encourage enlistment. The draft was conducted by lottery in each congressional district based on quotas assigned to each district based on the number of eligible men and the number of men from the district already serving. Draftees were required to report in the order in which their names were drawn. In 1863, there were riots in New York City opposing the draft, resulting in $1.5 million in property damage. Of the 2,690,401 Union soldiers who served during the war, 255,373 were draftees. 86,724 draft eligible men paid a "commutation" to avoid service and 117,986 paid for substitutes. The Enrollment Act lapsed at the close of the war.

World War I (U.S. participation 1917-1819): At the outbreak of World War I, there were 100,000 personnel in the all-volunteer United States Armed Forces. In May 1917, President Wilson signed the Selective Service Act into law authorizing the conscription of males ages 21 to 31 and authorizing the mobilization of the state National Guards into federal service. In 1918, the Congress expanded the draft to include males up to the age of 45. A report to the Secretary of War on the operation of the Selective Service System suggests the change was driven by concern that the war would extend into 1919 and that younger ages would not provide sufficient Class I recruits to meet military needs, necessitating either the drafting of less qualified Class II and III recruits or raising the age of the draft (Second Report of the Provost Marshal General to the Secretary of War on the Operations of the Selective Service System to December 20, 1918, 1919).

In contrast to the Civil War draft, the World War I draft was selective, rather than based on a lottery. The government, through the Selective Service system, could select draft-eligible individuals based on skills, background, and health. Also in contrast to the Civil War, substitutions, commutations, and bounties for enlistments were not permitted or provided; however, "100,000 deferments were provided to otherwise qualified men … to serve in the shipbuilding industry." To process the registration and draft, the Selective Service Act established over 4,600 civilian draft boards (i.e. not connected to the military) to hear claims for exemptions. "Out of the 24.2 million that registered for the draft in World War I, 2.8 million were eventually inducted." (Kamarck, 2021)

World War II: The Selective Training and Service Act was passed in 1940, prior to America's entry into the War. Although passed in the shadow of war, this was the first peacetime conscription in the United States. The law required men ages 21 to 35 to register with one of 6,442 district draft boards. The boards assigned numbers to eligible district registrants for a conscription lottery. A draft lottery was used from 1940-1942. Subsequently, draft boards inducted persons in their districts based on quotas and criteria set by the government akin to a selective service rather than lottery system. (A lottery system returned in 1969 until the cessation of the draft in 1973). "Approximately 10 million of the 16 million servicemembers who served during World War II were draftees." The relevant law lapsed in 1947.

Cold War and Vietnam, 1948-1973: Following World War II, the U.S. military shrank from 12 million to 1.5 million personnel. However, the Selective Service Act of 1948 was passed in response to concerns about Soviet military power and recruiting shortfalls and a draft resumed. In response to the outbreak of the Korean War the draft was extended until 1955 and the registration age lowered to 18. The authorization to conduct a draft was extended in four-year increments. Between 1950-1964 volunteers comprised 2/3 of the military and the draft was used to augment personnel needs, largely in the Army. (Interestingly, "precedence policy at the time was to fill quotas with delinquents first (those that failed to register or had otherwise failed to meet requirements of the selective service law), followed by volunteers for induction, then 25-year-olds down to 19-year-olds"). During the period 1965-1973 the draft was especially controversial in the context of military intervention in Vietnam. At the height of the U.S. intervention there were 500,000 U.S. armed forces in Vietnam. During this

period there were ongoing protests against the war and the draft. In May 1970, for example, at Kent State University four students were killed and nine wounded when Ohio National Guard soldiers fired upon anti-war protesters. An estimated 100,000 draft eligible men left the country in order to avoid service and prosecution as did 1,000 deserters.

Throughout this time frame the draft was perceived as inequitable and inconsistent in its application, especially around the topics of student deferment and racial demographics. With the backdrop of the Vietnam War, inequities took on added meaning. In 1966, President Johnson established the National Advisory Commission on Selective Service to study the system and make recommendations. The Commission was led by Burke Marshall, a leader of the Civil Rights Division of the Department of Justice during the Kennedy Administration. Among other things, the Commission studied economic and racial disparities in the administration of the draft as well as educational deferments, the most controversial draft deferment. The law and corresponding regulations required that college students receiving a draft notice be permitted to finish the current academic year and that high school seniors be allowed to graduate from high school prior to induction. However, draft boards were given discretion to extend educational deferments. Many boards did so, resulting as a matter of practice in de facto exemptions. As a matter of process, a student coming off deferment when they graduated would be subject to the 19-year-old draft lottery pool. The Commission recommended that under no circumstances should deferments become exceptions and no new student deferments should be allowed without determining public need (In Pursuit of Equity: Who serves when not all serve?, 1967).

It is estimated that approximately half, or 15.4 million men, of the 27 million men eligible for the draft during the Vietnam Conflict received educational deferments (Tom Valentine, 2016). Contrary to popular perception in the United States, a majority of personnel who served during the Vietnam conflict did so as volunteers and not conscripts (1,857,304 conscripts out of 8,744,000 total participants, or 21%) (Kamarck, 2021). *However*, a 1977 RAND study concluded that as many as 77% of volunteers during the Vietnam War volunteered to otherwise avoid induction (Richard V. L. Cooper, 1977). The draft lapsed with the advent of the AVF in 1973; however, in response to the Soviet invasion of Afghanistan in 1980, President Carter activated by proclamation a requirement for males turning 18 to register for a potential draft. The registration requirement has remained in place since.

Implementation of the Draft: Themes, Issues, and Implications. The U.S. experience with conscription reveals several implementation themes and issues with potential relevance to Ukraine. To start, perceptions about conscription were shaped by perceptions about whether the draft was administered in a fair manner, including in the issuance of deferments and exemptions, and whether the draft was equitable in its application, i.e., whether the burdens of conscription fell disproportionately on minorities and/or the economically underprivileged men, which in the United States might also fall disproportionately along racial lines. Likewise, perceptions about the draft impacted public support for government policies, this was especially true during the Vietnam Conflict, which was increasingly unpopular after the 1968 Tet Offensive and more so because of the draft. For example, the antiwar movement was spearheaded on college campuses where many students faced the prospect of conscription without an ongoing deferment or exemption. College-aged students also were more likely to have the familial capacity and connections to both protest the draft and avoid or evade its reach.

Process impacts perceptions of Equity and Fairness: In U.S. practice, the process of registration and induction was administered at the local level, during Vietnam at 4,080 separate draft boards (as of 1966) established at the county and metropolitan level. The boards would determine the class of the registrant, e.g., 1-A for “Available for Military Service,” 4-F for “Not Available for Military Service,” as well as the availability of any “clearly established” deferment or exemption, e.g., Class I-S Student Deferment. Registrants could appeal draft board decisions to a state Appeals

Board and in certain extraordinary circumstances to the President. The boards were made up of local civilians, who in theory were aware of local economic needs and circumstances. However, the multitude of boards led to variance in the application of deferments, a situation magnified when national policies were vague or discretionary. As a result, even the good faith application of the Selective Service Act led to disparate outcomes, including for similarly situated persons depending on where they lived. This in turn contributed to the perception that the draft was administered in an unfair and inconsistent manner, before accounting for those draft eligible men who successfully "gamed" the system leading to additional perception that the draft was "rigged" in favor of the wealthy and privileged.

The perception that the draft was applied inconsistently and inequitably was based on reality during the Civil War and Vietnam. Affluent and educated persons were more likely to avail themselves of deferments and exemptions, especially educational and medical deferments, or assignment to a National Guard unit, which during Vietnam were not deployed overseas. This was certainly true during the Civil War when a draftee could pay a substitute to stand in his place; and it was indirectly true during Vietnam, whose deferments favored those who could afford college and thus access to an educational deferment or the type of advisors and medical experts who might guide an appellant through the deferment and exemption process.

Current U.S. law requires that in the event of a draft selective service selection shall be made in an impartial manner and without discrimination on account of race or color. The challenge is putting principle to practice, especially during wartime. The U.S. experience suggests that impartiality depends on clear standards, transparently and evenly applied across districts and demographics. This might occur by limiting the number of decision-making draft boards, a centralized appeals process, or both. In U.S. practice, educational deferments have been especially problematic, as education can serve as a proxy for privilege and wealth, and depending on how applied, shift the burden of war to the economically depressed, which is not impartial.

Lottery v. selection: The U.S. has used both a selective method of induction and a lottery system of induction. A selective system is more likely to meet the specific needs of the military by allowing draft authorities to draft against skill and fitness criteria determined by the military. A random lottery, on the other hand, is more equitable in its application and more likely to be perceived as equitable. It also removes inconsistencies between draft boards and regions where a single drawing is used to determine the order in which conscription eligible and qualified men are inducted into service. During World War II and Vietnam when a lottery was used, it was based on the drawing of birthdates. Current law requires selection in an "impartial manner."

Mix of draft and volunteer: During periods of conscription, the U.S. has relied on a blend of volunteers and conscripts. Conscription has generally been used to augment and close recruiting shortfalls, rather than as the primary mechanism of recruitment. That is, the U.S. Government did not set its conscription goals based on a policy judgment about the optimum blend of volunteers and draftees from a war fighting perspective or based on pre-set numbers and formulas. The military sought to fill its ranks with volunteers first. But of course, the draft spurred some, and according to the earlier cited RAND report a majority during Vietnam, of eligible men to volunteer and thus control the timing of induction and the branch of accession, and many times, also the military role (e.g., infantry, intelligence, supply).

Wartime literature indicates that in a mixed recruitment context, attention must be paid to training military leaders in the different leadership skills needed to lead volunteers, draftees, and blended units. The importance and complexity of such differential training increases dramatically when a draft reaches across ages. In American practice, officers have uniformly been leading 19-year-old and 20-year-old draftees, which means that officers and NCOs may anticipate a fairly uniform level of maturity (or immaturity) and level of physical fitness. Any context that includes draftees across ages, and an average age of 40 as in the UAF, will require additional leadership

training and skill sets to equip officers and NCOs to inspire and lead the young, the old, and the middle-aged, as well as the fit and the less fit. Perhaps most complicated, young officers may find themselves leading and responsible for men their father's ages and with more leadership and lifetime experience than the officers and NCOs appointed to lead them.

Volunteer incentives. In American experience, and during every period of conscription, recruitment incentives and the level of recruitment incentives has impacted the number of persons required for conscription. Restated, enlistment bonuses decrease conscription numbers. In today's AVF context, polling data indicates that patriotism, competitive pay, and career opportunity are the most cited reasons for enlistment, or more likely some combination of all three (Jim Garamone, 2023). However, during the draft, the opportunity to control the timing of induction and branch of induction were important factors influencing voluntary enlistment. Current U.S. law prohibits the paying of bounties to induce a person to enter the Armed Forces, the furnishing of substitutes, or the purchase of release, all of which were prominent during the Civil War.

Age. The United States has uniformly drafted up rather than down the ladder of age. That is, the United States has drafted 19-year-olds before it has drafted 20-year-olds, etc. The one exception appears to have been during the 1950-1964 period, where there is indication that the United States drafted down from age 25 to 19. Legislative history indicates that younger men were preferred for conscription for physical reasons and because it was thought the conscription of younger men would also be less disruptive to family life, and the economy.

Deferments and Exemptions. The United States has throughout its conscription history permitted deferments and exemptions for critical occupations and industries and family dependencies. The areas of greatest controversy have centered around three areas: (1) Equity - the perception and often reality that wealthier persons were more likely to find a path to deferment or exemption and that the draft fell disproportionately on the poor. (2) Educational deferments during the Vietnam era, as noted, were the most numerous and controversial deferments. (3) Standardization - It should not be lost that some of the concern about equity and educational deferments stemmed not from the existence of the deferment or exemption, but the uneven and seemingly arbitrary manner in which the deferments were awarded. This is illustrated by the findings of the National Commission on Selective Service, which documented how different draft boards applied different standards when addressing deferments, some based on grade point average or an assessment of the value of a student's area of study, and some based on semester hours. United States practice and history demonstrates the importance of clear standards uniformly and consistently applied. The draft in the United States has never been "popular;" it has been viewed even less favorably when perceived as unfair or inconsistent. The college and graduate deferment was repealed in 1971 (See §3806 for a description of current deferments and exemptions.).

The National Commission on Selective Service examined the question of whether draftees would be less likely to go to college after service in the absence of an educational deferment, an argument that was given to continue the educational deferments through college. Likewise, the Commission looked at whether the absence of deferments would curtail officer recruitment. The Commission concluded that neither concern was well-founded. Post-service soldiers were as likely to go on to college as they would have been if they had gone straight from high school. And students in officer training programs were exempt from conscription.

Deterrence, Prosecution, and Pardons. In U.S. practice, adherence to the registration and conscription requirements has been predicated on incentives and disincentives. Incentive comes in the form of the benefit of voluntarily enlisting or commissioning and thus controlling one's selection of service, branch, and timing of induction; however, we surmise that such incentive only "works" if conscription is both predictable and likely, if not certain. However, the principal deterrent to draft evasion is the loss of benefits, including the opportunity to work for the federal government and access to federal financial assistance for education. Draft evasion can and has at times, increased the

prospect of induction, as for example, during the period 1950-1960 when it was used as one factor in the priority of draft. Under current law, but not in practice with an AVF, "any registrant who has failed or refused to report for induction shall continue to remain liable for induction and when available shall be immediately inducted."

Prosecution is also possible. In U.S. law, failure to register or report for the draft is a felony punishable by a fine of up to $250,000 and/or 5 years imprisonment in addition to state penalties. However, in U.S. practice prosecution is not the primary means of compulsion or enforcement. During the Vietnam era, there were between 2,000 and 4,000 prosecutions for failure to register or failure to report for induction each year (James B. Jacobs & Dennis McNamara, 1984). In 1977, President Jimmy Carter signed a proclamation pardoning all persons who had violated the Selective Service Act during the period 1964-1973. The pardon was controversial. The public perceived the pardon as directed at those persons who had left the United States to avoid the Vietnam era draft and subsequently found themselves ineligible to reenter the United States. President Carter did not issue a statement at the time of the pardon, but the act was considered a part of President Carter's effort to bring closure to America's Vietnam War experience. In Ukrainian context, the fear of prosecution of conscription will likely deter conscription eligible men from returning to Ukraine, thus compounding concerns about demographic declines.

Female Conscription, Registration, and Volunteer Service. One way to increase personnel is to conscript age-eligible women as well as men. Registration is an intermediate step, providing a contingency path to conscription in the event of an immediate need for an influx of personnel. According to the Pew Research Center, fewer than a third of countries (60) have an ongoing military draft; most exclude women. Six countries conscript women as part of universal military service schemes: Eritrea, Israel, Mali, Morocco, North Korea, and Tunisia. Five countries, including two NATO countries, have selective service systems that include men and women, although as a matter of practice it does not appear that these five countries conscript women (or men) who do not otherwise volunteer to serve in the armed forces. (Those countries are Benin, Cabo Verde, Mozambique, Norway, and Sweden). Another 23 countries, including the United States, have conscription laws, but do not actively draft personnel, male or female. 85 countries with militaries that do not authorize conscription rely on volunteer service (Drew Desilver, 2019).

United States Practice: Approximately 3 million women have served in the military in some fashion since the Revolutionary War, including 34,000 during World War I and 200,000 during World War II. (The first and only woman to receive the Medal of Honor, Mary Walker, was from Syracuse Medical College and served as a surgeon during the Civil War.) However, it was not until President Truman signed the Women's Armed Services Integration Act of 1948 that women were granted permanent and regular status in the Armed Forces. This was the same year that President Truman desegregated the Armed Forces. Women were not eligible to serve in "direct ground combat roles" (infantry, armor, artillery, combat aviation) until 2013. It should be noted that almost 80% of today's military positions are classified as noncombat. In a wartime context, involving an invasion, we would anticipate that the percentage of "combat" positions would increase; however, the point remains valid that most military positions even in wartime do not entail direct combat roles. A 2015 Memorandum from the Secretary of Defense and Chairman of the Joint Chiefs of Staff to the Secretaries of the military departments, who hold legal responsibility over recruitment, provides: "Anyone who can meet operationally relevant and gender-neutral standards, regardless of gender, should have the opportunity to serve in any position." As of 2022, 231,147 women served in the U.S. Armed Forces, or 17.5% of the active-duty force.

Although female service in the Armed Forces was at one point controversial, it is generally accepted today, although sexism remains a concern as does sexual assault. Selective Service registration for all women is a more controversial subject. In 2020, a National Commission was created to consider among other topics whether the United States should continue to maintain a

Selective Service System and registration requirement and if so, whether women should be obliged to register at the age of 18 as required of men. The Commission noted that the subject evoked the most passionate views from Americans of all the topics covered by the Commission. The Commission concluded that "the time is right to extend Selective Service System registration to include men and women, between the ages of 18 and 26. This is a necessary and fair step making it possible to draw on the talent of a unified Nation in time of national emergency." (Kamarck, 2021) Proponents of female registration cited the need to maximize the potential pool of talent in the case of a national security emergency, the uncertainty over what talent would be needed in the future, the prevalence of "noncombat" jobs to be filled (80%), principles of civic duty, and principles of equality and fairness. (Male litigants have also made equal protections claims). Opponents cited the different roles of women in society, the need to backfill domestic jobs in the event of a draft, and generalized differences in physical capabilities and differentiated equipment. However, as of July 2024 the law has not been amended to reflect this recommendation.

B. Recruitment Incentives and Disincentives. Marginal changes and adjustments over time can in their cumulative effect significantly change and improve the recruiting landscape. Given the long-term nature of the war, the status of the war, and the continuous nature of the Russian threat, changes in military recruitment and culture over time may pay dividends forward. This section identifies recruiting incentives and disincentives in U.S. practice, which may offer appropriate analogy for Ukrainian recruitment.

Recruiting and Retention Methods

1. Bonuses:

- **Recruiting Bonuses:** Currently every service offers some version of an enlistment bonus depending on the career field. The bonuses are generally paid out as a percentage increase in the service member's salary over the length of enlistment. For example, the Army is currently offering an initial enlistment bonus of $15,000 for a "quick to ship" to initial training with other bonuses potentially compiling to over $50,000 (Earn Bonuses While Pursing Your Passion, 2024). Historically, these amounts shift with recruiting and retention numbers and are targeted to whatever career fields that have the highest turnover.
- **Retention Bonuses:** All services also offer reenlistment bonuses for usually 3 or more years paid out in the same structure as enlistment bonuses. However, due to record high reenlistment those bonuses are currently limited to low density fields (Regular Army: Active Duty Bonus Sheet, 2024).

2. Education Benefits (concurrent with service)

- The DOD offers an in-service education benefit called Tuition Assistance (TA), where a service member may enroll in an accredited institution and receive up to $4,500 per fiscal year (Jim Absher, 2023).
- Credentialing support is also available for service members. This is an incentive program up to $1000 per year to pay for an approved credential such as Project Manager Certification, Lean Six Sigma, or one of 5 personal training certifications (Army COOL Credentialing Opportunities On-Line, 2024).

3. Special Pays (skill and duty/assignment) (Military Compensation, 2014)

- Every branch currently offers incentives for specific skills or duty assignments and usually range between $150-$250 per month while maintaining that skill status. At a base level these include parachute/jump pay, demolition pay, flight pay, and hostile fire pay.
- Other special pay can be offered at various amounts and periods for language proficiency, medical certification, and volunteering for a specific "hardship" tour or placement.

4. Military Retirement and Veteran Specific Federal Benefits

- One of the most successful recruiting tools is the promise of education benefits after service. The U.S. has offered the GI Bill for over 75 years to provide for secondary education opportunities with over 800,000 veterans using the current Post 9/11 GI Bill since 2009 (75 Years of the GI Bill: How Transformative It's Been, 2019).

- Military Retirement benefits continue to play a key role in military retention. The current 20-year military retirement model is one of the most positively correlated reasons for continued service after initial enlistment (Beth Asch, 2019).

- The Veterans' Affairs (VA) System provides medical care to all retirees and various levels of discounted medical insurance for all qualifying veterans. This also includes VA based non-medical benefits like government backed VA loans and credit card interest rate caps.

Command Climate and Military Justice. Although hard to measure, command climate should not be overlooked as an influence on recruiting. A credible civilian or military justice system that holds military leaders accountable for the conduct of their personnel, but also the morale and welfare of their personnel is also important. In U.S. practice and experience, it is thought, but hard to demonstrate that perceptions about military life (i.e., the command climate) and to a lesser degree the credibility of the justice system that upholds good order and discipline, impact recruitment.

Mothers and fathers do not want their sons and daughters to serve in a military that treats, or is perceived as treating, their children unfairly and they do not want their children to serve in an environment that is abusive. This conclusion is intuitive, but also hard to demonstrate; generally, polling is not collected on why eligible persons do *not* volunteer for the Armed Forces. However, what the U.S. data does show is that concerns about sexual assault in the military and racial disparities impacts recruiting. The DOD Fall 2021 Propensity Update, Youth Poll conducted by the Joint Advertising Market Research & Studies (JAMRS) shows that 30% of all respondents listed "Possibility of sexual harassment/assault" as a main reason why they would *not* consider joining the U.S. military (Fall 2021 Propensity Update, 2022). An earlier 2013 survey stated that, while 59% of Americans say that if they or a friend had a daughter who was thinking of joining the military, the allegations of sexual misconduct would *not be a sufficient reason* to tell her to stay out of the military, *38% say these allegations are a sufficient reason to dissuade a young woman from joining* (Sexual Assault in the Military Widely Seen as Important Issue, But No Agreement on Solution, 2013). Additional polling show racism or racial disparities has a negative effect on recruiting and retention. A 2021 Blue Star Families Social Impact Research Racial Equity & Inclusion poll found that: (1) 42% of service members of color in a new survey turned down an assignment or permanent change of station order because of concerns about racism and discrimination, even when they knew doing so could negatively affect their career because of perceptions of racism in the local community; and (2) 33% of active-duty families and 34% of veterans in the survey reported that concerns about racial and ethnic discrimination were a factor in conversations with family members about whether to stay in the military.

We do not presume to extrapolate from the U.S. experience knowledge about the Ukrainian experience or context. They are distinct. However, command climate undoubtedly matters to recruiting and retention. It is also often overlooked or neglected until it reaches crisis proportions as has happened in the U.S. with sexual assault. The military may be especially prone to overlook issues of command climate and their impact on recruiting during times of conflict when the focus is on victory, rather than reform. However, in U.S. practice, it should be noted that some of the most significant reforms in the military justice system occurred as a result of war or amidst war, albeit not involving an invasion of the homeland. The bedrock of the U.S. military justice system, for example, the Uniform Code of Military Justice, was a product of the World War II experience of U.S. veterans. Many veterans didn't like what they had seen or experienced of military justice during the war. Some

veterans, like Gerald Ford, went on to serve in Congress and led the movement to reform the system top to bottom. Arguably the most significant additional reforms to the U.S. military justice system occurred with passage of the Military Justice Act of 1968, at the height of the U.S. involvement in Vietnam. Among other things, the Act created the position of military judge to preside over courts-martial, which reform was implemented in 1969 on a global scale and in a wartime context. Likewise, many of the reforms to the U.S. military justice system to address sexual assault have occurred during the U.S. wars in Iraq and Afghanistan. In other words, wartime context in U.S. practice did not and does not preclude legal reform, it necessitates it as a professional and recruiting necessity.

We surmise that polling in Ukraine about command climate warrants attention. Analysts of 'military power and inequality within military ranks' describe a correlation between how different classes of service members are treated and the impact on military performance, morale, and cohesion (Jason Lyall, 2022). When segments of military service members (of the same class) are treated differently or poorly, and subject to worse treatment or increased punishment, grievances become more prevalent (Jason Lyall, 2022). Such grievances are made online and through social media weaving its way back to the public—and even the enemy. When such sentiments reach the public, that is when public opinion starts to form and have an effect on perception of the military, military justice, and the public's willingness to join the military (Jason Lyall, 2022). This perception, once formed, can also have a compounding effect on conscripted soldiers beyond performance, but to the extent of causing friction with superiors; again leading to more military justice and discipline issues.

Moreover, it is not evident, the Ukrainian public has, or would have confidence, in the Ukrainian justice system to address concerns about command climate. In 2019, military justice responsibility was transferred from the Ukrainian military to the Office of the Prosecutor General. There is nothing inherently correct or incorrect about such a transfer, which comports with EU standards. However, whereas the Ukrainian military is an institution that polls at record high trust in Ukraine, polls demonstrate that the Office of the Prosecutor General operates at a level of record low trust. Likewise, while anecdote is not evidence or data, conversations and interviews indicate the Ukrainian system of military discipline and justice is perceived by many within and outside of the service as Soviet in style and arbitrary and capricious in practice.

Unit Rotation and The American Experience. During the large-scale combat operations of the 20th Century, the U.S. military generally deployed units at the Army or Fleet level for the duration of the conflict. Replacement service members were brought in individually to supplement unit strength lost as casualties (Griggs, Haider, Flatebo, 2020). In this Individual Replacement System (IRS), the replacements were largely comprised of draftees who were trained domestically at a volume and pace commensurate with the existing causality rate and force structure goals. The purpose of IRS was to maintain the combat strength and cohesion of consistently deployed units by continually pairing veteran troops with fresh replacements.

The most prolific U.S. use of the IRS was during World War II, between 1942 and 1944 (The Personnel Replacement System if the United States Army, 1954). During that time, the U.S. Army specifically maintained 102 replacement battalions spread between the U.S., Pacific, and European Theaters. Troops would assemble after basic training in specific depots in the U.S., move to forward deployed replacement depots for additional training and garrison duties before finally being pushed forward to front line units. This iteration of IRS adequately manned and reinforced a U.S. Army of approximately 8 million soldiers fighting across four major combat theaters (Research Starters: US Military by the Numbers, 2024).

Another similar version of IRS was also used in the Korean and Vietnam Wars. However, during the Vietnam War the IRS was altered to a 365-day replacement system for the individual service members opposed to the previous causality and points-based end of tour system. These troops would rotate into a deployed unit for individual, one-year tours of duty at a staggard rate to retain unit cohesion (Roger Kaplan, 1987). However, this system was widely criticized due to the expanded draft

parameters for lower quality recruits, the length of the conflict, and systemic reviews that this replacement system had an overall negative effect of unit readiness.

Since the end of the Vietnam War and the introduction of the All-Volunteer Force in 1973, the U.S. has also moved away from the IRS and onto the Unit Replacement System (URS). The Department of Defense (DOD) currently operates a strategic level military deployment cycle designed to prioritize unit level readiness for long term contingency operations like the Global War on Terror (GWOT) (Griggs, Haider, Flatebo, 2020). The DOD and its branch components develop the URS schedule, essentially the time and rhythm in which a unit is deployed to a specific Combatant Command theater, by balancing the national priorities from the Administration's National Security Strategy against the total number of troops available between the active duty and reserve/national guard forces (Feickert, Kapp, 2014).

This balance is quantified by measuring the operational tempo (OPTEMPO), the required number of units/troops needed to meet the current national security priorities, against the personnel tempo (PERSTEMPO) or the amount of time individual service members spend conducting their official duties deployed in theater (Kristy N. Kamarck, 2022). Additionally, Congress further requires the DOD to establish specific dwell time (time spent home in the US) standards under 10 U.S.C. § 991. These standards state that service members are to spend no more than 220 days out of 365 or 400 days out of 730 deployed without a DOD waiver and additional pay (10 U.S.C. § 991, 2024). As a result of all these considerations, the current DOD policy requires a 1:2 deployment ratio to dwell timeline for active-duty forces and a 1:4 ratio for mobilized reserve troops (Memorandum for senior Pentagon leadership defense agency and DOD field activity directors, 2021).

In practice, the URS was largely effective at deploying joint forces to combat theaters like Iraq and Afghanistan during the post-invasion contingency operations. Although the exact deployment length often differed by branch, they were generally between 6 and 12 months with an overlapping Relief in Place handover to the new replacement unit. As the conflicts in Iraq and Afghanistan began to draw down, the lengths of these deployments were likewise shortened further improving dwell time issues. For example, in the early GWOT the U.S. Army routinely deployed forces on 12- to 15-month deployments but moved to a 9-month cycle in FY2012 to reduce stress on the force (Army Deployment Period Policy, 2011).

Overall, URS has proven to be a practical solution to long-term, low intensity conflicts. However, despite its longstanding use the URS also has a number of challenges. Notably, the loss of institutional knowledge in theater when a unit is replaced (Griggs, Haider, Flatebo, 2020). The new unit does not have the same understanding of the threat environment or the logistical challenges and will undoubtedly lose time trying to establish their new battle rhythm. These new units do not have an existing relationship with any partner forces or the indigenous people potentially regressing any of the previous unit's progress (John Amble, 2021). In short, the 20 plus year GWOT was fought akin to 20 distinct 1-year-long conflicts by different units with limited continuity.

Conclusion

Conclusion: Fair and Just. Each nation experiences war in a different manner. This includes the lifecycle of the military member, including the process of recruitment and conscription, training and service, demobilization, and reassimilation. However, we believe based on the U.S. experience that there are, or should be, at least three common themes to military service in a democracy.

First, as stated in the U.S. Military Selective Service Act, "in a free society the obligations and privileges of serving in the armed forces … should be shared generally, in accordance with a system of selection which is fair and just, and which is consistent with the maintenance of an effective national economy."

Second, certainty matters. Citizens are more likely to volunteer for service if they can be certain about the duration of service, the duration and quality of training, the type of service they will be

required to perform, the certainty of fair treatment in service, and the certainty of unit rotation and rest. Military members also want the certainty of knowing that the wounded will be cared for, the bereaved will be provided for, and the dead will be remembered.

Finally, reform cannot wait for victory or for peace. Victory may depend on reform, in both sustaining recruitment and sustaining popular support and morale.

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Математична модель стійкості функціонування системи ситуаційної обізнаності району операції (бойових дій) на основі використання розвідувальних безпілотних авіаційних систем

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Анотація. Наразі досвід ведення воєнних дій під час відсічі повномасштабній агресії російської федерації проти України показав надзвичайну ефективність безпілотних авіаційних комплексів (систем) у вирішенні завдань з ведення розвідки, ураження цілей противника, наведення та коригування вогню ракетних військ та артилерії, дистанційного мінування ділянок місцевості, транспортування матеріально-технічних засобів у визначені райони (зони) ведення операції тощо. Особлива увага при цьому приділяється безпілотним авіаційним комплексам (системам), які у взаємозв'язку утворюють систему ситуаційної обізнаності району операції (бойових дій).

Однак унаслідок впливу як внутрішніх (періодична зміна кількості безпілотних авіаційних комплексів (систем) у повітрі), так і зовнішніх факторів (вплив засобів радіоелектронної боротьби противника, вогневого ураження) така система є не стійкою, що проявляється у втраті розвідувальної інформації через неможливість її своєчасного оброблення.

Зважаючи на зазначене, у статті розроблено математичну модель стійкості функціонування системи ситуаційної обізнаності району операції, новизна якої полягає у тому, що вона описує функціонування системи під постійним впливом як зовнішніх, так і внутрішніх факторів за умови виконання завдань за призначенням *k* БпАК(С), а також визначає умови забезпечення стійкості функціонування системи у часі через обґрунтування допустимих обсягів інформації, які можуть оброблятися як на початку її функціонування, так і у подальшому, з інтенсивністю оброблення інформації, що постійно змінюється. За допомогою моделі можна визначити умови стійкого функціонування системи та тривалість оброблення інформації в ній при постійних збудженнях (постійному впливі факторів), що надає можливість корегування (за потреби) відповідних показників для досягнення потрібних значень оперативності та стійкості її функціонування.

Ключові слова: стійкість системи, середній обсяг інформації, рівняння Ляпунова, нелінійна динамічна система, постійне збудження системи, безпілотні авіаційні комплекси, система ситуаційної обізнаності.

Вступ (Introduction)

Досвід ведення воєнних дій під час відсічі повномасштабній агресії російської федерації (рф) проти України показав надзвичайну ефективність безпілотних авіаційних комплексів (систем) (БпАК(С)) у вирішенні завдань з ведення розвідки, ураження цілей противника, наведення та коригування вогню ракетних військ та артилерії, дистанційного мінування ділянок місцевості, транспортування матеріально-технічних засобів у визначені райони (зони) ведення операції тощо.

Результати, які демонструють сили оборони України на полі бою, застосовуючи БпАК(С), спонукали військово-політичне керівництво країни, промислові підприємства різного масштабу, волонтерські організації спрямувати фокус своєї уваги насамперед на ці зразки озброєння і військової техніки (ОВТ), щоб забезпечити потребу військ у БпАК(С).

Особливої уваги, з огляду на їх ефективне застосування, заслуговують БпАК(С), які використовуються для ведення розвідки противника. Але наразі основні розвідувальні спроможності військ (сил) Збройних Сил України (ЗС України) за рахунок використання БпАК(С) є лише на тактичному та частково на оперативному рівнях і в умовах переважаючої чисельності противника у силах і засобах постійно потребують нарощування.

В умовах війни з рф розвідувальні БпАК(С) різних класів від різних виробників довели свою ефективність під час ведення операцій (бойових дій) угрупованнями військ (сил) ЗС України та інших складових сил оборони України. Це призвело до підвищення вимог до розвідувальних БпАК(С), сприяло розвитку способів їх застосування, формуванню потреби в них, що, у свою чергу, обумовило необхідність розвитку форм і способів ведення воєнних дій військами (силами) ЗС України з урахуванням нових спроможностей, які надають розвідувальні БпАК(С).

У середньостроковій перспективі операційне середовище, в якому будуть діяти розвідувальні БпАК(С), набуде характерних рис максимально автоматизованого поля бою.

Очевидно, що автоматизація проникне у всі сегменти операційного середовища, починаючи від управління військами, переважно на тактичному та оперативному рівнях, і закінчуючи зразками ОВТ. Безумовно, ще більше скоротиться час на ухвалення управлінських рішень для своєчасного реагування на зміни в оперативній обстановці.

Наслідком цього стане безпрецедентний рівень ситуаційної обізнаності протиборчих сторін воєнного конфлікту. Тому надзвичайної значущості набуде вміння інформаційно переважати противника, який майже все про тебе знає.

Ключовими технологіями, які в таких умовах допоможуть підвищити ефективність застосування розвідувальних БпАК(С), звісно, будуть технології, які спрямовані на створення єдиного інформаційного середовища, що забезпечить в режимі реального часу обмін розвідувальною інформацією в районі ведення операції (бойових дій) під впливом як внутрішніх факторів (динамічної зміни кількості БпАК(С) у системі), так і зовнішніх, а саме: засобів радіоелектронної боротьби (РЕБ) та вогневого ураження противника. За цих умов вкрай важливим питанням, яке потребує негайного вирішення, є забезпечення стійкого функціонування такої системи ситуаційної обізнаності району операції (бойових дій) (ССОРО), створеної на основі використання розвідувальних БпАК(С) різних класів та типів сил оборони України, що й обумовлює актуальність теми статті.

Методологічна основа (Methodological Framework)

Повітряна розвідка із застосуванням БпАК(С) визначає комплекс заходів, спрямованих на добування та передавання розвідувальних даних про оперативну обстановку в заданих районах (зонах) в інтересах військових формувань ЗС України для підготовки і ведення операцій (бойових дій). За цільовою спрямованістю, способами та засобами отримання розвідувальної інформації повітряна розвідка із використанням БпАК(С) поділяється на видову (фоторозвідку, оптико-електронну (телевізійну, лазерну, інфрачервону) та радіолокаційну розвідку, радіоелектронну, радіаційну й хімічну).

Для забезпечення ефективного вирішення завдань у складі розвідувально-вогневих та розвідувально-ударних комплексів БпАК(С) мають інтегруватися в єдину систему розвідки та вогневого ураження, яка включає: систему повітряної розвідки та спостереження; систему управління застосуванням БпАК(С) (з автоматизованою системою бойового управління силами та обміном інформацією); систему вогневого ураження та радіоелектронної боротьби.

Інтеграція БпАК(С) у таку систему передбачає виконання завдань зі знищення повітряних цілей та завдавання ударів по наземних та морських цілях (об’єктах), здійснення радіоелектронного придушення систем (засобів) управління, радіозв’язку, радіонавігації, радіоелектронної розвідки противника.

Результати (Results)

З огляду на методологічну основу, математична модель стійкості функціонування ССОРО має описувати оперативність оброблення інформації в системі з n розвідувальних БпАК(С) в умовах постійної зміни їхньої кількості під впливом засобів РЕБ та вогневого ураження противника, а також доповнення системи (за потреби) додатковими розвідувальними БпАК(С). Оскільки на цей час в ССОРО, як правило, використовуються різні типи БпАК(С), кожен з яких, відповідно до своїх тактико-технічних характеристик, передає в ССОРО інформацію різного обсягу, то в ній під впливом зовнішніх та внутрішніх факторів відбувається динамічна зміна обсягів інформації, які мають бути своєчасно оброблені.

Іншими словами, така математична модель має бути динамічною системою, яка описує процес оброблення інформації в ССОРО у часі, що змінює свій стан в умовах постійних збуджень.

Таку систему в загальному випадку, якщо збудження діє постійно, може бути представлено як:

$$\frac{dx_i}{dt} = f_i(t, x_1, x_2, \dots, x_n), \quad (1)$$

де x_i – змінні умовної функції f_i, (i = 1, 2, … , n);

$x_i(t_0) = x_{i0}$;

t – інтервал змін.

Для всіх $t \geq t_0$ система:

$$\frac{dx_i}{dt} = f_i(t, x_1, x_2, \dots, x_n) + R_i(t, x_1, x_2, \dots, x_n), \quad (2)$$

де $x_i(t_0) = \tilde{x}_i(t_0)$;
$R_i(t, x_1, x_2, \dots, x_n)$ – малі за модулем,

що покладено в основу розроблення математичної моделі для визначення стійкості функціонування ССОРО при постійно діючих збудженнях.

Відповідно, для нелінійної диференціальної системи:

$$\frac{dy_i}{dt} = \mathrm{y}_i(t, y_1, y_2, \dots, y_n), \quad (3)$$

де $y_i = \mathrm{y}_i(t; t_0, y_0)$ – рішення системи для кожної точки (t_0, y_0) з початковими умовами: $\mathrm{y}_i(t_0; t_0, y_0) = y_0$.

Приймемо $\mathfrak{y} = \mathfrak{y}(t)$, $t_0 \leq t < \infty$, як рішення системи (3) (незбуджений рух), $\|y_i - \mathfrak{y}(t)\| \leq \varepsilon \leq \infty$. ε – окіл рішення $\mathfrak{y} = \mathfrak{y}(t)$.

Нехай:

$$x_i = \mathrm{y}_i - \mathfrak{y}(t), \quad (4)$$

де x_i – відхилення рішення y_i від рішення $\mathfrak{y}(t)$.

Оскільки

$$\frac{d\mathfrak{y}(t)}{dt} \equiv Y(t, \mathfrak{y}(t)), \quad (5)$$

то для x отримаємо диференціальне рівняння:

$$\frac{dx(t)}{dt} \equiv X(t, x), \quad (6)$$

де:

$$X(t, x) = [Y(t, x + \mathfrak{y}(t)) - Y(t, \mathfrak{y}(t))], \quad (7)$$
$$t_0 \leq t < \infty, \|x\| \leq \varepsilon.$$

Причому, зрозуміло, що: $X(t, 0) \equiv 0$.

Відповідно система (6) має тривіальне рішення $x = 0$, яке у просторі станів відповідає рішенню $\mathfrak{y} = \mathfrak{y}(t)$.

Таким чином, система (6) є приведеною або системою збудженого руху.

Зважаючи на це, у подальшому потрібно вважати, що на стійкість динамічної системи при постійно діючих збудженнях досліджується тривіальне рішення $x_i \equiv 0$, (i = 1, 2, … , n) системи рівнянь (1).

Тривіальне рішення системи (1) називається стійким по відношенню до постійно діючих збуджень, якщо для кожного $(\varepsilon) > 0$ можна підібрати $\delta_1 > 0$ та $\delta_2 > 0$ так, що із нерівностей $\sum_{i=1}^{n} R_i^2 < \delta_2^2$ при $t \geq t_0$ і $\sum_{i=1}^{n} x_{i0}^2 < \delta_1^2$ випливає:

$$\sum_{i=1}^{n} x_i^2(t) < \varepsilon^2, \quad (8)$$

де $t \geq t_0$;
$x_i(t), (i = 1,2, \dots, n)$ – рішення системи (1), що визначається початковими умовами $x_i(t_0) = x_{i0}$, (i = 1, 2, … , n).

Зважаючи на це, сформулюємо важливе означення, зміст якого використаємо під час розроблення математичної моделі стійкості функціонування ССОРО.

Означення. Функціонування ССОРО, яке описується системою диференціальних рівнянь (1), стійке при постійних змінах обсягів інформації у її станах $\vec{m}$, якщо для довільного інтервалу зміни обсягів інформації $\varepsilon > 0$ існують межі змін обсягів інформації $\delta_1(\varepsilon) > 0$ і $\delta_2(\varepsilon) > 0$ так, що середній загальний обсяг інформації, яка циркулює в ССОРО $\overline{N}(t) = \|\vec{m}\,(t)\| < \varepsilon,\ t \geq t_0$, за умови, що його початковий середній загальний обсяг інформації $\overline{N}(t_0) = \|\vec{m}_0\| < \delta_1(\varepsilon)$ і постійні зміни середніх обсягів інформації $\|R(t, \vec{m}(t))\| < \delta_2(\varepsilon)$. Причому $\|R(t, \vec{m}(t))\| < \delta_2(\varepsilon)$ для будь-яких $\|\vec{m}\| < \varepsilon$, і $t \geq t_0$.

Прийнявши означення до уваги, розглянемо систему диференціальних рівнянь з постійно діючими збуреннями $R(t, \vec{m}(t))$:

$$\frac{d\vec{m}(t)}{dt} = \Lambda^{\text{ССОРО}}(t) \cdot \vec{m}(t) + R(t, \vec{m}(t))\,,\ t \geq t, \tag{9}$$

де $\Lambda^{\text{ССОРО}}(t)$ – матриця ефективних інтенсивностей $\lambda_{ij}(t)$, яка визначає інтенсивність оброблення середніх обсягів інформації $\overline{m}_i$ в ССОРО у часі t за умови використання k БпАК(С) з урахуванням показника живучості ССОРО $P_{(k)}(t)$;

λ_{ij} – інтенсивності оброблення середніх обсягів інформації $\overline{m}_i$ в системі з k БпАК(С) у момент часу t;

$k = \overline{1,n}$.

У матрично-векторній формі для системи з k БпАК(С) інтенсивність оброблення інформації в ССОРО може бути визначено за виразом:

$$\Lambda^{\text{ССОРО}}(t) = \Lambda \cdot \vec{P}_{(k)}(t), \tag{10}$$

де Λ – матриця $i \times j$ зі сталими коефіцієнтами λ_{ij} (інтенсивностями оброблення середніх обсягів інформації $\overline{m}_i$ в ССОРО з k-го БпАК(С) у момент часу t;

$\vec{P}_{(k)}(t)$ – вектор ймовірностей знаходження в ССОРО у момент часу t k БпАК(С).

Відповідно до теореми Малкіна про стійкість таких систем мають виконуватися нерівності для функції Ляпунова $V(\vec{m}(t), t)$:

$$V(\vec{m}(t), t) \geq w_1(\vec{m}(t)),$$

$$\frac{\partial V(\vec{m}(t), t)}{\partial t} + \sum_{i=1}^{n} \frac{\partial V(\vec{m}(t), t)}{\partial m_i} \cdot \Lambda^{\text{БпАС}}(t) \cdot m_i(t) \leq -\,w_2\big(\vec{m}(t)\big) \leq 0, \tag{11}$$

де $w_1(\vec{m}(t))$ та $w_2\big(\vec{m}(t)\big)$ – неперервні позитивно визначені функції.

Приймемо:

$$\|R(t, \vec{m}(t))\| < \delta_2(\varepsilon), \tag{12}$$

де $\delta_2(\varepsilon)$ – мале число в околі ε.

Тоді виконується нерівність:

$$\frac{dV(\vec{m}(t), t)}{dt} = \frac{\partial V(\vec{m}(t), t)}{\partial t} +$$

$$+\sum_{i=1}^{n}[\Lambda^{\text{БпАС}}(t)\cdot m_i(t)+R(\vec{m}(t),t)]\frac{\partial V(\vec{m}(t),t)}{\partial m_i}<0. \quad (13)$$

З нерівності (13) можемо записати, що:

$$\|\vec{m}(t)\| < \varepsilon, \quad (14)$$

де $\vec{m}(t)=\mathrm{M}(t,t_0)\,\vec{m}(t_0)+\int_{t_0}^{t}\mathrm{M}(t,\tau)\;R(t,\vec{m}(\tau))\,d\tau$ – розв'язок системи диференціальних рівнянь (9) у формі Коші;

$\mathrm{M}(t,\tau)$ – фундаментальна матриця розв'язків системи диференціальних рівнянь, нормована за моментом τ.

Нехай:

$$\|\mathrm{M}(t,t_0)\|\le \mathrm{A}_1,$$

$$\int_{t_0}^{t}\|\mathrm{M}(t,\tau)\|\le \mathrm{A}_2,\ t\ge t_0, \quad (15)$$

де A_1 – загальний середній обсяг інформації, яка циркулює в ССОРО у момент часу t;

A_2 – сумарне збільшення середнього обсягу інформації, яка циркулює в ССОРО за час τ.

Тоді, здійснюючи оцінювання за нормою:

$$\|\vec{m}(t)\|=\mathrm{A}_1\cdot\delta_1(\varepsilon)+\mathrm{A}_2\cdot\delta_2(\varepsilon)<\varepsilon,\quad t>t_0, \quad (16)$$

де $\delta_1(\varepsilon)$ та $\delta_2(\varepsilon)$ – малі числа в околі ε;

ε – максимально допустиме відхилення траєкторії функції $\vec{m}(t)$ від заданого значення.

Відповідно, умовами стійкості функціонування ССОРО є:

$$\|\vec{m}(t_0)\|<\delta_1(\varepsilon),$$

$$\|R(t,\vec{m}(t))\|<\delta_2(\varepsilon). \quad (17)$$

Розв'язавши систему диференціальних рівнянь (9) у формі Коші для будь-якого часу $t_0\le t<\infty$ за виразом:

$$\vec{m}(t)=\mathrm{M}(t,t_0)\,\vec{m}(t_0)+\int_{t_0}^{t}\mathrm{M}(t,\tau)\;R(t,\vec{m}(\tau))d\tau, \quad (18)$$

дотримуючись при цьому вимог (15), (17) для динамічних систем з постійно діючими збуреннями $R(\vec{m}(t),t)$, тривалість оброблення інформації в ССОРО можна визначити за виразом:

$$t_k(\vec{m}(t_k),\varepsilon)=t_0-\lambda_{\text{мах}}(\mathrm{B}(t))\ln\frac{\varepsilon^2\cdot\lambda_{\text{мін}}(\mathrm{B}(t_k))}{V(t_0)}, \quad (19)$$

де $t_k(\vec{m}(t_k),\varepsilon)=\bar{T}_{\text{цу}}$ – середня тривалість оброблення інформації в ССОРО при постійно діючих збуреннях $R(\vec{m}(t),t)$ у k-й момент часу;

$\mathrm{B}(t_k)$ – матриця зі змінними у часі елементами $b_{ij}(t)$ із функції Ляпунова у квадратичній формі: $V(\vec{m},\,t)=(\mathrm{B}(t_k)\,\vec{m}(t_k),\vec{m}(t_k))$;

$\big(\mathrm{B}(t_k)\,\vec{m}(t_k),\vec{m}(t_k)\big)$ – скалярний добуток векторів $\mathrm{B}(t_k)\,\vec{m}(t_k)$ на $\vec{m}(t_k)$;

$\lambda_{\text{мін}}(\mathrm{B}(t_k))$ та $\lambda_{\text{мах}}(\mathrm{B}(t_k))$ – мінімальні та максимальні власні функції матричної функції Ляпунова $\mathrm{B}(t_k)$;

$\vec{m}(t_k)$ – вектор середніх обсягів інформації, яка обробляється в ССОРО у k-й момент часу;
t_0 – початковий час на момент виникнення перехідного процесу в ССОРО.

Представлена сукупність математичних співвідношень (1)–(19) визначає зміст математичної моделі стійкості функціонування ССОРО у цілому.

Обговорення (Discussions)

На підставі аналізу останніх публікацій у сфері розроблення математичних моделей, які описують функціонування складних інформаційних систем (Semenenko O., 2022; Dobrovolskyi Y., 2022; Гусак Ю. А., 2021; Павленко П. М., 2017; Кадієвський В. А., 2014; Бахрушин В. Є., 2009; Ткаченко В. І., 2008; Шматок С. О., 2004), можна констатувати, що на цей час розроблені й застосовуються математичні моделі, за допомогою яких можна визначити таку їхню властивість, як стійкість функціонування:

при постійних інтенсивностях оброблення інформації в стаціонарному режимі (під час планового здійснення інформаційного процесу) та обсягах інформації, які можуть коливатися у заздалегідь передбачуваних (прогнозованих) межах;

при постійних інтенсивностях оброблення інформації, обсяги якої внаслідок впливу зовнішніх факторів піддаються короткотерміновим збудженням;

при змінних інтенсивностях оброблення інформації, обсяги якої внаслідок різких змін оперативної обстановки піддаються короткотерміновим збудженням.

Узявши це до уваги, важливим та логічним постає питання щодо розроблення математичної моделі функціонування інформаційної системи при постійних збудженнях, яка описує стійкість її функціонування у цілому.

Висновок (Conclusion)

У статті розроблено математичну модель стійкості функціонування ССОРО. Новизна моделі полягає у тому, що вона описує функціонування ССОРО під постійним впливом як зовнішніх, так і внутрішніх факторів за умови виконання завдань за призначенням k БпАК(С), а також визначає умови забезпечення стійкості функціонування системи у часі через обґрунтування допустимих обсягів інформації, які можуть оброблятися як на початку її функціонування, так і у подальшому, з інтенсивністю оброблення інформації, що постійно змінюється. За допомогою цієї моделі можна визначити умови стійкого функціонування ССОРО та тривалість оброблення інформації в ній при постійних збудженнях (постійному впливі факторів), що надає можливість корегування (за потреби) відповідних показників для досягнення потрібних значень оперативності та стійкості її функціонування.

Рекомендації (Recommendations)

Розроблену математичну модель стійкості функціонування ССОРО може бути використано структурними підрозділами планування застосування військ (сил) та управління ними органів управління ЗС України оперативного рівня під час підготовки та ведення операції (бойових дій) для планування розвідки противника з використанням БпАК(С).

Модель може бути використано під час: розрахунку часу на підготовку операції (бойових дій); розроблення календарного плану підготовки операції (бойових дій); розроблення графіка роботи командувача угруповання військ під час оперативного планування.

Застосовуючи розроблену математичну модель, можна оптимізувати процес побудови організаційної структури ССОРО для забезпечення її стійкого функціонування.

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A mathematical model of the stability of the operation of the situational awareness system of the area of operations (combat operations) based on the use of reconnaissance unmanned aircraft systems

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Abstract. The combat actions experience during the repulsion of the russian federation's full-scale aggression against Ukraine has shown the extraordinary effectiveness of unmanned aerial systems (systems) in solving the tasks of reconnaissance, destroying enemy targets, directing and regulating the missile and artillery forces' fire, remotely mining areas, transporting material and technical assets to the designated areas (zones) of the operation, etc. Particular attention is paid to unmanned aerial systems (systems), which interconnect to form an area of operation (combat operations) situational awareness system.

However, due to the influence of both internal (periodic changes in the number of unmanned aerial complexes (systems) in the air) and external factors (influence of enemy electronic warfare, fire strikes), such a system is not stable, which is reflected in the loss of intelligence information due to the inability to process it in a timely manner.

Considering the above, the article develops a mathematical model of the sustainability of the functioning of an area of operation situational awareness system, the novelty of which is that it describes the system's functioning under the constant influence of both external and internal factors,

under the condition of performing the designated tasks k UAVC (S), and also determines the conditions for ensuring the sustainability of the system's functioning over time through the justification of the permissible information volumes that can be processed both at the beginning of its functioning and in the future, with the intensity of information processing constantly changing. With the help of the model, it is possible to determine the system's stable functioning conditions and the information processing duration under constant disturbances (influence of constant factors), which makes it possible to adjust (if need) the relevant indicators to achieve the required values of operational and sustainable of it's functioning.

Keywords: system sustainability, average volume of information, Lyapunov equation, nonlinear dynamic system, constant system disturbance, unmanned aerial systems, situational awareness system.

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Problematic issues in the navy of the Armed Forces of Ukraine's training for the future network-centric undersea warfare

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Abstract. Within the framework of execution of the Naval Doctrine of Ukraine for the period up to 2035, in order to create the basis for its own undersea warfare concept, an analysis of Ukraine's capabilities to comply with the main operational concepts of the US Navy's undersea warfare was carried out. It is determined that the first three of the five operational concepts could be applied to ensure dominance in the undersea space of Ukraine's responsibility zone in the Azov-Black Sea region, and the last two operational concepts are intended for use in distant war theatres. The contradictions that have arisen as a consequence of disproportionate trends in the undersea warfare methods development between individual operational concepts of undersea warfare are identified. Taking into consideration the identified contradictions, the US Navy's undersea warfare concept has been adapted to the Ukraine's geopolitical and geographical conditions. The research goal is to identify promising warfare assets in undersea space, the use of which will allow Ukraine to dominate undersea space within the exclusive economic zone borders in the Black Sea. The main research objective is to correctly select priorities when elaborating a strategic plan for the submarine fleet development of the Navy of the Armed Forces of Ukraine.

Ukraine is a maritime state and should define its own doctrine, concept and strategic plan for participation in the future undersea warfare, primarily in the internal seas war theatre

Keywords: undersea network-centric warfare, seabed warfare, undersea space dominance, undersea situational awareness, undersea warfare battlefield organisation.

Introduction

Undersea warfare is one of the three naval warfare operational domains, which involves a triad of underwater, surface, and air (including space) forces and assets. In the underwater space, network-

centric warfare is conducted with the use of specific military-technical assets that form its information and sensor layers, guided and autonomous weapons that form its executive layer (Peshekhonov V.G., 2016), (Baulyn V., 2009). War on the seabed (seabed warfare), the object of which is the seabed infrastructure, is considered separately, but, in our opinion, is an integral part of undersea warfare. The emergence of the new term ‘seabed warfare’ is related to the danger that, in the conditions of a new hybrid warfare type, suddenly and unexpectedly appeared in the sabotage against such components of the rapidly expanding seabed infrastructure in the world oceans as gas pipelines and fibre optic cables.

Warfare in underwater space is significantly different from warfare in other naval warfare operational domains. Underwater, there is extremely low situational awareness, challenging positioning, and low speed and capacity of hydroacoustic communications. In underwater space, all of this, on the one hand, narrows the range of destruction assets that are effectively used during combat actions at sea, on land and in the air, and, on the other hand, significantly increases the ability to covertly and anonymously use high-precision autonomous weapons from underwater, including when enemy targets are on land and even in the air.

The Navy of the Armed Forces of Ukraine's training for the future network-centric undersea warfare is associated with defining the underwater space as one of the modern warfare operational areas. The current undersea warfare experience shows that submarines are the most dangerous and at the same time the less vulnerable undersea warfare weapon. For this purpose, they are nuclear weapons carriers and have received the strategic level weapon status. The invulnerability of modern submarines to existing anti-submarine warfare (ASW) assets was confirmed by an incident involving a russian navy submarine in Swedish territorial waters (Baltic Sea) with depths of up to 100 m, which took place on 19th of October 2014. That day, Swedish radio reconnaissance equipment detected information about the time and approximate area of the submarine's accident. During several days, a search was conducted unsuccessfully in the area of 30×60 km around the submarine's accident site. As a result, the submarine successfully left the accident area (Sweden calls off suspected submarine search., 2014).

The Ukrainian war experience against the russian black sea fleet shows that over the two years of combat actions at sea, up to 30% of the surface vessels of the black sea fleet were destroyed by Ukraine. At the same time, not a single submarine, not a single autonomous unmanned underwater vehicle, not a single autonomous weapon unit that can be deployed in underwater space was destroyed at sea. It should be emphasised that autonomous weapons, the development of which was subject to certain legal restrictions until recently, are becoming the most effective in a new hybrid warfare due to the integration of artificial intelligence. In underwater space, the autonomous weapon's use is facilitated by the secrecy of its deployment on the seabed and the corresponding simplified ‘false flag’ use. Underwater autonomous weapons are seabed missile launchers, all types of mines, including modern missile and torpedo mines, autonomous underwater vehicles (multipurpose, strike, reconnaissance, transport), etc.

The relevance of the Navy of the Armed Forces of Ukraine's training for the future network-centric undersea warfare is confirmed by the losses the global economy suddenly and unexpectedly began to suffer as a result of a new hybrid type of undersea warfare. Over the past three years, a number of high-profile sabotage incidents have taken place in underwater space:

‘cutting’ off 66 km of submarine cable near the Norwegian coast (15.04.2021) (Who stole 10 tonnes of Norwegian cable at a depth of 2.5 km?, 2021)

- explosions of the Nord Stream 2 subsea gas pipelines in the Baltic Sea (26.09.2022) (russian warships were in the Nord Stream area several days before the explosions - media, 2023);

- breaks in fibre optic cables and a gas pipeline in the Baltic Sea (08.10.2023) (Finland reported damage to a russian cable in the Baltic Sea, 2023);

- breaks in fibre-optic cables in the Red Sea (27.02.2024) (Houthis attacked submarine internet cables connecting Europe and Asia, 2024).

In the current circumstances, the French Navy adopted a strategy for seabed warfare on 14th of February 2022, and NATO created a new special structural unit, the Undersea Warfare Centre, on 16th of June 2023. Despite these actions, all civilian fibre-optic submarine networks, special communications cables, and pipelines are in constant danger and will remain so indefinitely.

Ukraine is a maritime state and must define its own doctrine, concept and strategic plan for participation in the future underwater warfare, primarily in the internal seas war theatre.

Literature review

Currently, the undersea warfare doctrine, i.e., sustainable dominance in the underwater space, is realised through the network-centric warfare 'system of systems' implementation, which aims to use information superiority and thus to obtain the ability to conduct combat actions at a high-quality level. The 'system of systems' (hereinafter referred to as SoS) concept is considered in terms of sensor systems interaction, command and control system and high-precision weapons command in order to provide situational awareness, rapid situation assessment, and differentiated weapons use.

The research is aimed at identifying perspective warfare assets in underwater space, the application of which will allow Ukraine to dominate underwater space within the exclusive economic zone in the Black Sea's borders.

Achieving the set goal requires an analysis of the world's leading countries' experience. The undersea network-centric warfare US Navy's general concept is based on the implementation of five operational concepts (David R., 2018):

1. Advanced Undersea Warfare System, (hereinafter AUWS), which provides for the application of an underwater unmanned systems' distributed network that can be quickly deployed and configured to form a combat space and establish an access denial zone;
2. Forward Deployed Energy and Communications Outpost, (hereinafter FDECO), which provides for the construction of an underwater docking station network, underwater communication and navigation stations;
3. Modular Undersea Effectors (hereinafter referred to as MUSE) is a module system containing warfare assets capable of deploying communication nodes, weapons, distractors, false targets, traps, etc;
4. HYDRA is a logistics system for supporting combat actions in underwater space, using ultra-large autonomous unmanned underwater vehicles;
5. Upward Falling Payloads (hereinafter referred to as UFP), which provides for weapons, ammunition and military equipment pre-hidden on the seabed for further, time-delayed, distance activation in order to create information, sensor and executive layers of network-centric warfare.

The research main goal is to correctly select priorities in the strategic plan elaboration for the submarine fleet development of the Navy of the Armed Forces of Ukraine. At the current technological stage of society's development, all the world's leading countries are in a conceptual confusion state, as the ways to achieve dominance in underwater space over other countries are not defined. According to The Program Executive Officer for PEO (USC) (U.S. Department of Defence, 2022), '...in some of the undersea warfare strategic areas, a revolutionary technological leap is needed that is insurmountable for the enemy'. This can be achieved by mastering new energy support physical principles in underwater space, implementing priority developments in the area of 'artificial intelligence', and developing weapons that apply new strike physical principles.

According to the results of our analysis, in NATO countries, the realisation of the undersea warfare concept at the strategic planning level includes the following tasks:

- significant increase in the undersea warfare assets' autonomy;

- introduction of artificial intelligence into the underwater warfare assets command and control systems, including autonomous weapon command and control systems;
- creation of sensor networks of the information and underwater network-centric warfare sensor layers and their carriers;
- development of new weapons physical principles being effective in underwater space.

Information on the undersea warfare planning tactical level is contained in the annual activity plans of the Defense Advanced Research Projects Agency (DARPA) (Department of Defence Fiscal Year, 2023).

The fact that a ‘revolutionary technological leap’, insurmountable for the enemy, can lead to an unexpected victory on the battlefield is confirmed by successful combat experience of the Javelin ATGM used against russian armoured vehicles as a high-tech weapon sample. The use of Javelin ATGMs was the main reason for the successful spring-summer offensive campaign of the Land Forces of the Armed Forces of Ukraine in 2022. The russian army, which in some areas has mastered the 5th technological level and is armed with modern surface vessels, is being defeated in naval battles with Ukraine, equipped by the 6th technological level countries. Ukrainian analogues of the Maritime Tactical Systems (MARTAC) are highly effective in destroying modern russian surface vessels. The integration of robotics with ‘artificial intelligence’ on the battlefield, meaning loitering munition, thanks to automatic target identification technology, displaces snipers, for example. This has fundamentally changed the combat actions' character directly on the front line. It is worth pointing out that the first loitering munitions were used in a naval battle on 25 October 1944. It was a group of five Japanese kamikaze jets that sank the aircraft carrier St. Lo in one battle and disabled three other aircraft carriers. They differed from modern robotic loitering munitions in having the pilot's intelligence, which is now being replaced by artificial intelligence. At that time, not only aircraft were used, but also manned missiles ‘Yokosuka MXY7 Oka’ to hit maritime targets, manned torpedoes ‘Kaitaen’ and kamikaze speedboats.

Materials and Methods

The formulation of the undersea warfare concept requires certain knowledge of differences between combat actions over and under water. Compared to airspace, underwater space is ineffective for electronic intelligence, electronic warfare, aerospace reconnaissance, and cyber weapons, which are successfully used over sea, on land, and in the air. Unlike airspace, the negative weather conditions affecting combat actions underwater are significantly minimised. Through the fact that water is practically incompressible, the main damage physics principle, apart from direct hit, is overpressure. It is important to remember that an increase in the explosive's mass weight does not lead to a proportional increase in the destruction radius in water. In other words, only highly precision weapons that guarantee a direct strike are most effective in underwater space.

In addition, the water environment density is 800 times higher than the air density, which reduces the kinetic weapons effectiveness, reduces the threats from chemical and bacteriological weapons, from underwater explosion light and heat waves, and from radiological contamination after a nuclear underwater explosion.

At the current scientific and technical level, the most dangerous weapons of undersea warfare are still nuclear submarines such as Virginia-class, autonomous unmanned strike vehicles with nuclear power plants such as Poseidon type, deep-sea ballistic missiles such as Skiff type (Level of modern weapons, 2013), mines, mines-torpedoes such as Hammerhead type (Hammerhead: torpedo of the future, 2020). These underwater weapons types are capable of operating autonomously, using their own information and sensor support, i.e., they do not require additional seabed infrastructure, which provides enhanced communication relay capabilities, increased underwater positioning precision, and enhanced target detection and identification capabilities.

According to the future undersea warfare operational concepts AUWS and HYDRO, the nuclear submarines will be replaced by ultra-large autonomous unmanned underwater vehicles (hereinafter LDUUVs) (Saballa J., 2023) with a completely new power supply physical principle (Hollings A., 2022), which will be the main weapons and military technical assets carriers of undersea network-centric warfare. The AUWS operational concept is complemented by the seabed infrastructure of the future FDECO network-centric warfare information layer.

It is important to take into account that in the water environment, compared to the air environment, there are restrictions on electromagnetic waves distribution in the radio and optical (visible and infrared spectrum parts) spectral ranges, which in airspace are effectively used for communication and in radio and laser location. Unlike distribution in the atmosphere, in the water environment, laser and radio communication (GHz band) is practically limited to a 10 m range. This makes it impossible to use GPS and Starlink, which are successfully used on the battlefield in airspace. At the present stage, only acoustic waves are an alternative to electromagnetic waves in underwater space.

Results and Discussions

Let's consider the FDECO operational concept principle on Seaweb system example, which is applied in NATO countries (Rice J, 2003), (Reed M., 2006). Seaweb networks connect stationary and mobile nodes distributed over a large aquatic area (Rice J, 2005).

A Seaweb test of the sound underwater communication system took place in 2003 in the Gulf of Mexico by the US and Canadian joint fleets (US Navy Seaweb programme, 2024). Underwater communication was carried out through the communication relay by a sea-bed hydroacoustic modem network.

The situational awareness provided by the network-centric warfare sensor layer depends crucially on the positioning accuracy of underwater vehicles, as foreseen by the FDECO concept. The Seaweb long baseline principle (LBL) seabed navigation network of hydroacoustic beacon was tested in 2005 (Diogenes Laertius, 2019).

It should be noted that underwater hydroacoustic data communication assets are characterised by low signal-to-noise ratio, limited data volumes and low speed. In addition, the overcoming negative impact of refraction problem needs to be solved, by means of which acoustic shadow zones appear in the underwater space (PubMed, 2009), (Kapochkina A., 2022).

As it has been shown, the seabed infrastructure is the main seabed warfare target, so the creation of information and sensor layers of the future network-centric warfare requires the foresight of its covert use and/or protection methods.

The Navy of the Armed Forces of of Ukraine's training for future network-centric undersea warfare should be carried out within the NATO countries' general concept framework. However, it should be considered that the 5 undersea warfare operational concepts were formulated gradually, extending over time from the first to the fifth. When the undersea network-centric warfare concept was implemented in the form of a distributed network of underwater unmanned systems (AUWS) that perform its sensor and executive layers' functions, the need for reliable communication, electricity power restoration, and sufficient positioning accuracy ensuring became apparent. Only then was FDECO implemented, which provides for the creation of an SoS information layer, thus significantly improving its general concept's characteristics. Only after the information, sensor and executive layers of network-centric undersea warfare were created, the idea of a auxiliary warfare assets system's creation MUSE arose. In conditions of gradual (dynamic) development of the undersea warfare general concept, some principles of the previous operational concept AUWS may contradict the next operational concept's principles - FDECO. That is, the AUWS operational concept's further development may require a significant improvement of the FDECO operational concept, or even its rebuttal. An analysis carried out of the dynamic transformation specifics of

NATO's general concept of future undersea warfare gives grounds to state that dogmatic adherence to these 5 operational concepts is inadmissible in preparing the Ukrainian Navy for future undersea warfare. The considered NATO undersea warfare operational concepts are aimed at achieving dominance in the underwater space, which includes both defensive and offensive tasks. The first three undersea warfare operational concepts deal with the general tasks of shaping the battle space and establishing an access denied zone. The fourth and fifth operational concepts solve these tasks in a distant battlefield theatre, which do not expand to the responsibility area of the Navy of the Armed Forces of Ukraine in the Azov Sea and in the Ukraine's exclusive economic zone in the Black Sea.

Let's consider some specific examples of the modernisation dynamic impact of the AUWS operational concept on the FDECO operational concept's relevance. Currently, in the Navy of the Armed Forces of Ukraine's area of responsibility in the Azov-Black Sea region, underwater autonomous unmanned vehicles Remus-100 are used for the covert detection and identification of sea mines' tasks, which require high-quality communication for remote underwater target identification and for building a minefield map require precision positioning. Thus, at the current scientific and technical level of the PMO Navy of the Armed Forces of Ukraine, the AUWS operational concept is coordinated with the FDECO operational concept. But at the scientific and technical level of NATO's PMO, littoral combat ships (hereinafter LCS) already have Remote Multi-Mission Vehicles (hereinafter RMMV) in service, which do not demand an underwater information layer of network-centric warfare, because they are constructively able to use Starlink and GPS while in underwater space (Jimenez R., 2010).

It is worth noting that a similar situation is observed in the ASW area, where NATO countries have already deployed three underwater acoustic direction-finding centres in the world's oceans at the level corresponding to network-centric undersea warfare: IMOS, EGO/Coriolis, IOOS (Active Global Glider Tracks, 2024), (IMOS Ocean Gliders, 2024).

In order to ensure the covert use of underwater network-centric warfare information and sensory layers' sensors operating on a passive basis, we propose the use of mobile platforms. Promising networked hydroacoustic ASW systems operating on the primary acoustic field are considered to be manoeuvrable systems with the use of noiseless above- and underwater autonomous vehicles (gliders type) (IMOS Ocean Gliders, 2024). For assets operating exclusively on the positional principle (hydroacoustic lighthouses of the seabed positional acoustic direction-finding system), the use of mobile platforms is proposed. Mobile platforms solve the secrecy problem by means of a pre-planned, episodic change in the spatial position of the seabed infrastructure elements. One of the typical variants of such a platform is a seabed crawler autonomous unmanned underwater vehicle (Howard, R., 2019). The U.S. Navy employs a hybrid type manoeuvrable acoustic direction-finding platform with an aircraft platform - the Aqua-Quad quadcopter. The hydroacoustic beacon network can also be surface-based, which additionally allows the ultra-short baseline's application (hereinafter USBL) and short baseline's application (hereinafter SBL) of underwater positioning systems, which, unlike LBL, ensure positioning continuity. This platform type uses GPS and satellite communications and is able to operate outside the network-centric underwater warfare information layer's coverage.

It is worth noting that the information layer of the underwater network-centric warfare system can be used by both underwater platforms and surface ships, using special hydroacoustic equipment. Such communication and positioning duplication of surface ships is expedient in the conditions of both own and enemy electronic warfare.

So far, the wired data exchange principle is still being applied. For example, DARPA is implementing the development of the Tactical Underwater Network Architecture (Howard, R., 2019), a cable-based system for underwater fibre-optic communication. It is considered that such a system will replace conventional radio communications in overwater space in case the enemy employs electronic warfare. Link 16 standard is used for radio communications between buoys of this system and surface ships and aircraft.

In the Ukrainian Navy of the Armed Forces of Ukraine's shallow water areas of responsibility in the Black and Azov Seas, which occupy the largest part of the water areas, undersea warfare can be conducted by methods and assets that are not available in deep water. It is about the possibility of exchanging data directly through the sea surface, i.e., via a microwave radio channel (Ali F.M., 2020). By combining different physical principles of underwater communication, hybrid communication assets can be created in which the strengths of each method increase the reliability of the hybrid system as a whole (Gage C. P., 2019).

Considering the energy supply perspectives for undersea warfare through the implementation of new physical principles of power generation patented by Lockheed Martin Corporation, in the future, we can expect the implementation of laser technologies for identifying underwater targets, primarily in the interests of the PMO.

Conclusion

Navy of the Armed Forces of Ukraine's training for opposing russia in underwater space requires ‘breaking the current undersea warfare paradigm’. It is necessary to leave in the past the 4-5th technological level armaments and be guided by the network-centric undersea warfare requirements at the 6th technological level armaments and military equipment, which involves the shift to high-precision and autonomous weapons, robotic military equipment platforms.

The main result of our research is a scientific justification that the network-centric principle of forming a battle space and using high-precision weapons will win in the future undersea warfare, including thanks to the network platforms‘manoeuvrability and the unification of the SoS information and sensor layers’ equipment.

Now, watching the developments from the “top” of 2024, we can see the prerequisites for the intellect's victory over the ‘iron’. The kamikaze pilots were in fact the artificial intelligence of high-precision loitering munitions that unexpectedly crushed the US Pacific Fleet's ‘iron’ with lightning speed. Only 70 years have passed and the results of the ‘designers’ modellers", thanks to the 6th technology level technologies, are unexpectedly easily winning over the 5th technology level technologies.

In the undersea network-centric warfare environment conditions, especially in the internal seas and in the coastal ocean area at the exit from the naval base, the modern submarines' vulnerability is expected to increase and, accordingly, their employment effectiveness will decrease. We can expect an increase in interest in technologies for covert deployment of long-range missile launchers on the seabed. Smart mines, as the MUSE operational concept implementation, which involves the deployment of distractions, false targets, and traps, fit well into the network-centric warfare logic.

Recommendations

Considering the Ukraine's experience in the war against russia, it can be stated that the attack on Ukraine was intended, among other things, to seize the military-industrial complex enterprises, without which, due to the russia's technological backlog, it became impossible to produce and maintain aircraft engines, modern avionics, and strategic missiles. This is a typical situation, for example, on the eve of the Second World War (1938), Germany invaded technologically advanced Czechoslovakia, a country with a powerful military-industrial complex at that time, for the same purpose.

In the current geopolitical situation, China openly declares the intention to capture Taiwan, a country with the 6th technological level. The question arises whether it is possible for a country with the 5th technological level to take over a country with the 6th technological level? It is well-known that at the 6th technological level, the victory in the war is won practically without the use of kinetic weapons. The 5th technological level weapons in this war do not give an advantage on the battlefield.

In connection with our study's main content, which is based on the combat experience of gaining victory in the modern war in the Black Sea, we consider it appropriate to recommend reconsidering the possible consequences of an inevitable naval battle in the Taiwan Strait between China's attacking surface ships and autonomous robotic strike (above-water, underwater, air) systems with artificial intelligence that can be developed and manufactured in Taiwan.

Taking into consideration the fundamental changes that have taken place on the battlefield in Ukraine due to the use of unmanned systems with artificial intelligence, we believe that any technologically advanced country can achieve a technological breakthrough in war, regardless of its size, population, military industrial complex resource base, etc. This is proved by Ukraine's combat experience, which uses weapons from the world's leading countries in the war against russia. For example, Taiwan's current technological level already gives reasons to doubt the success of the Chinese Navy's naval operation in the Taiwan Strait.

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Self-management in professional activities as a prevention measure and reducing an urgency addiction impact

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Abstract. The modern specialist's professional activity is characterised by significant labour intensity. Significant workloads in extreme situations, task complexity and insufficient time to complete them, making optimal decisions lead to the occurrence of individual psychosomatic and professional deformations, in particular, urgency addiction, addictive behaviour.

The research relevance, significance and expediency these deformations is currently conditioned by: a) the complexity, dynamism, intensity of human professional activity; b) the requirements for ensuring high quality training of specialists, their mastering of new approaches regarding self-management of the continuous development process; c) insufficient development of this problem in physiology, psychology, psychiatry; d) the necessity to find effective prevention and psychological rehabilitation methods for specialists with certain addictions types; e) russian aggression against Ukraine and their consequences for military, defence and civil area's specialists.

The research goal is to highlight the psychological and physiological scientists' views on the essence and content of the “urgency addiction” and “addictive behaviour” concepts and to justify the

main self-management tools for preventing and reducing the urgency addiction impact in professional activities.

The research methodological basis comprises a general scientific method system, namely: scientific research analysis of domestic and foreign scientists-psychologists, psychiatrists, physiologists, clinicians on the urgency addiction, addictive behaviour, self-management concepts; induction, deduction, synthesis, comparison – to summarise scientific sources on the personality psychosomatic and professional deformations' essence; systematic approach – to substantiate the main self-management tools aimed at preventing and reducing the urgency addiction impact in professional activities.

The article reveals the urgency addiction essence, addictive behaviour, personality professional deformation in the conditions of fulfilling employment functions, task complexity and lack of time for their implementation; the main tools of self-management in professional activity aimed to prevent and reduce the urgency addiction impact are justified.

The article's materials are of scientific and practical importance for specialists in the research field and specialists whose interests include self-management in the prevention and reduction of the urgency addiction in professional activities.

Keywords: personality, professional deformation, urgency addiction, addictive behaviour, self-management.

Introduction

The speed and intensification of the world's military-political, socio-economic, scientific, technical, and information processes leads to a constant complication of the specialists' professional activities, puts higher demands on the modern person's ability to adapt to the life's new realities not only on the basis of intellectual, physical, but also, mainly, on the person's mental capabilities, which is caused by the following factors: increasing work intellectualisation; increasing the mental activity role associated with the cognitive sphere and psychomotives; the formation of an activity model based on an unreasonable increase in the task number, with a simultaneous lack of time to complete them; the significance and responsibility for made decisions and performance results; increased requirements for self-education and professional qualification continuous improvement. Significant workloads in the conditions of complication and increase in tasks number, lack of time for their performance lead to personality psychosomatic and professional deformations - urgency addiction, addictive behaviour, which necessitate an adequate search for ways to prevent them, in particular, self-management tools.

Urgency addiction, addictive behaviour, and self-management in professional activities became the research subject of domestic and foreign scientists in the problems of psychology, physiology, psychiatry, and personality transformation as a biological system in the following areas:

- the urgency addiction concept and essence (Tassi, 1993; Shibko, 2008; Mykhailyshyn, Schmidzen, 2020);
- addiction development dynamics (Buhaiova, 2010; Zmanovska, Rybnikov, 2010);
- addictive behaviour (Maksymova, 2002; Dennis L. Thombs, Cynthia J. Osborn, 2019; Addictive Behaviour Psychology, 2022);
- the addictive behaviour's main factors, professional addictions (Mudryk, 2016; Sidak, 2015);
- self-management skills acquisition as a prevention tool for urgecy addiction (Lukashevych, 2010; Babchynska & Midliar, 2016; Linman, 2016);
- personality transformation (as a biological system) in professional activities under the influence of both external and inner factors (Prikhodko, 2022).

The research relevance, significance and expediency on the chosen subject is currently determined by the following factors:

- complexity, dynamism, intensity of human professional activity;
- the requirements to ensure high quality training of specialists, their mastery of new approaches to self-management of the continuous development process (Strategy for the Higher Education Development in Ukraine, 2021);
- insufficient development of this problem in psychology, psychiatry, physiology (Depression, 2007);
-the necessity to find effective prevention and psychological rehabilitation methods for specialists with certain addictions types;
- russian aggression against Ukraine and their consequences for military, defence and civil area's specialists (Military Security Strategy of Ukraine, 2021; About national resistance fundamentals, 2021).

Methodological Framework

The research methodological basis consists of a general scientific method system, in particular: scientific research analysis of domestic and foreign scientists-psychologists, psychiatrists, physiologists, clinicians on the problems of urgency addiction, addictive behaviour, self-management concepts; induction, deduction, synthesis, comparison – to summarise scientific sources on the personality psychosomatic and professional deformations essence; systematic approach – to justify the main self-management tools aimed at preventing and reducing the urgency addiction in professional activities impact.

Results

The wide range of understanding and interpretation of the "urgency addiction" and "addictive behaviour" concepts by psychologists, psychiatrists, physiologists, and clinicians testifies to their complexity, systematic nature, and dependence on the semiotic approaches that have become the research subject.

Urgency in the general sense means emergency, immediacy; necessity. Addiction (from the Latin addictus - blindly devoted; someone who has fallen into slavish dependence under the influence of various external or inner factors. Addiction shapes the so-called addictive behaviour - behaviour caused by a person's desire to "escape" from real life by changing the state of their consciousness.

The " urgency addiction" concept was first introduced by N. Tassi (1993). The researcher identified: 1) the main characteristics inherent in this addiction: strict monitoring of time by the addict; life realisation at "high speed"; all work-related requirements constantly being accepted; personal time rejection; inability to enjoy the present moment; emotionally negative attitude to the future; 2) an urgency addiction typology: the first type – planning urgency addict is constantly occupied, mainly, with planning their activities; he/she shows anxiety signs in situations of the need to change the task implementation tactics or in relations with people, to change the activity programme at the stage of its implementation; in a situation where it is necessary to solve several tasks in a limited period of time, a person has a fear of not having time to do what is demanded of him/her; the second type - "workaholic" or non-modelling; a characteristic feature of the urgency addiction in this group is workaholism which means a strong desire to work, constant thinking about emerging problems in the activity process, irritability while engaged in another activity type; the third type is "hasty" or inflexible; it is characterised by frequent goal changes before the activity starts, fantasising, unsuccessful predictions about his/her actions; the employee is more likely to look for a similar situation with an already known action programme in previous experience than to experiment in new circumstances.

Further researches (Shybko, 2008; Mykhailyshyn, Schmidzen, 2020) were aimed at identifying the features characteristic for an urgency-dependent personality:

- a desire to control time and an awareness of the subjugating the events course's impossibility;
- professional duties fulfilment to the detriment of meeting the recreation and interpersonal relationships needs;
- acceptance of absolutely all requirements related to professional activities;
- loss of the ability to enjoy life in the present, obsession with future tasks or past failures;
- ignoring the past, pushing emotionally charged experiences into the unconscious;
- fear the future;
- the desire to procrastinate, to realise own's goals and desires, combined with the feeling that time is running out.

A wide range of research by a number of scientists has been devoted to exploring the essential features and definitions of the ‘addiction’, ‘dependence’, and ‘addictive behaviour’ concepts.

V. Velykyi (2009) understands addictions as any unrestrained cravings and hobbies that go beyond the norm, in which the fascination object or a certain activity becomes a determining factor in human behaviour, while partially or completely displacing all other vital activities (Buhaiova, 2010).

According to L. Ilnytska (2008), modern scientific literature defines addiction as an obsession with a substance or a type of activity, which includes an uncontrolled desire to take this substance or practice an activity to achieve the desired mental effect.

It is important to understand the following factors:

- the transformation mechanism of a person's activity into addictive behaviour (Buhaiova, 2010); the researcher identified the following conditions: the desire to escape from reality by changing the psychological state without taking chemicals; activity should occupy a dominant position in the life and consciousness of the individual; activity should harm social ties and other the individual's life vital areas;
- the personality's addiction formation and development dynamics (Zmanovska & Rybnikov, 2010) by the following stages: emotional level; a certain frequency of addiction means implementation; at the same time, there is a correlation between the addiction rhythm and life difficulties, and the lower the resistance threshold to frustration, the higher the rhythm; an individual gradually loses a sense of reality, becomes indifferent to others' experiences, the ability to empathise and understand others is sharply reduced; loss of the personality's own inner world, the personality destruction process; destruction of not only the personality's psyche, but also its biological processes, causing all vital resources to be exhausted, damage to organs and the personality's functioning system in general.

Based on the above, it can be seen that the personality addiction problem is complex, includes biological, social, economic, psychological, psychoanalytic and other components and expresses itself in the addictive behaviour form. The addictive behaviour essence lies in the fact that, trying to escape from reality, the addict tries to artificially change his/her mental state, and this gives him/her the illusion of safety, emotional balance renewal.

Research analysis (Maksymova, 2002; Dennis L. Thombs, Cynthia J. Osborn, 2019; Addictive Behaviour Psychology, 2022) allows us to come to the conclusion that regardless of the addiction type, there are common addictive behavioural signs: persistent desire to change psychophysical state; and a persistent desire to change the psychophysical state; a continuous process of addiction formation and development; cyclical dependent behaviour; the logical occurrence of personality changes and social maladjustment; the formation of an addictive attitude, i.e. a set of cognitive, emotional and behavioural characteristics that cause an addictive attitude to life; excessive emotional attitude to the addictive object; mistrust to specialists who try to provide medical and social assistance; turning the addictive object into existence's goal; denial of addiction and its severity.

The primary motive of individuals prone to addictive behaviour (Zmanovska & Rybnykov, 2010) is to active change their unsatisfactory mental state, which they often view as ‘grey’, ‘boring’,

‘monotonous’, ‘apathetic’; such a person fails to identify in reality any activity areas that can attract his/her attention for a long time, make him/her happy or cause other expressed emotional reaction; life seems uninteresting to him/her due to its routine and monotony; he/she does not accept what is considered normal in society, and the need to do something, engage in any activity, follow any traditions and norms accepted in the family or society; we can say that an individual with an addictive behavioural orientation has significantly reduced activity in everyday life, filled with demands and expectations; at the same time, addictive activity is selective in those life spheres that, even temporarily, brings pleasure to a person and pulls him/her out of the emotional stagnation (soullessness) world; he/she can show unusual activity to achieve a goal.

The reasons for addictive behaviour can be the following: social and professional inability, discrepancies between personal plans and subjective-objective reasons complicating their implementation, financial problems, conflicts in the family, intimate and domestic spheres, a drop in social prestige, problems with one's own appearance related to the aging process, and egocentric attitudes.

The addictive behaviour factors (Addictive Behaviour Psychology, 2022) include the following

- biological, which include heredity, central nervous system diseases, cerebral cortex, etc;
- social - macro- and micro-environmental factors: family influence, the person's closest social environment, traditions in society, culture, mass media influence, etc;
- psychological - inner conflicts, neurotic tendencies, difficulties in communication and interpersonal interaction, self-concept specific features, self-esteem, stress, trauma.

The research analysis (Mudryk, 2016; Sidak, 2015) allows us to single out the following addictive behavioural features:

- dominance of personality motives and attitudes aimed at satisfying pathological needs;
- a personality's weak resistance to experiencing frustration;
- the person's readiness to engage in illegal behaviour to meet the needs on which he/she is dependent;
- the desire to go beyond the prohibited boundaries;
- low stress resistance;
- perfectionism in practical activities;
- desire for adventure;
- desire to engage in behaviour that is destructive for the person who is characterised by this behaviour;
- adaptive strategies inadequacy;
- external locus of control.

Another aspect of addictive behaviour that has become the psychologists' research subject is professional personality's deformation. Professional deformation is a type of emotional and cognitive distortion that occurs under the professinal activity influence and is often interpreted by scientists as a manifestation of specialist's personality maladjustment (impaired ability or complete inability to adapt to the environment and professional activity forms due to psychosomatic disorders).

Various sources analysis of the ‘professional deformation’ concept showed that researchers studying this phenomenon do not have a single view on the phenomenon's essence, except for the recognition that personality professional deformation is indicated by personal changes that occur under the influence of performing a professional role.

Professional deformation symptoms may include professionally caused accentuations, professional stresses (distresses), social interaction disorders, self-esteem instability, job dissatisfaction, physiological discomfort, motivational disorders, inner conflicts, increased situational learned helplessness, and professional fears. Professional deformation is a syndrome that develops against chronic stress background and leads to the exhaustion of emotional, energetic and individual

resources of a working person. It occurs as a result of negative emotions accumulating internally without appropriate ‘discharge’ or release from them (Bilova, Koval, Doroshenko, 2022).

Therefore, professional addictions in their pathological form, as today's realities show, are becoming more and more common. According to S. Udovyk (2002), the number of people with psychogenic disorders is growing rapidly in the world. Therefore, today one of the most important practical tasks is to preserve the specialist's professional health, prevent professional addictions and form a harmoniously developed personality.

Researchers consider self-management to be an effective tool for preventing and reducing the impact of urgent addiction in professional activities.

Self-management is a relevant and promising area in scientific management. This direction in management arose due to the society's needs and is intended to increase the human activity efficiency on the basis of achieving personal and professional goals (Lukashevych, 2010). The main reasons for self-management appearing include the following: actualisation of the management skills importance in professional activities; search for ways to manage personal development, overcome stress, psychosomatic disorders; preservation and increase of the gained creative potential and leadership qualities.

Self-management is aimed at maximising the use of a specialist's own capabilities and consciously managing their working time in order to prevent circumstances where there is a risk of a time shortage for performing professional duties (tasks). The main goal of self-management is to make maximum use of personal capabilities, consciously manage yourself (self-management, self-determination) both in your professional activity and in your personal life. Important components of the self-management process include personal growth, intellectual and professional development, and psychological and physical health support.

Self-management basics include personal effectiveness, on the basis of which one efficiently manages his/her own resources: time, space, communications, and finances. Individual efficiency or a person's effective activity is impossible without achieving a certain level of development through self-development. Self-development (individual development) is a process in which a person gains the ability to protect himself / herself, manage current events, form positive relationships with the world around him / her and enjoy life. The self-development process is carried out by overcoming obstacles and developing personal qualities that contribute to reaching goals and tasks (will, perseverance, stress resistance, ability to influence people, etc.) The following components are combined in this process: personal development (personal growth; intellectual development; professional (qualification) development; psychological and physical support (Babchynska, Midliar, 2016; Linman, 2016).

The main theoretical self-management concepts as an idea around which a system of self-improvement methods and techniques is formed to achieve certain goals:

- the ‘saving your own time’ idea (L. Seiwert);
- the overcoming personal limitations idea (M. Woodcock and D. Francis);
- improving personal business life culture (A. Khrolenko);
- the achieving personal professional success idea (Bärbel and H. Schwalbe).

For our study, the L. Seiwert's concept is important as the most rational and universal, because it contains the most important moments from other concepts and at the same time is aimed at the formation and development of skills and time management qualities in professional activities to prevent various addictions. In L. Seiwert's concept, self-management is the consistent and targeted use of proven work methods in everyday practice in order to use your time optimally and meaningfully, i.e., it is essentially time management. The researcher defines the following self-management benefits (Seiwert, 2015): performing work with lower costs; better work organisation; better work results; less rush and stress; more job satisfaction; higher work motivation; increased

qualifications; less workload; fewer mistakes in performing your functions; achieving professional and life goals in the shortest possible time.

In the self-management concept, the determining factor is time in the context of optimising self-management activities; stressor elimination or reduction impact; predicting the stressor's negative impact; taking into consideration the stressor avoidance dynamics depending on extreme conditions; formalising (planning) activities and making appropriate decisions; using personal and collective experience; taking into account the importance of material, technical and other resources; inner and outer individual motivation.

The research analysis (Seiwert, 2010; Sakun, Avetisian, Kaluhina, 2012; Shtepa, 2009) and other generalisations allow us to determine and justify the main factors that contribute to the professional activity optimisation in space and time in order to prevent and reduce the urgency addiction impact.

Reasons identification that can lead to unproductive time loss in the professional activity process and contribute to psychosomatic disorders:

- unclear goal statement;
- lack of task prioritisation;
- trying to do too much at once;
- lack of a future task picture and ways to solve it;
- irrational working day planning;
- personal disorganisation;
- excessive pedantry;
- lack of motivation (indifferent attitude to work);
- lack of service tools and database organisation by functional responsibilities;
- shortcomings in responsibility's distribution;
-Inability to say "no" when it distracts from work;
- lack of self-discipline;
- inability to follow through;
- prolonged meetings, appointments;
- insufficient preparation for conversations and discussions;
- lack of communication skills;
- excessive sociability;
- excessive business records;
- procrastination syndrome;
- haste, impatience;
- inability to concentrate, overcome stress;
- lack of control, self-control.

The main reasons for professional stress include the following: 1) stress related to the work content: maintaining prolonged concentration, monotony, sameness, very difficult tasks, physical effort at the limit of the body's abilities, the need to perform a significant task number, unexpected load of new tasks, etc. 2) stress from the work organisation: too fast work pace, rigid task schedule, irregular working hours, constant rush, time pressure, conflicts in the team; 3) stress related to the certain professional activity fulfilment: lack of control over work or too much responsibility in the organisation, material risk, moral problems, risk to health and psyche.

Self-management functions.

1. Goal setting (personal goal analysis and formation).

Setting a goal requires expressing clear intentions and precise formulation of obvious and hidden needs, interests, desires or tasks, as well as actions and deeds orientation towards the defined goals and their fulfilment. Each goal is meaningful only when the timeframe for its implementation is set and the desired results are formulated.

2. Planning (plans' development and alternative options for your activities).

Planning is intended to ensure the optimal use of probably the most valuable asset - time, that is: a) or use the existing time for fruitful and successful professional activity (maximum criterion); b) or achieve the goal with the least possible time expenditure (minimum criterion). The better the time is managed (planned), the more efficiently it will be used in personal psychological and professional interests. Planning as an integral part of self-management tasks and rules means preparing for the goals implementation and structuring (organising) time.

Drawing up a plan is closely related to the issues and tasks to be performed, usually within the working hours, taking into account the individual's competence, physical and psychological capabilities. Establishing the timeframes required to achieve personal and professional goals gives a sense of confidence in the implementation feasibility and task priority for long-term, medium-term, monthly and daily goals.

The planning benefits are evident in the following areas of self-management: goals achievement, time advantage, visibility, setting priorities, deadlines, time reserves, increased efficiency, task redistribution, and stress avoidance or reduction.

3. Making decisions about received tasks.

Decision-making involves selecting priority tasks, i.e. setting priorities in their implementation, which does not mean wasting time and energy on separate, often insignificant problems.

Advantages of working on priority tasks:

- working on really important and necessary tasks;
- solving issues according to their urgency;
- concentration of attention on performing only one task;
- completing the task on time within the planned time frame;
- achieving goals in the best way possible in the circumstances;
- exclude tasks that could be accomplished by others;
- not leaving unfulfilled tasks that match potential opportunities;
- feeling satisfied with the task accomplished within the established timeframe;
- avoiding stressful overloads.

4. Implementation and organisation (drawing up a daily routine and organising a personal work process in order to achieve the set tasks).

The ‘implementation and organisation’ function in self-management involves drawing up a daily routine and organising a personal work process in order to fulfil the tasks and achieve the goal. L. Skibytska and O. Skibytskyi (2007) defined work organisation rules that allow increasing the self-management efficiency: a) not to take on many tasks in one day; b) plan 2-3 priority tasks and 4-5 less important tasks for the current day, and finish with simpler and more enjoyable ones; c) leave 20-30% of time for unforeseen tasks every day, because proper work organisation is the key to a professional's success in the struggle for time. This will help you become organised and keep this quality forever. In addition, the researchers point out that the effective use of leaders' working time is impossible without the use of scientifically based work and rest regimes. The main forms of optimal self-organisation in the work environment include the culture of interviews, meetings, telephone conversations, relationships, and information processing. A rather important task is to master the methods of overcoming the inefficient time use factors.

5. Control (self-control and results control).

The control function (self-control) helps to improve and, ideally, optimise the working process. All of the above self-management functions will not be as effective if appropriate control is not carried out. This applies not only to control over the result, but also to control over the process, and the last one should be carried out with particular care. Control (self-control) should identify efficiency reserves and encourage taking corrective actions.

6. Information and communications.

Information and communications are the most important function of any management process, social relations, social system, professional human relations. To a certain extent, other functions "rotate" around this function, since communications as an information exchange are necessary in all stages of the self-management process.

The information component involves searching for and analysing information about the main human activities' sides, namely: professional, organisational, material and domestic, social and psychological. Information processing should be streamlined and systematised, focused on achieving certain goals.

The communication component is implemented through the personal relationships establishing with team members of different functional purposes.

It is worth pointing out a number of limitations that should have a negative impact on the self-management functions' implementation in the professional activity process and thus reduce the effectiveness of urgency addiction prevention and addictive behaviour:

- inability to set and achieve goals clearly and step by step, overcome weaknesses, show will and perseverance;
- lack of self-management skills in planning and organising professional activities;
- indistinctness of the personality's motivational sphere and personal values;
- lack of skills in effective and persistent profession mastering, independent knowledge gaining;
- poor leadership, creative and communication skills development;
- insufficient reflexivity, lack of developed aptitudes for the practical implementation of personal inner and outer dialogue.

Discussions

The dynamic development of modern societies' almost all components is interconnected action and interaction's consequence of the following systems: "person-person"; "person-collective"; "person-society". The transformational processes that take place in this case are influenced by external and internal factors of different nature (Prikhodko, 2022). For societies, these processes are characterised by such expressions as development, stagnation, and decline. In such interconnected circumstances, a person undergoes psychological structural changes in the following directions: intellectual and creative development; degradation, professional deformation. The human factor (human potential development) in the above systems is a) an important priority of Ukraine's national interests and national security (Military Security Strategy of Ukraine, 2021; About the basis of national resistance, 2021); b) decisive, as it affects the specialist's professional activity at different hierarchical functional levels of society. The constant complication of the specialists 'professional activity, the increase in the tasks' number in conditions of insufficient time to complete them exhausts not only a person's intellectual and physical capabilities, but also mainly psychological ones, which ultimately leads to personality psychosomatic and professional deformations, in particular, urgency addiction, addictive behaviour, and leads to search for effective mechanisms of their prevention or impact reduction. The process of becoming addicted, as practice shows, can occur suddenly. In the case of successful results in professional activities, a person feels full of strength, energy and enthusiasm: he/she has a full sense that he/she can cope with any task, spending all his/her time, often not standardised, on the task's fulfilment, ignoring rest, rational time planning, which can ultimately lead to systemic negative consequences.

The views' analysis and generalisation on urgency addiction concept and essence, its development dynamics (Bugaiova, 2010; Mykhailyshyn, Schmidzen, 2020; Tassi, 1993, etc.), on addictive behaviour and its main factors (Maksymova, 2002; Sidak; Dennis L. Thombs, Cynthia J. Osborn, 2019) shows that the personality addiction problem is complex, includes biological, economic, psychological, psychoanalytic components and manifests itself in human activity in an addictive behaviour form, which, in turn, means that, in an effort to avoid reality, the addict tries to change his/her mental state by addingictive behaviour, and this gives him/her safety illusion and emotional balance restoration.

Researchers (Bugaiova, 2010; Zmanovska, Rybnikov, 2010) emphasise the importance of understanding such factors as the mechanism of personality activity transformation into his/her addictive behaviour (the desire to escape from reality by changing the psychological state without the use of chemicals, etc.); personality addiction formation and development (emotional level; a certain frequency of addictive means implementation, loss of the personality's own inner world, the personality destruction process, etc.)

Researchers believe that self-management aimed at preserving a specialist's professional health, preventing professional addictions by actualising the importance of leadership skills in professional activities; finding ways to manage personal development, overcoming stress, psychosomatic disorders; preserving and increasing the acquired creative potential and leadership qualities is an effective means of preventing and reducing urgency addiction in professional activities (Lukashevych, 2010). Self-management allows you to make maximum use of personal capabilities, consciously manage yourself (self-management, self-determination) both in professional activities and in your personal life (personal growth, intellectual, professional development, psychological and physical health support).

Each self-management theoretical concept presented in the study, along with the implementation methods, can be used for self-assessment and self-development of professional qualities, to increase one's business potential, and to prevent or reduce the impact of urgent addiction. At the same time, all these concepts have certain disadvantages, such as the following

- they are quite labour-intensive and take a lot of time;
- the results of a person's work on himself/herself according to the proposed recommendations depend on the approaches used, since there are no universal methods for use in everyday activities.

In our research, we chose L. Seiwert's (2015) concept, where self-management is a consistent and purposeful use of work's tested methods in everyday practice in order to make optimal use of your time, by yourself to facilitate the psychosomatic disorders prevention, i.e. their preventive measures.

The foregoing is largely relevant to the military personnel of the Armed Forces of Ukraine, especially in the current period of russian aggression against Ukraine:

- military and professional activity is a significant part of a military personnel's life;
- excessive physical and psychological stress in the conditions of combat actions;
- the likelihood of fulfilling tasks that suddenly arise in a limited time frame;
- unregulated working hours;
- stressfulness, professional activity's strict regulation: social norms' specificity, clearly defined lifestyle, relationship regulation, leadership's strict centralisation, strict discipline, internal order and personnel's actions' clear regulation;
- the urgent necessity to improve a set of activities to ensure conditions for preventing urgency addiction, supporting the military personnel's mental health at a level that minimises personnel turnover and maintains combat capability level of units and units in peacetime and wartime.

Based on the research analysis (Seiwert, 2010; Sakun, Avetisian, Kaluhina, 2012; Shtepa, 2009) and the author's generalisations, the main factors that contribute to the professional activity optimisation in space and time in order to prevent and reduce the impact of urgency addiction are defined and justified:

- reasons that can lead to unproductive time loss in the professional activity process and contribute to psychosomatic disorders;
- the reasons for professional stress: 1) the work content, maintaining long-term concentration, very difficult tasks, physical effort at the limit of the body's capabilities, etc.; 2) the necessity to perform a significant task number, unexpected new tasks load, etc: 3) work organisation: too fast a work pace, rigid schedule of performing tasks, irregular working hours, etc.; 4) constant haste, time pressure, conflicts in the team, etc.; 5) performing certain professional activities: lack of control over work or too much responsibility in the organisation, material risk, moral problems, risk to health and psyche;
- self-management functions: 1) goal setting (analysing and formulating personal goals); 2)

planning (developing plans and alternative options for your activities); 3) making decisions on received tasks; 4) implementation and organisation (drawing up a daily routine and organising personal work process in order to achieve the assigned tasks); 5) control (self-control and results control); 6) information and communication;

- restrictions that should negatively affect the self-management functions implementation in the professional activity course and thereby reduce the urgency addiction and addictive behaviour prevention effectiveness.

It is worth highlighting that self-management's practical significance in professional activities as a means of urgency addiction's prevention and reduction impact:

- provides a holistic view of the self-management essence, starting from its definition, through the goals', functions', and techniques' allocation;
- focuses on individual management activities in each of the main self-management components;
- focuses on self-assessment of the personality potential in each function, allows to compare the result with the required norm, recommends how to improve the result in practice;
- directs the personality to self-education, rational, planned time use;
- gives confidence in professional activity while reducing the stress threat.

Conclusion

The specialist's professional activity in the conditions of fundamental knowledge and technologies' rapid development is characterised by significant work intensity. Intellectual and physical workloads, adverse effects of information, socio-economic, communication, and stress factors lead to a decrease in work productivity, personality's psychosomatic and professional deformations - urgency addiction, addiction, and addictive behaviour.

Urgency addiction and addictive behaviour occur as a result of a complex interaction of hereditary, biochemical, social and personality psychological factors, such as: external physical environment; external social conditions; inner hereditary-biological, psychophysiological and individual-typological preconditions; inner personal reasons and mechanisms of addictive behaviour.

Researchers consider self-management to be an effective means of preventing and reducing the urgency addiction's impact in professional activities, the essence for which is considered as: a) the science about personality self-management and self-organisation; b) the specialist's ability to plan the types of his/her activities; c) managing his/her own resources to achieve success in professional activities; d) a strategy for building a professional career; e) the personality's activity focused on self-development and management of his/her own professional growth, psychosomatic state, overcoming addiction's impact. Therefore, the self-management concept essence covers a number of categories related to the personality self-realisation problem: self-organisation, self-knowledge, self-improvement, self-control, optimal use of own capabilities, resources and time to achieve success and psychosomatic stability.

Recommendations

The results presented in the research regarding the urgency addiction, addictive behaviour, and self-management are of scientific and practical importance and can be useful for specialists in any professional field.

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Algorithm for adaptive energy-cyclostationary detection of noise-like signals

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Abstract. Contemporary radio communication systems and assets operate in a complex radioelectronic environment. These systems and assets are integrated into a single network by means of digital radio communications means, which are increasingly using noise-like signals to transmit information. In conditions of constant monitoring by radio frequency spectrum analysis assets and radiation source direction finding in the conduct of hostilities, the need to ensure the covert control of forces and assets remains relevant. Thus, the forces and assets' task of detecting, analysing, direction finding and further controlling the covert radio communication systems' detected signals is no less relevant. The object's problem, which is partially addressed in this research, is the need to increase the probability that noise-like signals can be correctly detected on the background of additive white Gaussian noise by modern automated detection and analysis assets. The article is aimed at improving the algorithm for detecting noise-like signals by using an adaptive energy-cyclostationary detection device. The article reviews the known methods of radio detection and compares their effectiveness in detecting and analysing the noise-like signals parameters on the white Gaussian additive noise background. The effectiveness issues of using an adaptive energy-cyclostationary device for detecting noise-like signals in radio communication systems are researched. The study results and the operation algorithm of the proposed detection device, which combines the energy and cyclostationary detection methods' properties, allow increasing the probability of detecting noise-like signals at lower signal-to-noise ratios values.

Keywords: radio communication systems, noise-like signal, algorithm, correct detection probability, Gaussian noise, energy detection device, cyclostationary detection device.

Introduction

In the armed forces of many countries, information support for commanders is performed by using automated command and control systems (Masnoy, Sudakov, 2003). These systems are connected into a single network by digital radio communications assets using noise-like signals (NLS) (Chaika, 2004). The noise-like signals have the high energy concealment property from radio technical intelligence (RTI), which allows the radio communication system (RCS) to function effectively at very small signal-to-noise ratio's (SNR) values at the receiver input (up to -30 dB) (Borisov, Zinchuk, Lymarev et al., 2003).

Today, the problem of radio technical assets (RTAs) effective jamming is solved by generating interference based on a posteriori information about the parameters of their radio signals. The receivers used to detect and estimate the parameters of RTA's radio signals do not provide high-quality tasks fulfilment when receiving the NLS. Therefore, the NLS detection task remains not completely solved.

Literature review

To devices that provide NLS detection, the following types can be attributed: energy (Varakin, 1985; Poisel, 2008; Kay, 1998; Fishman, 1992; Urkowitz, 1967), detection using a matched filter (Kay, 1998;

Torrieri, 2005), cyclostationary (Napolitano, 2012; Gardner, Spooner, 1992; Gardner, Zivanovic, 1991; Dandawate, Giannakis, 1994), detection using eigenvalues (Zeng, Liang, 2009; Penna, Garello, Spirito, 2009; Cardoso, Debbah, Bianchi, Najim, 2008), detection based on wavelet transforms (Khmelev, Trushkov, 2014), covariance detection methods (Zeng, Liang, 2009). The last four methods' groups are quite effective at small signal-to-noise ratio (SNR) values, but require complex calculations. When solving electronic warfare (EW) tasks, the time spent on detecting and analysing the parameters of radio signals, including NLS, should be minimal (Perunov, Fomichev, Yudin, 2003).

Therefore, the task of developing (improving) methods for detecting and estimating the noise-like signal parameters that ensure prompt decision-making at low SNR values in the EW interests remains relevant.

Materials and Methods

For the NLS detection in the EW's interests, it is most appropriate to use an energy detection device (Perunov, Fomichev, Yudin, 2003; Torrieri, 2005). This is a relatively simple detection method, but requires precise information about the noise power spectral density to determine the detection threshold. Moreover, an incorrect estimate leads to errors in decision-making (Fishman, 1992).

Cyclostationary detection is an alternative detection method because communication signals are cyclostationary and noise is stationary (Napolitano, 2012). The cyclostationary method's advantage is the ability to operate without a priori information about N_0 and detect signals at small SNR values. However, one major disadvantage of cyclostationary detection methods is the large amount of calculations.

Taking into account the operation limitations of the energy detection device (a priori information about N_0), the idea of this article is to synthesise such a device that is invariant to N_0, by combining a cyclostationary detection device and an energy detection device with a doubling frequency.

Let us assume that the NLS detection $s(t)$ occurs on the white Gaussian noise background $n(t)$ with power spectral density N_0.

The energy detection device's (radiometer) schematic diagram is shown in Fig. 1. The band-pass filter has a central frequency $f_{c\phi}$ and a bandwidth $W_{c\phi}$. Behind it is placed a quadratic device, the voltage from the output of which goes to the integrator and then to the threshold device input, where it is compared with the pre-set energy threshold ξ_0. At the threshold device's output with the analysis interval T_a, a decision is made.

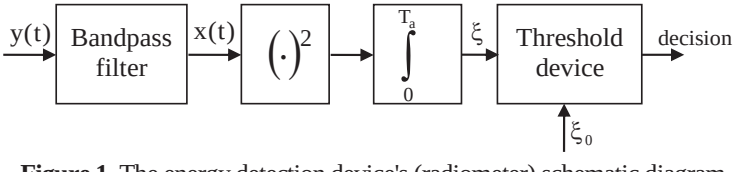


Figure 1. The energy detection device's (radiometer) schematic diagram

On the integrator output, the following magnitude is formed (Varakin, 1985)

$$\xi = \frac{1}{T_a}\int_0^{T_a} x^2(t)dt\,, \tag{1}$$

where $x(t)$ – fluctuations at the output of the radiometer bandpass filter.

The threshold device compares the magnitude ξ with a certain constant ξ_0, which is a function from the desired level of false alarm probability.

Let's consider two hypotheses: H_0 – the radiometer's input receives only noise $n(t)$ and H_1 the radiometer's input receives an additive signal $s(t)$ and noise $n(t)$ combination. At a small SNR, which is quite common in practice, a long analysis time is required for reliable detection. he probability density function of the radiometer output statistics at $W_{сф}T_a >> 1$ approximated by a Gaussian law, then for both hypotheses the expressions for the mathematical expectation μ and variance σ of the signal energy estimate are (Torrieri, 2005):

$$\begin{aligned} H_0: \quad & \mu_1 = N_0 \cdot T_a \cdot W_{сф}, & \sigma_1^2 = N_0^2 \cdot T_a \cdot W_{сф}, \\ H_1: \quad & \mu_2 = N_0 \cdot T_a \cdot W_{сф} \cdot (1+\rho), & \sigma_2^2 = N_0^2 \cdot T_a \cdot W_{сф} \cdot (1+2\rho), \end{aligned} \qquad (2)$$

where $\rho = \dfrac{P_c}{W_{сф} \cdot N_0}$ – the signal power ratio to the noise power spectral density in the filter passband; P_c – signal power $x(t)$ for the analysis time T_a.

Radiometer efficiency is characterised by the false alarm probability P_{xm} and the correct detection probability P_B of signal. Expressions for their calculation (Torrieri, 2005):

$$\begin{aligned} P_{xm} &\approx Q\left(\frac{\xi_0 - N_0 \cdot T_a \cdot W_{сф}}{N_0\sqrt{T_a \cdot W_{сф}}}\right), \\ P_B &\approx Q\left(\frac{\xi_0 - N_0 \cdot T_a \cdot W_{сф} \cdot (\rho+1)}{N_0\sqrt{T_a \cdot W_{сф} \cdot (2\rho+1)}}\right), \end{aligned} \qquad (3)$$

where $Q(x) = \dfrac{1}{\sqrt{2\pi}} \int_x^\infty exp\left(-\dfrac{u^2}{2}\right) du$ – generalised Marcum's function (Torrieri, 2005).

To ensure the required values of the false alarm probability P_{xm} it is possible to calculate the radiometer threshold level as an energy detection device (Torrieri, 2005):

$$\xi_0 \approx N_0\left(\sqrt{T_a \cdot W_{сф}} \cdot Q^{-1}(P_{xm}) + T_a \cdot W_{сф}\right), \qquad (4)$$

де $Q^{-1}(\cdot)$ – inverse Marcum's function.

Despite the detailed analysis of the above structural scheme (Fig. 1), its scope is limited, because it is necessary to a priori know the noise power spectral density N_0. Despite the detailed analysis of the above structural scheme (Fig. 1), its scope is limited, because it is necessary to a priori know the noise power spectral density . In the case of performing reconnaissance tasks, as a rule, the SNR real values is also unknown (Borisov, Zinchuk, Lymarev et al., 2003). The noise level estimation brings additional errors, especially during the NLS detection, when other signals may be present in a given frequency range. Besides, the detection threshold cannot be determined exactly, so the radiometer's operating characteristics deteriorate significantly.

Let us compare the radiometer's operationing efficiency and the detection device with frequency doubling (Fig. 2) according to the criterion given in (Poisel, 2008) – the SNR output level, according to which the best detection device is determined by the maximum SNR level on the output.

Let the input of each detection device be a noise-like signal combination with additive white Gaussian noise with one-sided power spectral density N_0. SNR level on the input for both detection devices $\rho_{вх}$ is defined as $\rho_{вх} = E_{імп}/N_0$, where $E_{імп} = P_{імп}\tau_{імп}$ – the pulse energy of NLS code sequence and, as a rule, $\rho_{вх} < 1$.

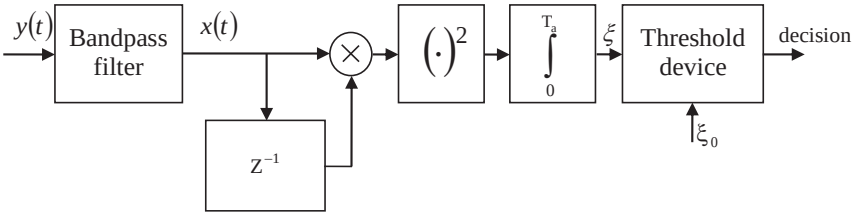


Figure 2. Block diagram of the frequency doubling detection device

The following correlations exist between the SNR input and output values for each detection device (Poisel, 2008):

$$\rho_p = 0.667\, N_{імп}\rho_{вх}^2,$$
$$\rho_{пч} = 0.333\, N_{імп}\rho_{вх}^2, \quad (5)$$

where $N_{імп}$ – code sequence pulses number for the analysis time T_a.

Fig. 3 shows the dependence between the input and output SNR values for the two detection devices considered above at $N_{імп} = 10^6$. As can be seen, the energy detection device has better detection characteristics at all SNR values on the input.

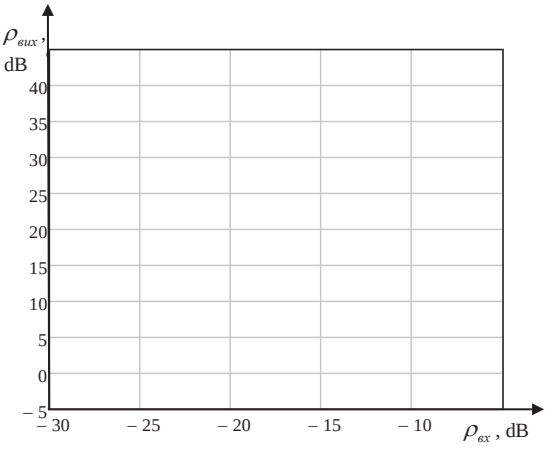


Figure 3. WHS output values dependence graphs versus input values for the radiometer (solid line) and the frequency doubling detection device (dashed line)

Let's conduct a comparative analysis of the detection probability dependence $P_в$ rom the SNR output values. We will use the calculation expressions $P_в$ or a radiometer and a frequency-doubling detection device (Poisel, 2008):

$$P_в^p = \frac{1}{2} erfc\left[erfc^{-1}(2P_{хт}) - \sqrt{\frac{\rho_p}{2}} \right], \quad (6)$$

$$P_в^{пч} = \int_{-ln(P_{хт})}^{\infty} e^{-(z+\rho_{пч})} \cdot I_0(2\sqrt{z \cdot \rho_{пч}})dz,$$

where $erfc(x) = \frac{2}{\sqrt{\pi}} \int_x^{\infty} \exp(-t^2)dt$ – additional error integral, I_0 – modified zero-order Bessel function.

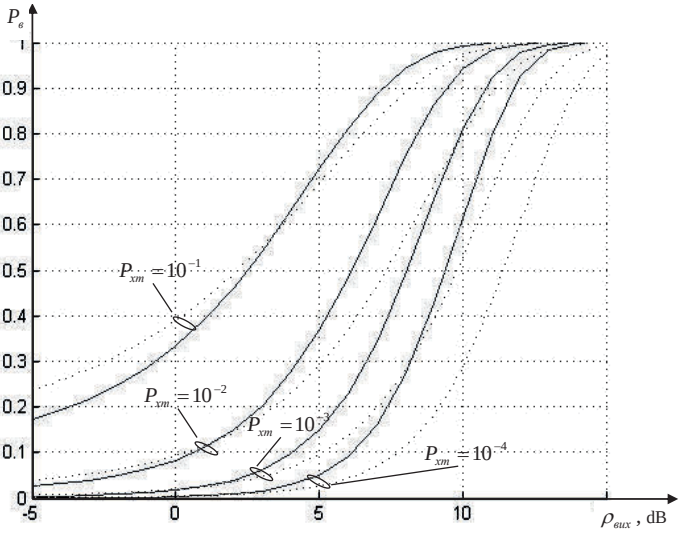


Figure 4. Detection probability dependence graphs $P_в$ versus output SNR values for a radiometer (solid line) and a frequency-doubling detector (dashed line)

As shown in Fig. 4 $P_в^p$ exceeds $P_в^{пч}$ not for all SNR output values. Using the above considerations, it is proposed to combine these two detection devices together and introduce a commutator and an analysis module (Fig. 5), which evaluates the value $P_в^p$ and $P_в^{пч}$ according to expressions (6). The decision-making will be based on those detection device data, the estimated detection probability of which is higher, if the probability of both detection devices is the same, the radiometer is preferred.

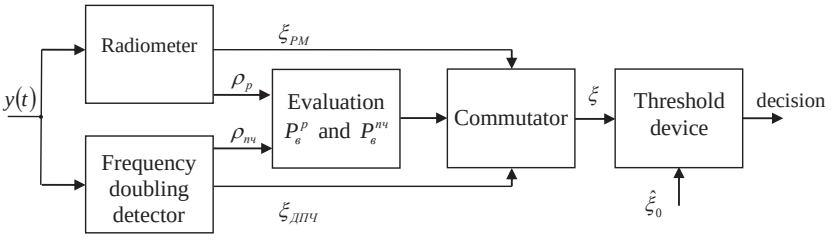


Figure 5. Energy detection device structural diagram

Radiometer operation's analysis in case of errors in assessment N_0 showed that in the case of detection, when the evaluated noise level values $\hat{N}_0$ less than its real indicator N_0, the energy level of the

received signal falls into the interval $[\hat{\xi}_0, \xi_0]$ (fig. 6a). This leads to a hypothesis being accepted H_1 in a signal absence, which increases the false alarm probability.

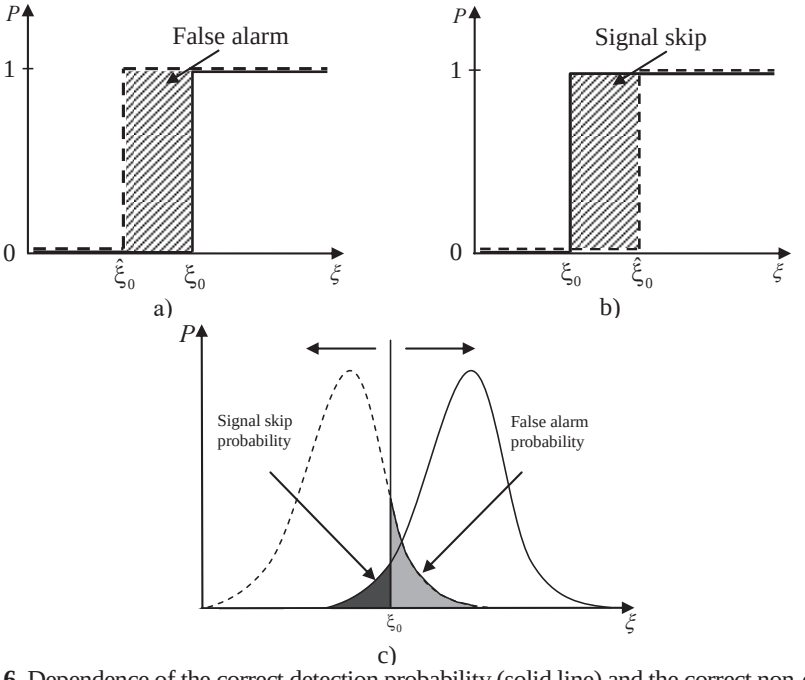


Figure 6. Dependence of the correct detection probability (solid line) and the correct non-detection probability (dashed line) from the threshold threshold values

With $\hat{N}_0 > N_0$ the incorrect decision occurs when the energy level of the received signal falls into the interval $\left[\xi_0, \hat{\xi}_0\right]$ (Fig. 6b). This error leads to the hypothesis acceptance H_0 n case when the signal is present, which increases the probability of skipping the target.

Fig. 7 shows the detection probability dependence graphs from the SNR on the receiver input according to expressions (3) and (4) with $W_{cф} = 1$ MHz, $T_a = 10^{-4}$ s, $P_{xm} = 10^{-3}$ and different estimation error values $\hat{N}_0$.

Thus, the use of noise power spectral density estimation leads to additional errors occurring at the NLS detection. As a consequence, an inaccurately determined detection threshold leads to an incorrect decision-making about the signal presence or absence in the threshold radiometer device.

It is known (Perunov, Fomichev, Yudin, 2003) that to evaluate the cyclostationary signal correlation properties, the autocorrelation function can be used

$$R_x(t,\tau) = \sum_{\alpha} R_x^{\alpha}(\tau) e^{j2\pi\alpha \cdot t}, \tag{7}$$

where $R_x^{\alpha}(\tau)$ – process cyclic autocorrelation function $x(t)$ with cyclic frequency α; τ – observation time interval.

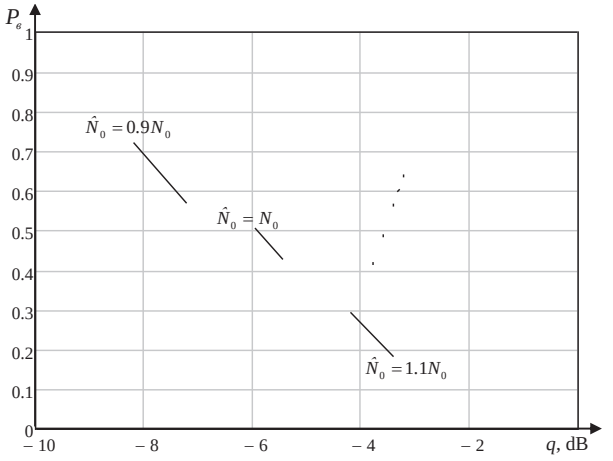


Figure 7. Signal detection probability dependence from SNR under estimation errors N_0

The cyclic autocorrelation function values can be obtained from the expression (Perunov, Fomichev, Yudin, 2003):

$$R_x^{\alpha}(\tau) = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} x\left(t+\frac{\tau}{2}\right) \cdot x\left(t-\frac{\tau}{2}\right)^{*} e^{-j2\pi\alpha t} dt, \tag{8}$$

When the cyclostationary model is adapted to the useful signal, the statistical test at multicyclic coherent detection has the following form (Napolitano, 2012):

$$\begin{gathered} \xi = \sum_{\alpha} \frac{1}{N_0^2} \int_{-W_{c\phi}/2}^{W_{c\phi}/2} R_x^{\alpha}(\tau)^{*} R_y^{\alpha}(\tau) d\tau, \\ \xi^{u} < \xi_0^{u} \text{ at } H_0, \\ \xi^{u} > \xi_0^{u} \text{ at } H_1. \end{gathered} \tag{9}$$

where $R_y^{\alpha}(\tau)$ – cyclic autocorrelation function $\mathrm{y(t)}$, ξ^{u} – threshold at the cyclostationary detection method.

Results

Besides the sensitivity to the values N_0, which reduces the detection efficiency at small SNR values, the energy detection device is the best solution for detecting an NLS with unknown parameters. Moreover, this method is very easy to perform. At the same time, cyclostationary detection is quite effective, but requires a significant amount of calculations or a priori information about the cyclic frequency to make a quick decision. This information is unknown, so the detection process becomes too complex and cannot be implemented in real time. However, these two detection methods can supplement each other, which is proposed in this article by creating a hybrid detection device (Fig. 8).

Let us assume that the values N_0 is a time-varying value, ξ – is the received signal energy $x(t)$ during the observation time T_a after i -iteration, $\xi_0 = \infty$ – is the initial values of the hybrid detection device energy threshold.

The adaptive energy-cyclostationary detection operation algorithm for noise-like signals is shown in Fig. 9. The energy detection device calculates the energy ξ of the received signal over time T_a according to (1). If $\xi < \xi_0$ – the energy detection device cannot make an exact decision about the signal presence or

absence. In this case, a test for the received oscillation cyclostationarity is performed $x(t)$. If the signal is not detected, the calculated values ξ^{u} is stored in the array $|\xi|$, from which the variable average μ_1 and according to (2) and (4) calculated $\hat{N}_0$ and $\hat{\xi}_0$. Into the variable ξ_0 is stored (reassigned) the values $\hat{\xi}_0$ and detection process starts from the beginning. The algorithm would end its operation, when $\hat{\xi}_0$ equates ξ_0, i.e. signal $x(t)$ is not detected, and the detection threshold values determined by both detection devices will be identical.

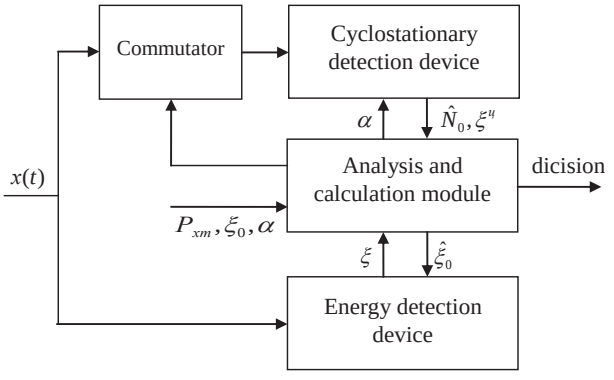


Figure 8. Hybrid detection device schematic diagram.

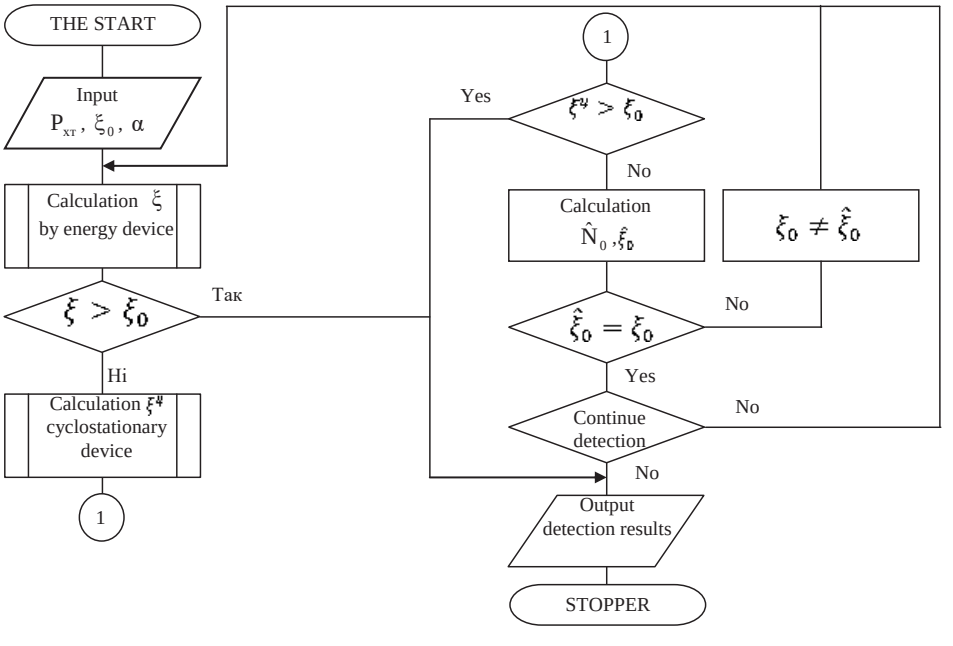


Figure 9. Adaptive energy-cyclostationary noise-like signal detection operating algorithm

As a result of using the proposed algorithm, the number of calculation operations during detection is reduced from $N^2 + 0.5N\,log_2\,N$ (for a cyclostationary detection device at the start of the algorithm operation) till $N\,log_2\,N$ (for a radiometer at the calculated values $\hat{\xi}_0$). Thus, the quality of the proposed hybrid detection device (Fig. 9) approaches the cyclostationary one in quality and has the time for analysis corresponding to the energy detection device.

From the modelling results graphs (Fig. 10), it can be seen that by using the proposed hybrid device, we have a gain in detection probability at SNR smaller values. This gain is achieved by using the detection device with a frequency doubling (as part of the energy detector) of the detection threshold values calculated by the cyclostationary device.

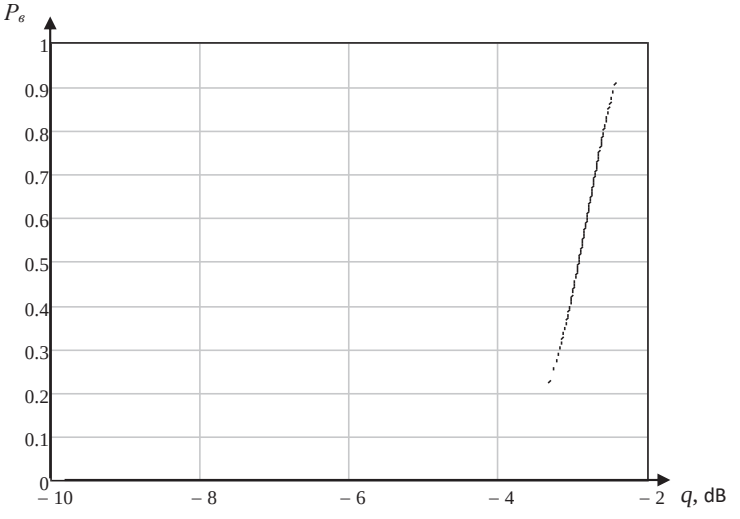


Figure 10. Detection probability dependence versus SNR of the proposed detection device using a detector with frequency doubling (dashed line) and without it (solid line)

Discussions

The prospects for further research may include: specifying the detection conditions for noise-like radio signals with pseudo-random operating frequency tuning and direct spectrum expansion; optimising the mathematical and algorithmic support for the noise-like radio signal detection process; minimising computational costs.

Conclusion

1. The hybrid detection device combines the energy and cyclostationary methods' properties, which ensures an increased probability of noise-like signals correct detection at the time costs corresponding to the energy detection device.

2. Combining two detection devices (a radiometer and a frequency-doubling detection device) into one - an energy one, in which, depending on the SNR at the outputs, a decision is made about the use of one or the other device according to the maximum probability criteria for the correct radio signal detection. The comparison results of the efficiency of their use at an output SNR at different values are presented.

3. The probability dependence of the NLS correct detection on the determination accuracy of the noise power spectral density and the corresponding detection threshold is shown.

4. The use of a cyclostationary detection device as part of a hybrid one provides the possibility of selective refinement of the noise power spectral density and detection threshold.

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Chemical, biological and radiological reconnaissance process of potentially dangerous objects as a queueing theory with priorities

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Abstract. The relevance of the study is due to the fact that according to the experience of the Russia-Ukraine war, during combat actions in urbanized areas, chemical, biological and radiological reconnaissance is of particular importance due to the fact that the destruction (accidents) at potentially dangerous facilities can lead to a complex nuclear, biological and chemical situation that will negatively affect troops. This requires a presentation of the chemical, biological and radiological reconnaissance process due to such characteristics that will allow to assess the effectiveness of its conduct in a complicated chemical, biological and radiological situation. In this regard, the article presents one of the approaches to present the process of chemical, biological and radiological reconnaissance of potentially hazardous objects as a queueing theory with priorities. The leading approach in the presented process is the employment of such characteristics as the intensity of receiving and servicing requests for chemical, biological and radiological reconnaissance, their average number, the average waiting time for an arbitrarily selected request, and the average length of the request queue. In the process of chemical, biological and radiological reconnaissance as a queueing theory with priorities, the distributions of the duration of servicing requests for chemical, biological and radiological reconnaissance activities are the same for the requirements of all priority categories, and the distributions of the duration of servicing these requests in all channels are exponential with average service speeds. The article describes the characteristics of the chemical, biological and radiological reconnaissance process, which depends on the number of reconnaissance objects and their priority during combat actions in urbanized areas and the number and capabilities of chemical, biological and radiological intelligence technical means involved in the execution of tasks. The materials of the article will be interesting for officials of military command and control bodies who plan chemical, biological, and radiological reconnaissance during combat actions, especially in urbanized areas.

Keywords: urbanized areas, intensity, request, channel.

Introduction

In the context of the full-scale invasion of the armed forces of russian federation (RF armed forces), which has been ongoing since February 24, 2022, there are potential chemical, biological, radiological and nuclear (CBRN) threats that could result in significant losses for the Armed Forces of Ukraine (AFU). These threats are reflected in the guiding documents (Instruction on the Functioning of the System of Prevention and Warning of Chemical, Biological, Radiological and Nuclear Threats (incidents) in the system of the Ministry of Defense of Ukraine, 2023) and require strengthening the capabilities of the Armed Forces of Ukraine to protect against these threats in accordance with the decrees of the President of Ukraine (National Security Strategy of Ukraine, 2020), (Military Security Strategy of Ukraine, 2021), (Strategic Defense Bulletin of Ukraine, 2021).

Today, there is an increase in the level of CBRN threats as a result of combat actions in urbanized areas of cities and large industrial agglomerations due to their saturation with a large number of potentially dangerous objects (PDOs), in particular, nuclear power, chemical and oil refining industries, whose destruction (accidents) can lead to a complex chemical, biological, radiation (CBR) situation (Military and Historical Description of the russia-Ukraine War, 2023), which will negatively affect troops (Methodology for Assessing the Situation in Man-Made and Natural Emergencies, 2018).

Combat actions near the Chornobyl and Zaporizhzhia nuclear power plants in 2022 are the relevant examples of this, damage to sections of the Togliatti-Odesa ammonia pipeline, and incidents involving the leakage of highly toxic substances as a result of damage to chemical industry facilities in Donetsk region. In addition, of particular concern are the repeated attempts by the russian armed forces to use chemical warfare agents and the constant threats by some russian officials to use nuclear weapons against the Armed Forces of Ukraine (Zaluzhnyi, Moisiuk, Shaptala, 2022).

This demonstrates the relevance and importance of troops support, which is carried out to create favorable conditions for successful preparation and conduct of combat operations, and to ensure the performance of assigned tasks (Lessons of the russia-Ukraine War of 2022: military factors, 2022). An important component of troops support is their CBRN protection. CBRN protection of troops is a set of activities to plan and execute tasks aimed at minimizing troop losses during operations under CBR contamination. One of the CBRN protection important tasks is the CBR reconnaissance activities implementation (Doctrine on Chemical, Biological, Radiological and Nuclear Protection of Troops (Forces), 2020).

CBR reconnaissance is organized and carried out with the purpose of timely detection of CBR contamination at control points, routes of deployment, supply routes, evacuation routes, in the areas of troops' concentration and operation for their notification. It is carried out by regular and specially trained non-staff CBR reconnaissance units, personnel of the operational duty service of military command and control bodies by collecting data on CBR situation on the routes of movement, areas and directions of troops' operations (Marushchenko, Haidabuka, Halak, 2010).

Despite the possible scale of the consequences of CBRN threats and unfavourable situation for the troops, the capabilities of the Armed Forces of Ukraine to conduct CBR reconnaissance are still limited. This affects the timeliness of detecting and assessing CBR contamination and does not allow military command and control bodies of various levels to make necessary operational decisions in a timely manner. Thus, it is obvious that CBR reconnaissance of the PDO in modern warfare conditions in urbanized areas is of particular importance.

Therefore, in order to enhance the Armed Forces of Ukraine capabilities for CBRN protection of troops, there is a need to present the CBRN reconnaissance process as a set of sequential actions aimed at timely detection of CBRN contamination at the PDO. For this purpose, it is proposed to present the CBR reconnaissance process as queueing theory, which has such characteristics as the intensity of receiving and servicing requests for reconnaissance, their average number, the average waiting time for an arbitrarily selected request and the average length of the request queue, which

will allow to assess the effectiveness of CBR reconnaissance of the PDO, especially in a complicated CBR situation.

Materials and Methods

By its nature, CBRN missions are aimed at protecting troops during combat operations in urbanized areas, in particular performing PDO CBR reconnaissance activities, is to serve a random flow of requests with a certain priority. Therefore, to represent the process of these activities, it is proposed to apply the queueing theory model with priorities ($_{Mi/M/s}$):($NPRP/\infty/\infty$), (Taha, 1985). In this model, it is assumed that several queues are formed before the maintenance section of requests for CBR reconnaissance of the PDO, in each of which the requests have a certain level of relative priority. The first queue of these requests has the highest priority, and the last one has the lowest priority. The initiated procedure for servicing requests for PDO CBR reconnaissance activities is brought to an end.

In addition, in this model, the distributions of the duration of servicing requests for CBR reconnaissance activities are the same for the requirements of all priority categories of the PDO, and the distributions of the duration of servicing these requests in all service channels are exponential with average service speeds. The service channel is defined as a technical means (TM) intended for CBR reconnaissance activities. Receiving requests of the appropriate priority for PDO CBR reconnaissance activities is distributed in time in accordance with the Poisson law and is characterized by the average frequency of receipt.

The PDO CBR reconnaissance process as a queueing theory with priorities ($_{Mi}$ / *M* / *s*):($NPRP/\infty/\infty$) is characterized by the following indicators:

$_{Mi}$ is the Poisson law of distribution of the time of receipt of requests for CBR reconnaissance activities in the *i-th* queue ($i = 1, 2, ... j$);

M is the Poisson law of distribution of the time of servicing requests for CBR reconnaissance activities;

n is *the* number of service channels (CBR reconnaissance tasks);

NPRP is a service discipline that stipulates that CBR will be conducted without interruption (a system with relative priority);

the number of applications in the system and the capacity of the application source are not limited.

The PDO CBR reconnaissance process as a queueing theory with priorities is shown in Figure 1.

It is proposed to calculate the characteristics of the PDO CBR reconnaissance process as a queueing theory with priorities and to assess the effectiveness of CBR reconnaissance in three stages.

At the first stage, the priority of CBRN reconnaissance objects is determined by their importance during combat actions in urbanized areas.

For this purpose, the factors that influence the prioritization of these objects on the basis of their importance are determined, namely:

the degree of CBR reconnaissance objects importance;

the degree of CBR reconnaissance objects importance on the basis of the importance of military subsystems, in whose interests they are used;

the degree of CBR reconnaissance objects importance for the CBRN troops protection system.

Further, using the identified factors, a scale of pairwise comparisons is selected to assess the CBR reconnaissance objects importance, in particular, PDO, during combat operations in urbanized areas, for which a calculation model of expert evaluation of hierarchical structures is developed (Velychko, Kolomiiets, Hordienko, Shevtsov, Karpenko, Haber, 2015).

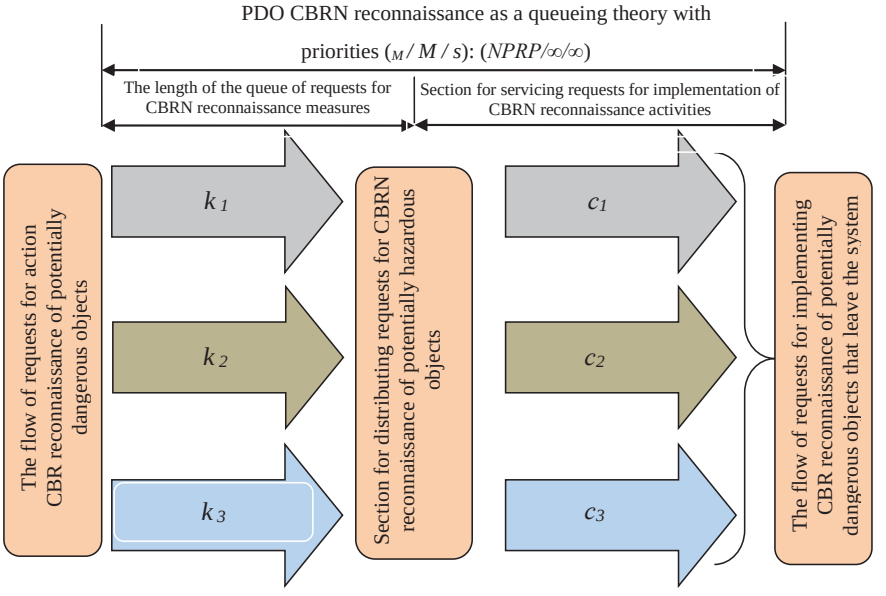


Figure 1. PDO CBR reconnaissance process as a queueing theory with priorities

Notes: k_1 - request with the highest priority; k_2 - request with medium priority; k_3 - request with the lowest priority; $_{c1}$, $_{c2}$, $c3$- service **channels**.
Source: developed by the authors on the basis of queueing theory research (Taha, 1985).

As a result of the comparison of the selected factors and alternatives, balanced inversely symmetric eigenvector evaluation matrices are formed for all rows in the comparison matrices of the identified factors and alternatives. After checking the numerical and ordinal consistency of the filled-in matrices and determining the indices of their consistency, the CBR reconnaissance objects' priority during combat actions in urbanized areas is distributed according to Harrington's "scale of desirability" (Shutiak, 2020).

The CBR reconnaissance objects prioritisation according to Harrington's "scale of desirability" is shown in Table 1.

Table 1. The CBRN reconnaissance objects prioritisation according to Harrington's "scale of desirability"

Harrington's scale of desirability	CBRN reconnaissance objects prioritisation
1,0–0,81	Highest priority (excellent level)
0,80–0,31	Medium priority (good and satisfactory)
0,30–0	Lowest priority (lower level)

Source: developed by the authors on the basis of research on the distribution of priorities (Shutiak, 2020)

At the second stage, the following characteristics of the performing CBR reconnaissance activities process during combat actions in urbanized areas are consistently determined, such as the intensity of receipt and servicing of requests for CBR reconnaissance activities of the PDO with the *k-th* priority, *units/day*:

$$\lambda_1 = \frac{q_{k1}}{T}; \lambda_2 = \frac{q_{k2}}{T}; \lambda_3 = \frac{q_{k3}}{T}; \mu = \frac{t_{r3}}{t_p}, \quad (1)$$

where $\lambda_{1(2,3)}$ is the intensity of receipt of requests for CBRN reconnaissance activities of the PDO with the *k-th* priority,

units/day; μ - is the intensity of servicing requests for CBRN reconnaissance activities of the PDO,

units/day; $q_{k1(k2,k3)}$ - the number of CBRN reconnaissance objects with the *k-th* priority during *T* days of combat of combat operations, units*;*

t_{T3} - average time of productive operation of CBRN reconnaissance vehicles during the day, *hours/day*;

t_p - is the average reconnaissance time of one PDO, *hours;*

T - duration of combat operations, *days*.

Employing (1), we calculate the average number of requests for CBRN reconnaissance activities of the *k-th* priority that are received during the service of one request *with* service channels, units*:*

$$S_1 = \frac{\lambda_1}{c \cdot \mu};\ S_2 = S_1 + \frac{\lambda_2}{c \cdot \mu};\ S_3 = S_2 + \frac{\lambda_3}{c \cdot \mu}, \tag{2}$$

Where c is the number of vehicles engaged in CBR reconnaissance activities, *units.*

After that, the relative reduced intensity of requests for PDO CBR reconnaissance activities the is determined:

$$\rho = \frac{\lambda_n}{\mu}, \tag{3}$$

where $\lambda_n = \lambda_1 + \lambda_2 + \lambda_3$.

Employing the initial data and the indicators calculated in (1) and (3), the average value of the exponential distribution is calculated:

$$E = \frac{1}{\mu \cdot c\left[\rho^{-c} \cdot (c-\rho) \cdot (c-1)! \sum_{n=0}^{c-1} \frac{\rho^n}{n!} + 1\right]}. \tag{4}$$

Next, we calculate the average waiting time for PDO CBR reconnaissance activities of each priority, in *days*:

$$Y_1 = \frac{E}{(1-S_1)},\ Y_2 = \frac{E}{(1-S_1)\cdot(1-S_2)},\ Y_3 = \frac{E}{(1-S_2)\cdot(1-S_3)}. \tag{5}$$

After that, the average waiting time for an arbitrarily selected request for PDO CBR reconnaissance activities is determined, in *days*:

$$Y' = \left(\frac{\lambda_1}{\lambda_n}\right) \cdot Y_1 + \left(\frac{\lambda_2}{\lambda_n}\right) \cdot Y_2 + \left(\frac{\lambda_3}{\lambda_n}\right) \cdot Y_3. \tag{6}$$

Next, we calculate the average length of the queue of requests for PDO CBR reconnaissance, units:

$$L_q = \lambda_n \cdot Y'. \tag{7}$$

At the third stage, the effectiveness of PDO CBR reconnaissance is assessed according to the following condition:

$$L_q \le L_0, \tag{8}$$

where $L0$ is the maximum number of requests in the queue for PDO CBR reconnaissance, *units*.

If the accepted condition is met, PDO CBR reconnaissance is considered to be effective.

As an example, consider one of the options for calculating the characteristics of the PDO CBR reconnaissance process as a queueing theory with priorities and assessing the CBR reconnaissance effectiveness.

Initial data:

CBRN reconnaissance objects number - 150 *units*;

combat actions duration (T) - 10 *days*;

average time of productive operation of CBR reconnaissance vehicles during a day ($tPro$) - 10 *hours/day*;

average time of reconnaissance of one PDO by CBR reconnaissance vehicles (tr) - 1 *hour;*

CBR vehicles number engaged in CBR activities (s) - 2 *units;*

the maximum number of requests in the queue for the PDO CBR reconnaissance activities implementation ($L0$) - 10 *units*.

Under such conditions, the procedure for calculating the characteristics of the PDO CBR process as a priority-based queueing theory and assessing the CBR reconnaissance effectiveness is as follows:

1. Employing the initial data, we prioritize CBR reconnaissance objects according to their importance during combat actions in urbanized areas:

highest priority ($qk1$) - 20 *units;*

medium priority ($qk2$) - 50 *units;*

lowest priority ($qk3$) - 80 *units*.

2. Using (1), we determine the intensity of receipt (λ) and service (μ) of requests for PDO CBR reconnaissance activities with the *kth* priority:

the request receipt intensity for PDO CBR reconnaissance activities of the highest priority ($qk1$) - $\lambda 1 = 2$ *units/day*;

the requests intensity for PDO CBR reconnaissance activities of the medium priority ($qk2$) - $\lambda 2 = 5$ *units/day*;

the requests intensity for PDO CBR reconnaissance activities of the lowest priority ($qk3$) - $\lambda 2 = 8$ *units/day*;

servicing requests intensity for PDO CBR reconnaissance activities - $\mu = 10$ *units/day*.

3. Employing (2), we calculate the average number of requests (S) for CBR reconnaissance activities of the *k-th* priority that are received during the service of one request *with* service channels:

the requests average number for PDO CBR reconnaissance activities of the highest priority - $S1 = 0.1$ *units;*

the requests average number for PDO CBR reconnaissance activities of the medium priority - $S2 = 0.35$ *units;*

the average number of requests for PDO CBR reconnaissance activities of the lowest priority - $S3 = 0.75$ *units*.

4. Equation (3) is used to determine the relative reduced intensity of requests (ρ) for PDO CBR reconnaissance activities: $\rho = 1{,}5$.

5. Using equation (4), we calculate the mean value of the exponential distribution: $E = 0{,}065$.

6. Using (5), we calculate the average waiting time (Y) for PDO CBR reconnaissance activities implementation of each priority:

the average waiting time for PDO CBR reconnaissance activities implementation of the highest priority is $y1 = 0.072$ *days*;

the average waiting time for PDO CBR reconnaissance activities implementation of the medium priority is $y2 = 0.111$ *days*;

the average waiting time for PDO CBR reconnaissance activities of the lowest priority is $_{Y3}$ = 0.393 *days*.

7. Using (6), we determine the average waiting time for an arbitrarily selected request (*Y'*) for PDO CBR reconnaissance activities: *Y'* = 0.26 *days*.

8. Using (7), we calculate the average length of the queue of requests ($_{Lq}$) for PDO CBR reconnaissance activities implementation: $Lq_{=}$ 4 *units*.

9. We compare the received in a paragraph 8 result of the requests queue average length calculation (L_q) for PDO CBR reconnaissance activities realisation with the maximum number of these requests (L_0) assumed in the initial data and conclude that PDO CBRN reconnaissance implementation under the given conditions of the situation is effective.

Results and Discussions

Thus, by calculating of the PDO CBR reconnaissance process characteristics as a queueing theory with priorities, in particular, the intensity of receiving and servicing requests for CBR reconnaissance activities of a certain priority, the average number of requests for these activities, the relative reduced intensity of receiving requests, the average waiting time for CBRN reconnaissance activities of a certain and arbitrarily selected priority, the average length of the queue of requests for these activities, the PDO CBR reconnaissance effectiveness was assessed.

This assessment shows that the calculating results of the PDO CBR reconnaissance process characteristics as a prioritised queueing theory depends on the factors that influence the PDO prioritisation by their importance during combat operations in urbanised areas, the CBR reconnaissance objects number and the CBR reconnaissance assets' number and capabilities involved in the tasks execution. The analysis of studies and publications showed that issues related to the troops' CBRN protection process, in particular CBR reconnaissance, have been addressed in a number of works. For example, the general issues of CBR reconnaissance organisation and performance (Radiation, Chemical, Biological Protection of Units, 2007), tactics of radiation, chemical, biological protection troops in relation to the CBRN reconnaissance activities execution (Shvets, Marushchenko, Koval, 2008), tactical calculations substantiation for CBRN protection tasks and activities, in particular CBR reconnaissance activities (Hutchenko, Hyshko, Prokofiev, 2017). However, the PDO CBR reconnaissance process as a queueing theory with priorities was not considered in these studies and publications. The russia-Ukraine war experience convinces us that during the conduct of combat actions in urbanised areas with a PDO large number, the volume of CBR reconnaissance activities will increase and the priorities for their performance will change. This requires consideration of the CBR reconnaissance process through such characteristics that will allow to assess the effectiveness of its conduct in a CBR-complicated environment, which was done in the article with the help of the studied queueing theory with priorities (Taha, 1985).

Conclusion

In this manner, the above dependencies make it possible to present the PDO CBR reconnaissance process through the receipt intensity and requests servicing for the CBR reconnaissance activities, the requests average number of the *k-th* priority received by the service channel, the average waiting time for an arbitrarily selected request for the performance of these objects' activities of the *k-th* priority and the request queue average length, which allows to assess the PDO CBR reconnaissance effectiveness, especially in a complicated CBR situation. The research has shown that these indicators mainly depend on the PDO's number and priority, the CBR reconnaissance vehicles' number and capabilities. One of the advantages of the considered approach is that when presenting the PDO CBRN reconnaissance process as the queueing theory with priorities,

the degree of reconnaissance importance objects for the military and the CBR security system is taken into account.

Prospects for further research in this area are to consider the processes of other CBRN protection activities for troops, considering the loss of CBRN assets and possibilities for their recovery during combat operations in urbanised areas.

Recommendations

The materials of the publication will be of interest to military command and control bodies who are planning the CBRN troops protection including CBR reconnaissance during combat operations in urbanised areas. The results of these calculations will allow assessing the PDO CBR reconnaissance effectiveness in the CBR complicated environment.

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Comprehensive methodology for the rational distribution of air defence assets to protect troops and objects from various types of air attack assets (general provisions)

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Abstract. This article presents the main provisions of a comprehensive methodology for the air defence assets' allocation to cover troops and objects from various types of air attack assets, which is based on two main methods: predicting the anticipated actions of air attack assets in a strike, the essence of which is the sequential distribution of specific air attack assets to the attack objects considering their importance and the advantage degree of the air attack assets' action on them, which allows to estimate predicted losses of troops and objects for the purpose to employ them further during the assessment of anti-aircraft missile systems capabilities to destroy certain types of air attack assets and the air defence assets' distribution to cover troops and objects, the essence of which is the anti-aircraft missile systems' sequential distribution (anti-aircraft missile systems composition options) to cover the most important objects considering expected actions of air attack assets and the advantage degree of certain types of anti-aircraft missile systems employment to destroy air attack assets of certain classes and types. The methodology's comprehensiveness essence lies in the following: determining the possible enemy's first missile and air strike objects' list, taking into account their importance; predicting the expected actions of air attack assets in the strike, taking into account the advantage of their use against cover objects (based on the eponymous method); assessing the anti-aircraft missile systems' capabilities to defeat certain types (classes) of air attack assets, taking into account the advantage of using these systems against these air attack assets' types; allocation of anti-

aircraft missile systems (based on the eponymous method), taking into account the specifics of their employment by individual types (classes) of air attack weapons to cover objects from air strikes.

Keywords: air attack assets, anti-aircraft missile cover, effectiveness assessment, enemy's actions prediction, air defence, assets allocation.

Introduction

From the experience of repulsing russian aggression, it follows that various types of air attack assets (AAA) can be used against troops and objects, namely: land-based non-strategic ballistic missile (NSBM); air-based, sea-based, land-based cruise missiles (CM); unmanned combat aerial vehicles (UCAV); manned aviation (MA). At the same time, it should be emphasized that the russian aerospace forces` aviation, missile forces and artillery of the land forces, as well as surface ships, submarines and coastal mobile missile systems of the Navy, launched combined strikes with ballistic, aeroballistic and cruise missiles. The following missile carriers were used to launch combined missile strikes:

– air-based cruise missile: X-101, X-55 (training missiles with nuclear warhead imitators), X-555 and X-22 – strategic bombers TU-160, TU-95 and TU-22M3; X-31, X-59 – fighter aircrafts and bombers SU-24, -30, -34, -35);

– sea-based cruise missile “Kalibr” – surface ships and submarines of the Black Sea Fleet and surface ships of the Caspian flotilla;

– land-based cruise missiles – “Iskander-K” tactical missile system;

– anti-ship missiles 3M-55 (P-800) “Onyx” – “Bastion-P” mobile coastal missile system;

– anti-ship missiles X-35 – “Bal” coastal missile system;

– non-strategic ballistic missile – Iskander-M” tactical missile system and “Tochka-U” tactical missile system;

– air-based aeroballistic missile X-47 – MIG-31K aircraft of “Kinzhal” aviation missile system;

– anti-aircraft guided missiles (whose flight, when firing at ground targets, is carried out practically along ballistic trajectories) – anti-aircraft systems launchers (AS) S-300P and S-400.

Table 1 shows some characteristics of the air attack assets used in the Russian-Ukrainian war since the beginning of full-scale aggression (Zhyvotovskyi, 2022), (Nor, 2022), (Katsan, 2022), (Kolesnyk, 2022), (Shkurat, 2023).

Employment of any type of air attack assets against specific targets is primarily determined by their availability, range, importance of the target, capabilities to destroy the target, economic and other considerations.

In meanwhile, air defence assets (ADA) that can be used to protect objects from air strikes are characterized by different capabilities to destroy different types of air attack assets and differ in their firing zones. Some anti-aircraft missile systems cannot be used at all to destroy certain types of air attack asssets (e.g., ballistic and aeroballistic missiles). In addition, covering objects from strikes by certain types of air attack assets (especially ballistic and cruise missiles) requires taking into account some peculiarities of the combat formation build-up of units armed with anti-aircraft systems. Table 2 shows the main characteristics of anti-aircraft systems in service with the Armed Forces of Ukraine at the beginning of the armed aggression of the russian federation, as well as some foreign systems provided by partner countries.

Thus, when organizing the protection of troops and objects from strikes by various types of air attack assets, it is necessary: first, to predict the actions of certain types of air attack assets on troops and objects; second, to ensure the rational distribution of air defence assets to protect troops and objects considering the peculiarities of their employment against certain types of air attack assets.

Materials and Methods

Many works have been devoted to predicting the actions of manned aviation and cruise missiles against troops and objects during air strike (Horodnov, 1999), (Onyshchenko, 2011), (Romanchenko, 2011). However, they do not consider the effects of non-strategic ballistic missiles (NSBMs) and UCAVs against troops and objects, especially when they are used together. In addition, these works do not fully take into account the characteristics of targets when predicting strikes by air attack assets.

Some peculiarities of building the objects' defence from CM and NSBM strikes were analyzed earlier (Romanchenko, 2011), (Toropchyn, 2003), (Zahorka, 1998). However, the objects' defence from these types of air attack assets strikes is considered separately, and the general capabilities of air defence assets to protect troops and objects from rocket and avitaion strikes (RAS) in an operation (during combat operations) are not taken into account.

Table 1. Some characteristics of main air attack assets used in russian-Ukrainian war.

Class (type) of air attack assets	Firing range (launch), km	Launch weight, kg	Warhead weight, kg	Maximal velocity, m/s	Flight height (max.), km	Accuracy (CEP), m	Maneuver possibility
Non-strategic ballistic missiles							
TMS 9M723 MS "Iskander-M"	500	3800	480	2100	50,0	5-7	+
TMS 9M79-1 MS "Tochka-U"	120	2010	470	800	26,0	100	–
Aeroballistic missiles							
ABM X-47M2 aviation MS "Kinzhal "	2000	3500	500	4080	50,0	3-5	+
ABM X-22 "Burya"	550	5675	900	1550	24,0	300	–
Anti-aircraft guided missiles							
AGM 5B55 S-300P SAM	120	1660	130	2000	27,0	*	–
AGM 48H6 S-400 SAM	259	1830	180	2000	27,0	*	–
Air-based cruise missiles							
CM X-555	3500	1280	410	230	6,0	20	+
CM X-101	5000	2400	430	270	6,0	10	+
CM X-59	290	930	320	290	50,0	5	
CM X-31	250	715	110	1000	16,0	*	
Sea-based cruise missiles							
CM 3M-14 "Kalibr-NK, -PCH"	2500	1450	450	270	6,0	5	+
Land-based cruise missiles							
CM 9M729 MS "Iskander-K"	2500	1770	450	270	6,0	5	+
Anti-ship CM 3M-55 "Onyx" of coastal MS "Bastion-P"	800	3000	300	880	14,0	3	–
Anti-ship CM X-35 of coastal MS "Bal"	130	620	145	290	6,0	10	+

Note* - data is absent.

Thus, the issue of substantiating the procedure and methods that should be used to allocate air defence assets in the organization of covering troops and objects from attacks by various types of air attack assets remains relevant today. The article proposes the general provisions of a comprehensive methodology for the rational allocation of air defence assets to protect troops and objects from attacks by various types of air attack assets, based on two main methods: determining the expected actions of air attack assets during strike and allocating air defence assets to protect troops and objects.

A Method for Predicting the Air Attack Assets' Expected Actions in a Strike.

Assessment of air enemy's possible actions is one of the important elements of air defence organization that ensure the validity of decisions made in the organizing process of the troops and objects from air strikes' protection, improving and developing methods of the air defence assets combat employment.

Table 2. Main characteristics of anti-aircraft assets.

Name of anti-aircraft asset	Main characteristics of the system						Capability to destroy BM and ABM
	Maximal range / target engagement height, km	Target's maximal velocity / AGM, m/s	Channeling on target, km	AGM weight / warhead, kg	Number of missiles (shots) in the SAM/ in the launcher, pcs.	Deployment time min.	
Anti-aircraft assets which were in service with the Armed Forces of Ukraine							
SAM system S-300PT (PS)	75 / 27	1300 / 2000	до 6	1665 / 133	48 / 4	90 (5)	+
SAM system S-300B1	75 / 25	3000 / 1200	до 6	2500 / 150	24 / 4	5	+
SAM system «Buk-M1»	35 / 22	830 / 1100	1	690 /70	4	5	–
CV SAM «Tor-M1»	12 / 6	700 / 850	1	165 / 15	8	5	–
CV SAM «Osa-AKM»	10 / 5	500 / 500	1	126 / 15	6	3	–
CV SAM «Strila-10M»	5 / 3,5	415 / 550	1	40 / 5	8	1	–
SPAAG «Tunguska-M»	8 / 3,5	500 / 900	1	42 / 9	8 (1904)	3	–
SPAAG-23-4 «Shilka»	2,5 / 1,5	450 / -	1	–	(2000)	3	–
ZU-23	2,5 / 1,5	400 / –	1	–		0,5	–
Anti-aircraft assets provided by partners							
«Patriot PAC-2» SAM MIM-104 C/D	90 / 25	2200 / 1750	до 8	906	до 36 / 4	30	+
«Patriot PAC-3» PR ERINT	40 / 20	3000 / 2300	до 8	316 / 24	до 144 / 16	30	+
MIM-104 F »	150 / 25	3000 / 2000	до 8	1500 / 90	до 36 / 4	30	+
SAMP-T	100 / 20	1000 / 3M	16	445 / 15	48 / 8	15	+
IRIS-T	40 / 20	1000 / 3M	24	87 / 11	24 / 8	10	–
Improved Hoc	50 / 18	/ 900	1	590 / 54	18 / 3	45	–
NASAMS	40 / 16	1000 / 1020	3	150 / 22	48 / 6	15	–
Krotal	10 / 6	500 /1250	1	73 / 13	8	3	–
SPAAG «Gepard»	4 / 3	400	1	–	(319)	3	–

The input data for predicting the expected actions of the air attack assets during strike are: the state's facilities and our troops to be covered from air strikes, as well as the composition of the grouping of air defence assets (for all objects that can be targeted by air attack assets, their importance is determined); the possible composition of the enemy's groups.

It is proposed to predict the expected actions of the enemy during the employment of different types of air attack assets during strike on the basis of the A Method for Predicting the Air Attack Assets' Expected Actions in a Strike, the structural diagram of which is shown in Fig. 1.

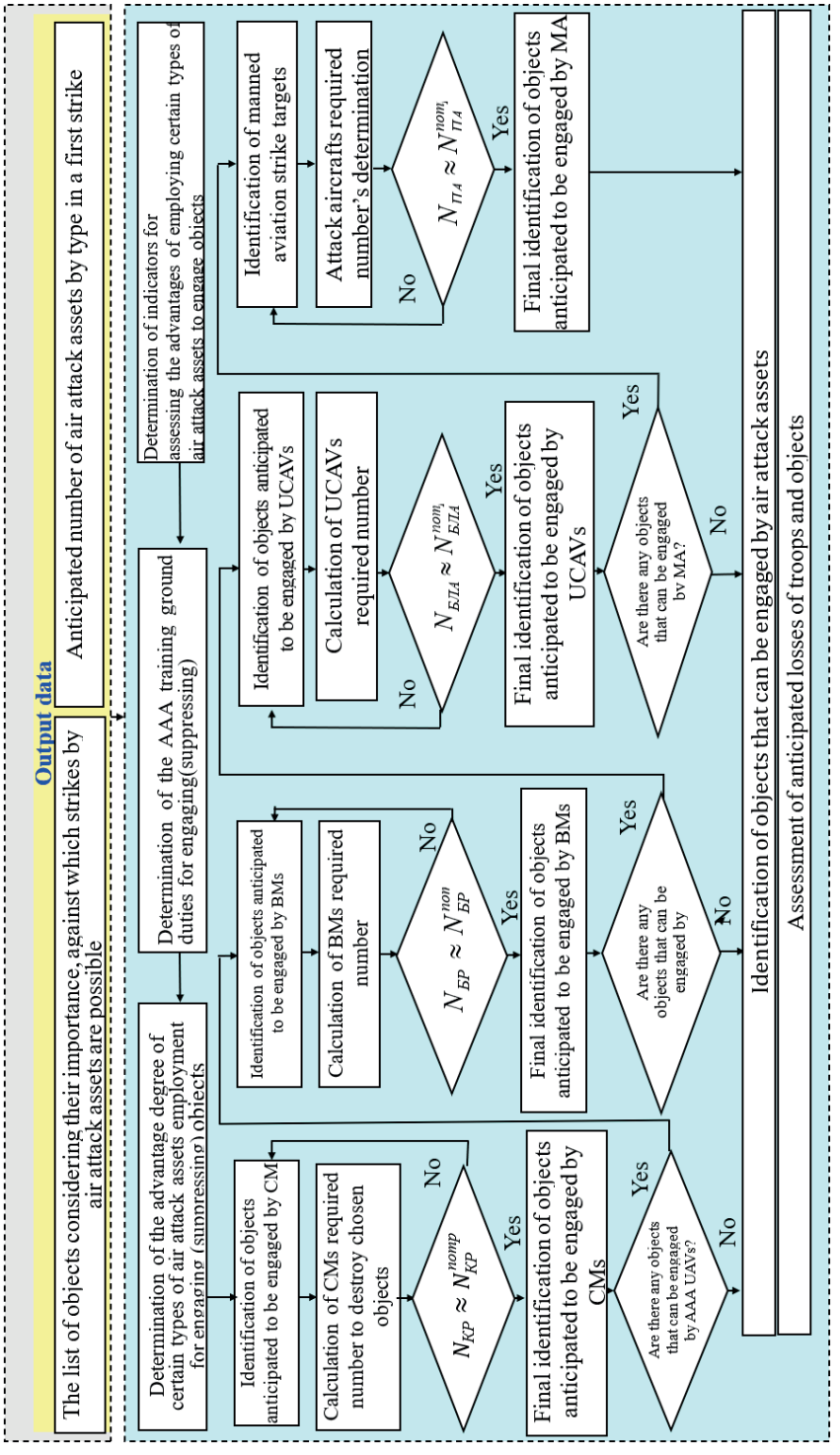


Figure 1. A Method for Predicting the Air Attack Assets' Expected Actions in a Strike block diagram

According to this method, for each target, taking into account its importance, it is planned to determine the degree of advantage of using specific types of air attack assets to defeat (suppress) it.

To determine the superiority degree, indicators can be used that characterise: condition fulfilment for the AAA's required range (determined by a topographic map); object's target destruction (suppression) probability when using one AAA; AAA's missile cost to destroy (suppress) an object; the object's coverage degree by air defence assets; possible personnel losses when using AAA; the necessity to deliver a point attack on an object; limitation on AAA's certain type number, etc.

To determine the advantage degree of AAA (air attack assets) certain types' application for each object, taxonomy methods can be used (Pliuta, 1989), the computational procedures of which have been worked out in detail in solving other problems.

The assessment results of the superiority degree of actions against the objects of AAA's certain types are the basis for forecasting the expected AAA actions against troops and objects.

Initially, considering the experience of military conflicts and the accepted operational formation of the AAA in the RAS (Rocket Aviation Strike), it is envisaged to distribute the strike forces to the CM (cruise missiles). To accomplish this task, as in (Horodnov, 1999), the iteration method is employed.

Objects of destruction (suppression) for CM are determined taking into account their importance and the degree of advantage of actions against them of this type of AAA. Iterations are carried out until the required number of CMs for destruction (suppression) of selected objects $\left(N_{KP}^{потр.}\right)$ is equal to the number of CMs that can be used in RAS (N_{KP}). Based on the results of iterations, the number of objects for which the effect of the CM is predicted may either decrease or increase.

Next, the presence of objects for which no CMs have been applied is checked. If there are no such objects, the objects that are expected to be affected by the AAA (in this case, only by the CM) are finally determined. If there are still targets that can be struck by the AAA, they are then distributed for destruction (suppression) by the AAAs next type (in this case, NSBM), also using the iteration method. The procedures used to allocate objects for destruction (suppression) by AAAs different types are similar.

Thus, the expected effects of AAAs different types on troops and objects in the RAS are predicted.

The results of determining the targets on which the effects of the AAAs are expected to be directed allow estimating the projected losses of troops and objects from their strikes.

The mathematical expectation of the value of the predicted losses that can be caused by a CM separately to economic and public administration objects and military objects in conventional units of their importance is determined by the formula:

$$M_{KP} = \sum_{i} B_{зн.i}^{KP} P_{зн.} + \sum_{j} B_{прид.i}^{KP} P_{прид.}, \quad (1)$$

where i, j are, respectively, the numbers of the economic and public administration object or military object to be destroyed or suppressed;

$m_{зн.}^{KP}$, - respectively, the number of objects to be destroyed or suppressed;

$B_{зн.i}^{KP}$ - is the importance coefficient of the i-th object;

$B_{приd.j}^{KP}$ - is the importance coefficient of the j-th object;

$P_{зн.}, P_{приd.}$ - probability of destruction, suppression of the object, respectively.

Similarly, the mathematical expectations of troops losses and objects from strikes by NSBMs (M_{NSBM}), UCAVs (M_{UCAV}), and MAs (M_{MA}) are determined in conventional units of importance.

The mathematical expectations of the total losses of economic and governmental objects and military targets from strikes by air attack assets are as follows:

$$M_{o} = M^{o}_{CM} + M^{o}_{NSBM} + M^{o}_{UCAV} + M^{o}_{MA};\ M_{в} = M^{в}_{CM} + M^{в}_{NSBM} + M^{в}_{UCAV} + M^{в}_{MA}. \quad (2)$$

Accordingly, the mathematical expectations of the projected values of relative losses are determined by the following formulas:

$$R_{o} = \frac{M_{o}}{\sum_{v=1}^{L} B_{v}};\ R_{в} = \frac{M_{в}}{\sum_{\xi=1}^{S} B_{\xi}}, \quad (3)$$

where B_v, B_ξ *are* the importance *coefficients* of the *v-th* economic and public administration object and the *-th* military object, respectively;

L, S - the number of economic and public administration objects and military objects, respectively, which may be targeted by the AAA for the purpose of striking (determined at the first stage of the methodology).

Thus, the proposed Method for predicting the expected actions of the AAA in a strike allows us to estimate the possible losses of troops and objects from air strikes in order to use the results of such prediction in the future when allocating air defence assets to protect the most important objects and troops.

Allocating air defence assets to protect troops and objects' method

The allocation of air defence forces and assets to protect troops and objects from attacks by various types of air attack assets is one of the important tasks in the organization of air defence.

To ensure such distribution, taking into account the peculiarities of the employment of air defence assets for certain types of air attack assets, we propose the of Allocation of Air Defence assets to Protect Troops and Objects' Method, the structural diagram of which is shown in Fig. 2.

When allocating air defence assets, the main attention should be paid to ensuring reliable anti-missile defence of the most important objects against NSBM strikes. This is primarily due to the advantage and suddenness of their employment in the first strikes of an enemy air offensive. The employment of cruise missiles in massive strikes has become an essential component of all operations conducted by the United States and its allies. It should be noted that the massive employment of expensive CRs in military operations (over 1 million US dollars per unit) is justified only at the first stage of hostilities. In the future, the main burden in fulfilling the tasks of destroying the enemy should be borne by aviation, which employs precision weapons.

For example, modern guided aviation bombs provide a relatively impressive effect at a lower cost, 60 times lower. Therefore, when allocating air defence assets to protect objects from unmanned aerial vehicles, it is necessary to take into account the possibility of using them even at the first stage of military operations of the MA (Manned Aviation).

The allocation of air defence assets depends on many factors that must be taken into account when organizing the protection of troops and objects from air strikes. The need to take into account the peculiarities of covering objects from strikes by such AAA as NSBM and CR requires a more thorough approach to the construction of combat formations of air defence units, i.e., the ways of employment air defence assets.

Obviously, when organizing air defence for each facility, it is necessary to assess the effectiveness of its coverage. For such an assessment, it is impossible to employ models for assessing the effectiveness of the air defence system as a whole, because they do not fully take into account the changes in the ways of covering individual objects from attacks by different types of air attack assets. In this case, it is preferable to employ partial models and methods (Romanchenko, 2011), (Chuev,

1965), which will optimize the composition and methods of employing air defence assets to protect individual objects.

The distribution of air defence assets launches with the protection organization for the most important objects, taking into account the results of predicting the expected actions of the AAA and the degree of advantage of employing certain types of SAM's to defeat certain types (classes) of AAA.

To protect the object, several or many variants of the SAM composition are formed. Employing the topographic map, the possibility of leveraging SAMs that were previously intended for covering other objects is taken into account.

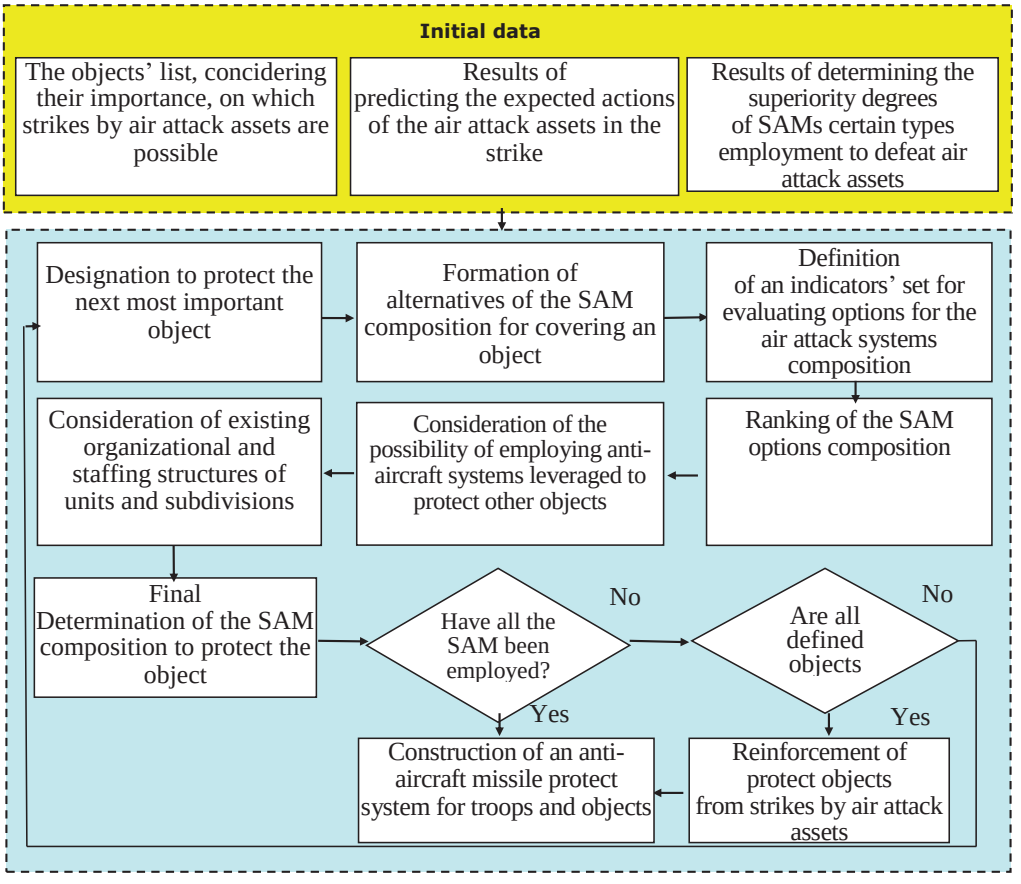


Figure 2. Flowchart of the Air Defence Forces and Assets Allocation for Troop and objects' cover Method

The selection of a rational variant of the SAM composition is carried out employing a set of indicators that characterize: the fire capabilities of the SAM composition that can be realized during the repulsion of an air defence strike on the object; the effectiveness of covering the object; losses of SAMs during an air attack assets strike repulsion; the SAM composition's cost; missile costs, etc.

Taxonomy methods can be employed to determine the rational composition of air attack assets for covering an object based on a set of the listed indicators (ranking of anti-aircraft missile system composition options) (Pliuta, 1989).

The process of allocating air defence assets to protect targets continues until all SAMs that can participate in the air operation are used or until all targets are protected.

If there are any SAMs left that are not employed, the coverage of individual targets is reinforced. This is how the system of air defence missile coverage of troops and objects is practically justified.

A comprehensive methodology for the air defence assets' rational allocation to protect troops and objects from attacks of air attack assets various types.

The structural diagram of the comprehensive methodology for the air defence assets' rational distribution to protect troops and objects from attacks by air attack assets various types is shown in Fig. 3.

At the methodology's ***first stage***, all targets that may be struck by AAA in the first rocket aviation strike of an air offensive operation are identified and their importance is assessed.

If we draw on the experience of recent military conflicts, it turns out that they usually began with an air offensive by the party that started them.

The first strikes were carried out against air defence objects, airfields, missile systems, troop control centers, energy objects, communication hubs, and other important targets employing unmanned air attack assets. At the same time, the employment of unmanned air attack assets in the first strikes to fulfill the tasks of an air offensive were not ruled out. This is due to the limited number of unmanned air attack assets and the need to perform special tasks.

The defending party may conduct an air operation, one of the main tasks of which is troops and objects' air defence. To organize this task, it is necessary, first of all, to determine the list of objects that can be targeted by AAAs to fulfill the tasks of the first rocket aviation strike.

It is believed that at the time of a military conflict, the number of AAAs by type is known. Predicting the expected number of AAAs in the first strike is based on their combat readiness and reserve coefficients. The operational formation of the first RAS, taking into account the employment of AAA in recent military conflicts, may include: a CR echelon; an NSBM echelon; groups or single UCAVs; a echelon or groups of MAs for various purposes.

At the first stage of the methodology, all targets that can be struck by AAAs in the first rocket aviation strike of an air offensive operation are identified. For this purpose, a topographic map is used, which shows economic and governmental facilities that may be located in the war zone, as well as the structure of the grouping of our troops.

To determine the coefficients of importance of economic and public administration objects and the coefficients of operational and tactical importance of military objects, it is advisable to use

the Method of Hierarchy Analysis (MAI) (Saaty, 1985), (Samokhvalov, 2007). Hierarchical representations of the tasks of determining the coefficients of importance of economic and public administration objects, as well as the coefficients of operational and tactical importance of military objects are shown in Fig. 4 (Onishchenko, 2011), (Tarasov, 2015).

The methodology's ***third stage*** is preparatory for the air defence assets' allocation with the aim to cover troops and objects from AAA strikes.

The effectiveness of defeating specific types of AAAs by anti-aircraft systems is determined by the results of shooting range tests or employing known models of their operation and analytical methods (Romanchenko,2011).

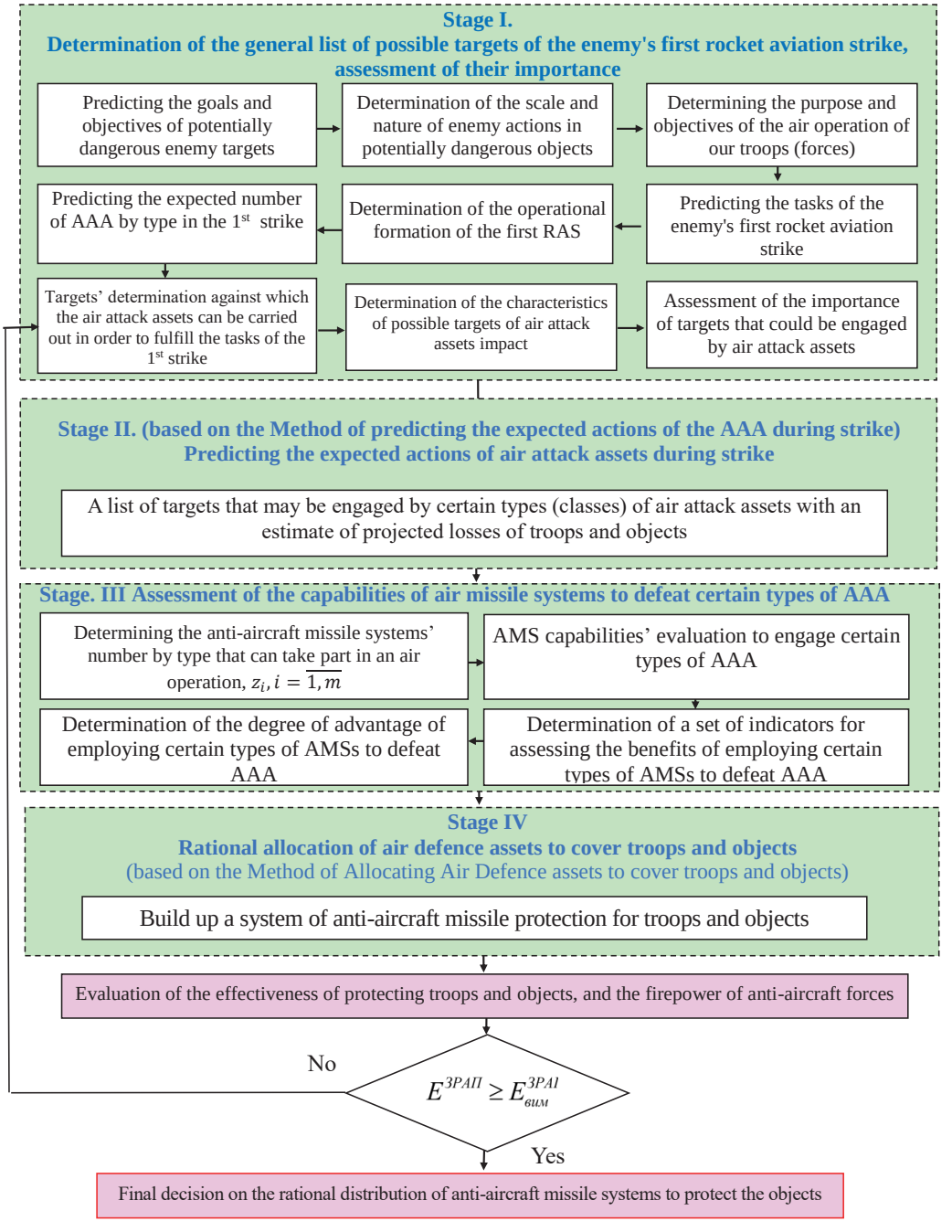


Figure 3. Block diagram of a comprehensive methodology for the allocation of air defence assets to cover troops and objects from strikes by various types of AAAs

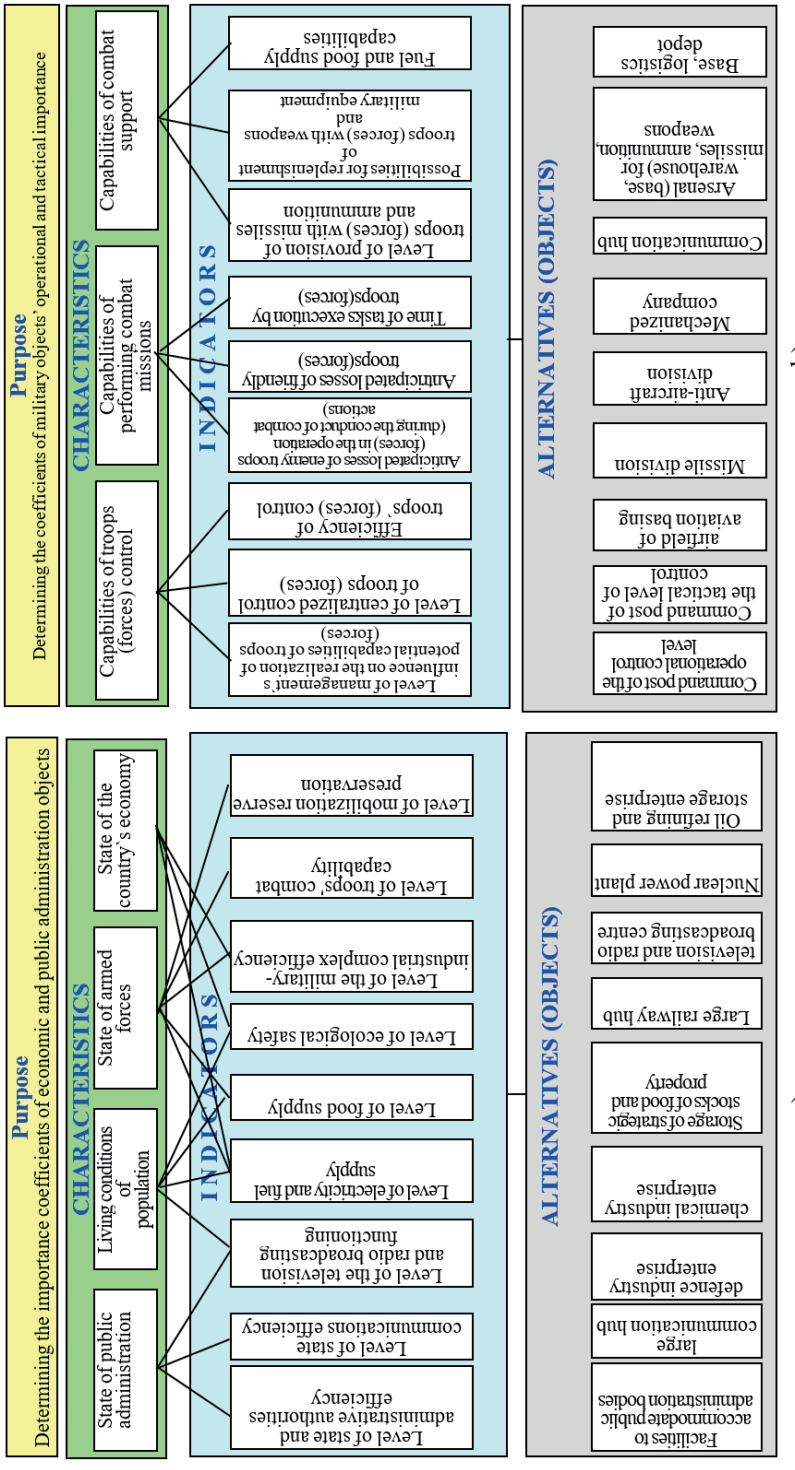


Figure 4. Hierarchical depiction of determining coefficients task: a)importance of economic and public administration objects (option); b) military objects' (option) operational and tactical importance

To determine the degree of advantage of using a SAM particular type to defeat a certain type of AAA, it is advisable to empoy indicators that characterize: the ability to operate on a certain type of AAA; probability, range and height of AAA defeat; protection against interference; limitations on the number of SAMs of a certain type, etc.

As in determining the degree of superiority of AAA actions against an object, the taxonomy method can be employed to assess the degree of superiority of SAMs actions against AAA.

To perform the methodology's ***fourth stage***, it is proposed to employ the previously mentioned aspects of *Allocating Air Defence Forces and Assets to Cover Troops and Objects Method*, as a result of which an air defence cover system for troops and objects is practically created.

The predicted effectiveness of the anti-aircraft cover system for troops and objects can be determined by mathematical models or analytical methods (Horodnov, 1999), (Romanchenko, 2011), (Tarasov, 2015), (Drobakha, 2004).

If the effectiveness of the anti-aircraft missile protection system for troops and objects does not meet the established requirements, it is necessary to specify the objects and re-distribute air defence assets to protect them.

Results and Discussions

Employing partial models and methods, it is possible to determine the mathematical expectations of the number of AAAs that can be destroyed by air defence assets from the composition of the details intended to destroy (suppress) each f-*st* object of the economy and public administration.

Then the probability of preserving the f-*st* object is determined by the formula (Romanchenko, 2011):

$$P_{зб.i} = \left(1 - P_{li}\right)^{r_i - \Delta r_i}, \tag{4}$$

P_{li} where is the destruction's probability of the f-*st* object when employing one AAA (determined at the second stage of the methodology).

The mathematical expectation of the value of relative losses of economic and public administration objects is determined by the formula:

$$R_{\partial} = \frac{\sum_{i=1}^{m^{\partial}_{зн.}} \left(1 - P_{зб.i}\right) B_i}{\sum_{l=1}^{L^{\partial}} B_l}, \tag{5}$$

where B_i is the importance coefficient of the *1st* object of economy and public administration; L^{∂} - the number of economic and public administration objects that may be affected by an AAA (determined at the first stage of the methodology);

$m^{\partial}_{зн.}$ - the *number of* economic and public administration objects to be destroyed in the first RAS (determined at the methodology's second stage).

The probability of survival of military objectives and the mathematical expectation of the military objectives' relative loss are determined by similar formulas.

When determining the mathematical expectations, it is necessary to take into account the destruction of AAAs not only by air defence assets covering the object, but also by other air defence systems, *i* .e., "in flight".

For the targets against which the employment of CMs, UCAVs, and MAs is expected, the values can be roughly determined using a mathematical model or analytical methodology for assessing the

effectiveness of the anti-aircraft system for troops and objects (Horodnov, 1999). Similarly, the value can be determined for the objects against which the employment of ballistic missiles is expected. Methods are employed to determine the mathematical expectations of the number of destroyed AAAs by type when repelling an *СМ, ВМ, UCAVs, or МА* air strike. The probability of destruction of any AAA by type from the strike force and means is determined by the following formulas:

$$P_{зн.КР} = \frac{M_{КР}}{N_{КР}}; \quad P_{зн.БР} = \frac{M_{БР}}{N_{БР}}; \quad P_{зн.БЛА} = \frac{M_{БЛА}}{N_{БЛА}}; \quad P_{зн.ПА} = \frac{M_{ПА}}{N_{ПА}}, \tag{6}$$

where $N_{КР}$ $N_{БР}$ $N_{БЛА}$ $N_{ПА}$ are the number of CMs, BMs, UCAVs, and aircraft participating in the AO.

Then the mathematical expectation Δr_i of the number of destroyed CMs from the CM squadron assigned to destroy the f-*st* object can be determined by the formula:

$$\Delta r_i = r_i P_{зн.СМ}. \tag{7}$$

Similarly, mathematical expectations are determined for the targets where UCAVs and MAs are expected to be emloyed.

Taking into account (7), formula (4) has the form:

$$P_{зб.i} = (1 - P_{li})^{r_i(1-P_{зн.СМ})}. \tag{8}$$

The definition of the mathematical expectation of the relative losses' value differs from its definition by formula (3), because the mathematical expectation takes into account the functioning of anti-aircraft protection system of troops and objects from air defence strikes, which is designed on the results of the air defence forces assets distribution employing the proposed methodology.

Conclusion

The methodology described above is as close as possible to the practical activities of command and control bodies involved in organizing the protection of troops and objects from air strikes. The process of allocating air defence assets to protect objects from air strikes is based mainly on the employment of practical experience of specialists. At the same time, the developed methodology allows to take into account the peculiarities of using certain types of anti-aircraft missile systems to protect objects from strikes of various types of air attack assets, as well as to substantiate recommendations for its improvement, and thereby increase the efficiency of the anti-aircraft missile system for covering troops and objects.

Thus, in order to develop recommendations for improving the effectiveness of combating unmanned air attack assets in the context of their integrated employment, an improved methodological apparatus is proposed to substantiate the allocation of air defence assets to protect troops and objects from attacks by different types of air attack assets, which includes:

- method for predicting the expected SAMs actions in a strike, the essence of which is the specific SAMs sequential distribution to the objects of attack, taking into account their importance and the degree of advantage of this SAM action on them, which allows to estimate the projected losses of troops and objects in order to use them in the future when assessing the capabilities of SAMs to defeat SAMs certain types (classes);

- method of allocating air defence assets to protect troops and objects, the essence of which is the SAMs (SAM composition options) sequential allocation to protect the most important objects, taking into account the expected actions of the AAA and the degree of advantage of using SAMs certain types to destroy AAAs certain classes and types;

- comprehensive methodology for the rational allocation of air defence assets to protect troops and objects from strikes by various types (classes) of air attack assets. The essence of the methodology is the following: determination of the list of possible targets of the enemy's first rocket aviation strike, taking into account their importance; predicting the AAAs expected actions in a strike, taking into account the advantages of their employment against protect objects (based on the method of the same name) assessing the SAMs capabilities to defeat AAAs certain types (classes), taking into account the advantages of employing these systems on these types of AAAs; SAMs distribution (based on the method of the same name), taking into account the peculiarities of their use on AAAs certain types (classes) to protect objects from air strikes.

Recommendations

The proposed comprehensive methodology makes it possible to solve a multi-criteria problem when build up an anti-aircraft missile protection system for a certain number of objects and troops, as well as when substantiating recommendations for organizing the protect of troops and objects from attacks by both AAAs certain types (primarily, BMs, CMs, UCAVs) and in the conditions of their integrated use.

In general, the methodology can be employed both in research and in planning an air operation.

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Evaluation of the effectiveness of the protection of strategically important objects from unmanned aerial vehicles by air defense forces

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Abstract. The relevance of this article is due to the need to protect strategically important objects from terrorist attacks from the air. In particular, the experience of the leading countries of the world shows that the most effective protection of strategically important objects from terrorist acts from the air is a combination of the principles of action of special purpose means, for which it is appropriate to consider some issues of compatibility of these means when protecting strategically important objects from terrorist acts or air attack. At the same time, the study of these issues will make it possible to evaluate the results of joint actions, as well as to develop scientifically based recommendations for their effective application. In this regard, this article is aimed at identifying the factors that, in the modern conditions of the russian-Ukrainian war, have the greatest impact on the effectiveness of engineering protection of strategically important objects. At the same time, taking into account these factors, an evaluation of the effectiveness of the protection of strategically important objects from unmanned aerial vehicles by air defense forces was carried out, the use of which will allow obtaining more correct results. And based on them, develop practical recommendations for increasing the protection of strategically important objects from unmanned aerial vehicles, in particular during hostilities. The article presents a structural and logical scheme of a methodical approach to the selection of the location of air defense means during the protection of strategically important objects from unmanned aerial vehicles, a description of the evaluation stages, the main output data, partial and generalized performance indicators, evaluation criteria and conditions are given. The need to unite the air defense system into a single whole is justified, and the criteria for evaluating the effectiveness of the organization of joint air defense actions are defined. This paper examines the issue of the joint use of air defense and radio-electronic influence during the protection of strategically important objects, the methods of determining the locations of physical influence means, which allows to evaluate the expected results of joint actions, as well as to develop scientifically based recommendations for their effective joint application in the composition of special groups and develop proposals for their special actions in various conditions during the protection and preservation of strategically important objects. The materials of the article are of practical value for management bodies, which, when planning the use of means of physical influence, perform calculations to determine the required volume of engineering measures to increase their survivability during the protection of strategically important objects from unmanned aerial vehicles.

Keywords: strategically important object, unmanned aerial vehicle, air defense forces, electronic warfare.

Introduction

A significant number of strategically important objects, in particular military ones, are located on the territory of most states, the degree of danger of which is established based on the share of the civilian population that falls into the zone of possible neutralization in the event of an accident on it. Strategically important facilities are energy, chemical, food, transport, financial and banking, information technology and telecommunication facilities, utilities: water, heat, gas supply; health care and nuclear industry, arsenals and military warehouses. At the same time, the consequences of accidents at strategically important objects are quite significant. This can result in the destruction or

destruction of infrastructure, cause significant economic losses, and most importantly can lead to the loss of human life.

The role and place of unmanned aerial vehicles in the conduct of military conflicts has led to their massive, integral and global application for the simultaneous solution of many problems. In particular, the development of unmanned aircraft has opened up new opportunities for carrying out terrorist actions from the air against strategically important objects. In particular, the assessment of armed conflicts (Libya, Syria, Nagorno-Karabakh, Ukraine) shows the growing role of unmanned aviation.

One of its important directions is related to the development of unmanned aerial vehicles, the use of which allows minimizing the loss of personnel, due to the replacement of human resources with high-tech means. This allows us to conclude that the enemy is highly likely to start hostilities directly with the use of missile weapons and aviation (including unmanned aircraft) by conducting an air offensive operation. Moving the armed struggle into the air space increases the role of the aviation and anti-aircraft components of the armed forces, the degree of achievement of the strategic goal of military operations will depend on the effectiveness of their application.

If aviation and air defense forces perform the tasks in an air defense operation, then the forces and assets of the ground forces will be able to implement the tasks during the ground part of the armed conflict, otherwise (without aviation and air defense assets) the enemy will achieve strategic goals and the conflict will be exhausted, or no one will perform tasks during the implementation of the ground part of the armed conflict.

The analysis of the russian-Ukrainian war indicates the growing use of unmanned aerial vehicles by the enemy to attack strategically important objects with the aim of destabilizing the situation in the country and reducing its defense capability (Zaluzhny, Moysyuk, Shaptala, 2022; Synyshyn M. M., Demchyshyn V. S., Karasyov D. L., Grinchenko V. V., Babiy Yu. O., Miroshnichenko O. V., 2023). In particular, taking into account these factors, the article evaluates the effectiveness of the protection of strategically important objects from unmanned aerial vehicles by air defense forces, the use of which will allow to obtain more correct results, and based on them to develop practical recommendations for improving them. Fulfillment of this task requires consideration of the conceptual apparatus of the interaction of air defense means and radio-electronic warfare when solving air defense tasks; determination of their compatibility and criteria for evaluating the effectiveness of the organization of interaction during the conduct of air defense by troops (forces).

Materials and Methods

The analysis of modern armed conflicts shows that the most effective protection of objects from terrorist actions from the air is a combination of efforts of special purpose means, for which it is appropriate to consider some issues of compatibility of these means when protecting strategically important objects from terrorist actions or air attack. The study of these issues will allow to evaluate the expected results of joint actions, as well as to develop scientifically based recommendations for their effective application.

This article deals with issues of interaction (Volkov A. F., Yanenko O. A., Kravchenko O. A., 2019) of the joint use of anti-aircraft defense and radio-electronic warfare during the protection of strategically important objects, methods of determining the locations of air defense equipment of defense and electronic warfare (Lezik O. V., Orekhov S. V., Kosenko G. P., 2015), which allows to evaluate the expected results of joint actions, as well as to develop scientifically based recommendations for their effective application as part of special groups and to develop practical recommendations regarding their special actions in various conditions during the protection and preservation of strategically important objects.

Drobakha G. A. (2014) considered the conceptual apparatus of the interaction of air defense means and electronic warfare when solving air defense tasks in the composition of interspecies groups of troops (forces), as well as its essence and content, forms and methods of its organization and implementation.

Volkov A. F. (2019) substantiated the need to unite the air defense system of interaction into a single whole, in particular, he considered the main issues of the usefulness of the relationships of cooperating elements of the interaction system during the air defense of troops (forces) and the dependence of interaction processes on the main properties of the system management, such as sustainability and responsiveness.

Lezik V. O. (2015) established that when assessing the effectiveness of interaction, it is necessary to measure the degree of benefit and usefulness of the relationships of cooperating elements of the interaction system, that is, the effectiveness of the influence of one of the interacting elements of the interaction system on another is measured by the change in the efficiency of the latter. At the same time, the indicators used to characterize each type of impact should reflect not only the positive result (the result of organized interaction), but also the possible negative consequences of unorganized interaction.

During the organization of air defense, the implementation of interoperability, which is a purposeful activity of commanders and largely allows to achieve the specified efficiency of the created air defense system, becomes of great importance. However, at this time there is no unambiguous interpretation of the concept of “compatibility”, which is due to the complexity of its structure and the need to cover the entire content when solving various tasks. The most widespread is the definition of the interaction of troops as agreed on goals, tasks, place, time and methods of performing the tasks of the actions of troops (forces) to achieve the goal of the battle (operation) (Lytvyn M., Allerov Yu., Kyrychenko I., 2003).

In particular, the interaction of troops is considered as one of the most important principles and conditions for the preparation and conduct of operations, the success of which can be achieved only by the united, clearly coordinated efforts of all forces and means based on a single plan and plan of combat operations. However, a significant drawback of the existing definitions of the concept of “compatibility” is that they do not take into account the mutual influence of the actions of troops (forces), which under certain conditions can become important for achieving the overall goal of the operation (battle, hostilities). It is known that the mutual influence of subjects on each other can be both positive and negative. In this regard, for two subjects it is possible to define two opposite types of mutual influence-opposition and interaction.

The main goal of the interaction of troops (forces) is rational use of the combat capabilities of the interacting troops (forces) and ensuring the safety of the troops (forces) involved in solving tasks. The content of the types of interaction is directly determined by the characteristics of the subjects of interaction. In particular, the tactical fire units of air defense may include firearms that are in service with armed formations and other law enforcement agencies, anti-drone nets, anti-cumulative grids and other commercial means. The tactical and special units of radio electronic warfare may include means of radio electronic warfare, means of radio electronic suppression, anti-drone guns and other means based on physical principles of operation. However, despite a sufficiently large number of scientific works, the issue of their interaction in solving the tasks of air defense forces, especially in its applied part, is not sufficiently disclosed. Let's consider the general issues of using anti-aircraft defenses on aircraft that can carry out terrorist actions from the air, in particular unmanned aerial vehicles.

The tasks of the air defense forces are carried out by means of air defense, which is carried out according to a certain plan, agreed on the purpose, task, place and time and aimed at neutralizing unmanned aerial vehicles and counteracting their influence on the objects of defense, or forcing it to refuse to perform specified tasks. Important components of the object's air defense forces are direct

physical impact on aircraft and maneuver (change of location) of air defense forces and electronic warfare means.

Air defense of the object begins from the moment of detection or receipt of information about the appearance of unmanned aerial vehicles and ends with its neutralization or cessation of influence on it.

The main characteristics of the object's anti-aircraft defense are the duration and number of unmanned aerial vehicles that were neutralized. Air defense means, depending on the situation and the tasks performed by them, can be placed directly on the terrain, vehicles, buildings, etc.

The places of their placement should correspond to the task, the level of the protected object, the expected impact of unmanned aerial vehicles and ensure:

a) focusing the main efforts on the preservation of strategically important objects;

b) the most complete use of opportunities for neutralization of unmanned aerial vehicles;

c) continuity and ease of management;

d) continuous interaction with other means involved in the protection of strategically important objects;

e) their rapid movement.

As a rule, no less than 3 places are assigned for the performance of tasks by means of air defense (Lezik O., Piskunov S., Volkov A., Sedyukh V., 2017).

Common places of placement must meet the requirements, in particular:

a) provide a circular view with closing angles in the responsible sector no more than 0.5°;

b) have good visibility on the terrain at a distance of at least 1,000 m from them;

c) have convenient driveways that allow you to quickly take your places on the terrain, etc.

If we are talking about the use of means that can neutralize unmanned aerial vehicles, then it is appropriate to talk about the system of measures that must be carried out to protect strategically important objects from terrorist actions from the air, namely:

a) during the implementation of measures to protect strategically important objects, all flights of aircraft over the object must be prohibited;

b) aircraft or their debris, within the zone of neutralization by means of air defense, must not fall on the territory of strategically important objects;

c) for the placement of air defense means, it is necessary to have previously equipped places along the entire zone (perimeter) that is intended for protection, or – in the most threatening directions;

d) before making a decision on organizing the protection of strategically important objects from terrorist actions or air attack, it is necessary to assess the size of strategically important objects and the area around it.

In particular, the assessment of strategically important objects should involve the study of its character and geometric dimensions, the importance of its elements, vulnerability, hiddenness.

As a result of the assessment of strategically important objects, the most likely methods of actions of unmanned aerial vehicles, the directions of concentration of efforts, the order and methods of attacking strategically important objects and its elements are determined.

At the same time, the assessment of the terrain determines its general nature and impact on the possible actions of unmanned aerial vehicles, the conditions for their detection, especially at low and extremely low altitudes, the presence and condition of nearby roads, etc. In each specific case, these factors must be taken into account when building a system for protecting strategically important objects from aerial attacks.

The choice of locations on the terrain of air defense means is determined by their considerable number of conditions and limitations. In particular, the number of places for their placement is determined by:

$$n = \left\lfloor \frac{L}{d} \right\rfloor, \quad (1)$$

where L – the length of the zone (perimeter) that is intended for protection;
d – the distance between the locations of anti-aircraft defenses.

To protect strategically important objects from terrorist attacks from the air, air defense forces can be rotated. To perform tasks, it is advisable to schedule the rotation of these means. The development of a rotation schedule will solve the problems of regulating the operation of various air defense means, will help preserve the resource and will allow constant possession of information about the situation around strategically important objects.

It is considered necessary to develop a methodology for choosing the location of air defense means during the protection of strategically important objects from unmanned aerial vehicles (Fig. 1), which consists of procedures and tasks that are performed sequentially, as a result of which proposals for choosing locations are formed means of anti-aircraft defense (Shincaruk O. N., Kyrylenko V. A., Babii Y. A., Polishchuk V. V., Babaryka A. O., Chukanov A. I., 2020; Babii Yu., Chesanovskyi I., Levchunets D., 2016).

The initial data for calculating the distance between air defense means (block 1) are:

a) types of unmanned aerial vehicles that can be used for strategically important objects;

b) geographic coordinates of strategically important objects and their spatial dimensions;

c) composition of anti-aircraft defense equipment allocated for the protection of strategically important objects;

d) the maximum effectiveness of the use of air defense means.

Initial data are selected from prepared databases, which are formed in advance or in the process of preparing the solution (block 1).

In block 2, the area of the fall of the debris of unmanned aerial vehicles after its neutralization is calculated. To perform this task, an existing model is used (Sukharevsky O. I., 2014). The calculation of the area of the fall of the wreckage of unmanned aerial vehicles is carried out in order to determine the necessary removal distance of the locations of air defense means from the perimeter of strategically important objects.

Analysis of the results of modeling the neutralization of unmanned aerial vehicles at all possible flight speeds and altitudes showed that the removal distance of placements should be within 1 to 2 km from strategically important objects.

Among the boundaries determining the operation of air defense means, the most important place is occupied by the range of unmanned aerial vehicles from strategically important objects, during which the task of its disposal should be set.

This range depends on which air defense device is tasked, and on the flight height of the unmanned aerial vehicle of the neutralization zone outside the strategically important object. The horizontal distance from the strategically important object to the boundaries of setting tasks for neutralizing unmanned aerial vehicles is determined by the expressions:

$$d_{UAV} = d_{t.out.AD} + V_{UAV}(t_{DTr.UAV} + t_{neut.UAV}), \quad (2)$$

where d_{UAV} – the horizontal distance from the strategically important object to the boundary of setting tasks;

$d_{t.out.AD}$ – distance from the location of air defense equipment from a strategically important object;

V_{UAV} – the speed of the unmanned aerial vehicle;

$t_{DTr.UAV}$ – the time of direct preparation of anti-aircraft defense means to neutralize an unmanned aerial vehicle;

$t_{neut.UAV}$ – time for neutralization of the unmanned aerial vehicle at the border of the neutralization zone.

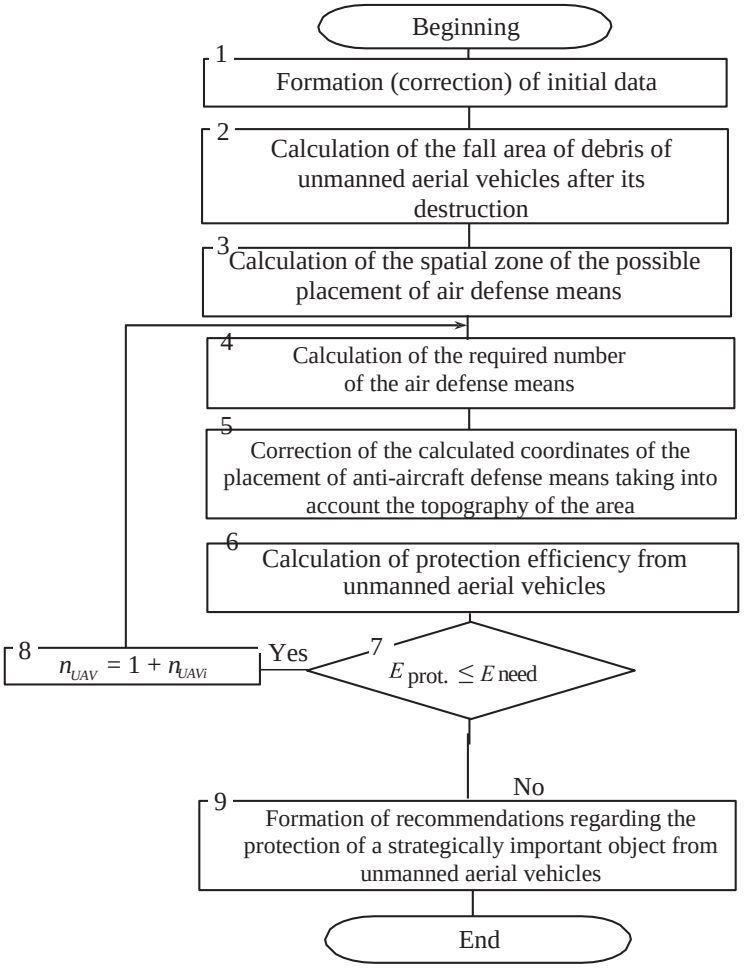


Figure 1. A structural and logical scheme of a methodical approach to the selection of the location of air defense means during the protection of a strategically important object from unmanned aerial vehicles

In block 3, the calculation of the spatial zone of the possible placement of air defense means is carried out. The wreckage of an unmanned aerial vehicle should not fall on a strategically important object, so the neutralization of an unmanned aerial vehicle should be carried out on average (depending on the type of unmanned aerial vehicle) at a distance of 2 km or more from a strategically important object.

In particular, the locations of anti-aircraft defense equipment must be moved beyond the territory of a strategically important object at a distance of 1 km or more. And the greater the distance of the placement of air defense means, the more the probability of preserving a strategically important object increases. On the other hand, the greater the distance of the location of air defense means from a strategically important object, the more means must be involved for its reliable protection. In practice, the number of anti-aircraft defenses that can perform tasks is limited (Horodnov V. P., 1987).

Therefore, it is necessary to place air defense facilities as close as possible to the strategically important object, guided by their characteristics and the number of air defense facilities allocated to protect the strategically important object. After obtaining the value of the necessary removal distance of the location of air defense means outside the strategically important object, the necessary number of them is calculated (block 4).

The next step is the implementation of the algorithm for correcting the calculated coordinates of the placement of anti-aircraft defenses based on the analysis of the digital terrain map (block 5).

If the terrain or the nature of the terrain creates obstacles for the placement of air defense means, then correction of their placement is carried out. The program of displaying anti-aircraft missile troops in accordance with the proposed locations on the electronic map is being implemented. For a more detailed and high-quality assessment of the placement of air defense means in block 6, an algorithm was implemented for assessing the degree of protection of a strategically important object from an unmanned aerial vehicle should be carried out on average (depending on the type of unmanned aerial vehicle.

The assessment of the degree of protection of a strategically important object is carried out in in the form of a calculation table showing the coefficients of the neutralization zones and the load coefficients of air defense means. Using this information (blocks 7–9) a final decision is made regarding the placement of air defense means.

In order to assess the impact of the compatibility of air defense and electronic warfare on the effectiveness of their actions, it is necessary to consider the meaning of the concept of “compatibility”, as well as to logically connect the concepts and terms related to the concept of “compatibility of air defense and electronic warfare” (Lezik V. O., 2015).

At the same time, the terminological system and its elements (terms) must have certain properties that are presented to it:

1. Systemic conditioning of terms, their interdependence, subordination according to a certain feature.
2. Unambiguity within military science and general science disciplines.
3. Context-independent term accuracy.
4. Correlation of the term with only one concept.
5. Shortness of the term and lexicographic approach to the creation of terms.
6. Terminology's ability to expand, clarify and change, the possibility of transition of the term to denote a generic concept.

Based on the listed requirements for terminology and the analysis of the existing main special terms, the “zone of joint actions of anti-aircraft defense and radioelectronic warfare” means the territory where they are located and the airspace where neutralization and radio electronic suppression of an unmanned aerial vehicle is carried out (Fig. 2).

Thus, the application of all possibilities related to the use of means in the zone of joint actions should be considered as a set of four constituent parts:

1. “Information interoperability of anti-aircraft defense and radioelectronic warfare” means the ability to carry out coordinated simultaneous actions of these means in the zone of joint duty.

2. “Compatibility regarding conditional neutralization of an unmanned aerial vehicle by means of air defense and electronic warfare” – as the ability to take coordinated actions on an unmanned

aerial vehicle in the zone of compatible actions of air defense and electronic warfare (Lezik V. O., 2015).

3. "Electromagnetic compatibility of the effective use of anti-aircraft defense and radio electronic warfare" means the ability of radioelectronic means to simultaneously function in real operating conditions with the required quality under the influence of unintentional radio interference and not to create unacceptable radio interference to other means.

4. "Compatibility for effectively changing the locations of anti-aircraft defense and radioelectronic warfare" – as the ability to simultaneously fold, move taking into account the passability of the means and place them in a new place.

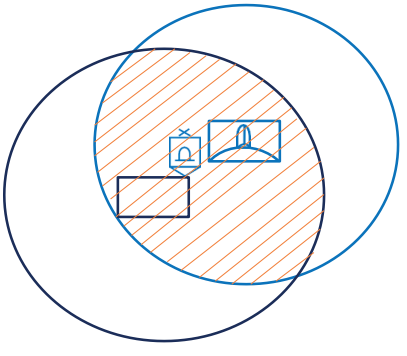


Figure 2. Zone of joint actions of air defense means and electronic warfare (indicated by a dotted line)

Results

The assessment of the effectiveness of the combined actions of air defense and radio electronic warfare as part of special means is intended to solve the scientific task, achieve the goal of the research and includes:

a) selection and substantiation of indicators of the effectiveness of the use of anti-aircraft defense and radio-electronic warfare;

b) a study of the dependence of the effectiveness of the combined actions of air defense and electronic warfare on formalized indicators of alternative options for the use of air defense.

The indicator of the quality of the result (effectiveness) of actions during the protection of a strategically important object is, in general, an m-dimensional vector that includes three groups of components: the achieved (expected) effect (g), time consumption (t) and resource consumption (c) and is described by the expression:

$$Y^m = [g^m, c^m, t^m], \tag{3}$$

Y^m – effectiveness of actions during the protection of a strategically important object;

m – factors and conditions that determine the effectiveness of actions during the protection of a strategically important object;

g^m – achieved (or expected) beneficial effect;

c^m – expenditure of resources;

t^m – waste of time.

We will consider ways to increase the effectiveness of protecting a strategically important object from an unmanned aerial vehicle due to the combined use of air defense and electronic warfare.

In general, the scientific task of researching the combined actions of anti-aircraft defense and radioelectronic warfare in the protection zone of a strategically important object is multivariate.

The number of options (n_{var}) depends on the number and types of these means and can be determined by the ratio:

$$n_{var} = (N_{ADMi} +1)(N_{ADMj} +1)(N_{nois.rad.interf.st.} +1)(N_{resp.-imp.radiointerf.st.} +1) \quad (4)$$

where N_{ADMi} – number of air defense means of the *i-th* type;
N_{ADMj} – number of air defense means of the *j-th* type;
$N_{nois.rad.interf.st.}$ – the number of noisy radiointerference stations;
$N_{resp.-imp.radiointerf.st.}$ – the number of response-impulse radiointerference stations.

The composition of anti-aircraft defense and radio-electronic warfare and the order of their deployment are mutually determined and closely interdependent. This relationship is caused, on the one hand, by those methodological approaches that exist to justify the optimal quantitative composition due to the necessary order of their placement, on the other hand, by the fact that any composition of means must be placed relative to the object of protection in a rational way (Lezik O. V., Ryazantsev S. S., Knysh D. V., 2015).

The effectiveness of joint actions depends both on the composition of the means and on the order of their placement, the parameters of which are the range of places of placement of air defense means ($d_{depl.ADM}$) and electronic warfare ($d_{depl..el.warfare}$) from the borders of the strategically important object and mutual distances between means of protection ($D_{ADM\text{-}EWF}$, D_{ADMi}, D_{EWFi}).

Thus, a rather complex nature of the dependence of the effectiveness of air defense and radio-electronic warfare measures is obtained, which can be presented in the form of a functional dependence:

$$\begin{aligned} E &= f\{N_{ADM}\} \mid N_{ADM}, d_{depl.ADM}, d_{depl.el.warfare}, D_{ADMi}, D_{EWFi}, D_{ADM\text{-}EWF} \mid = \text{const.} \\ E &= f\{N_{el.warfare}\} \mid N_{ADM}, d_{depl..el.warfare}, d_{depl.ADM}, D_{EWFi}, D_{ADMi}, D_{ADM\text{-}EWF} \mid = \text{const.} \end{aligned} \quad (4)$$

Locations of air defense and electronic warfare are subject to the requirements of the task, i.e. locations of air defense must be located at such a distance from the borders of a strategically important object that ensures the removal of the neutralization zone of the means abroad from which an attack by an unmanned aerial vehicle is possible. To assess the impact of the maximum effectiveness of the use of anti-aircraft defense and radioelectronic warfare on the effectiveness of their joint actions, let's return to the essence of the term “compatibility”.

The “zone of joint actions of the effective use of anti-aircraft defense and radio electronic warfare” means the territory where they are located and where neutralization and radio electronic suppression of unmanned aerial vehicles is carried out. The most adequate target assignment of air defense means during the protection of a strategically important object from an unmanned aerial vehicle is the indicator of the number of neutralized unmanned aerial vehicles from the total number of unmanned aerial vehicles that were involved in the attack.

In particular, with regard to the choice of indicators of the ratio of defense forces, the most complete confrontation of air defense means and unmanned aerial vehicles can reflect the ratio:

$$\partial_i = \frac{\text{NmaxUAV_ADMi} \times \lfloor 1-(1-\text{Pneutral.UAV_ADMi})^n \times \text{Ke.i.p.} \times N_{ADMi} \rfloor}{\text{Db.p.z.neutral ADMi} \times N_{UAV}} = \frac{\text{Kk.p.ADMi}}{N_{UAV}}, \quad (5)$$

where $N_{maxUAV_ADM_i}$ – the maximum number of unmanned aerial vehicles simultaneously neutralized by means of air defense of the *i-th* type;

$P_{neutral.UAV_ADM_i}$ – the probability of neutralizing unmanned aerial vehicles by means of air defense of the *i-th* type;

n – the number of missiles (resources) used to neutralize unmanned aerial vehicles;

$K_{e.i.p.}$ – efficiency ratio of information provision;

$D_{b.p.z.\ neutral\ ADM_i}$ – the limit parameter of the neutralization zone by means of anti-aircraft defense of the *i-th* type;

N_{UAV} – the number of unmanned aerial vehicles during an attack on a strategically important object;

$K_{k.p.\ ADM_i}$ – coefficient of the combat potential of air defense means of the *i-th* type.

Where $K_{e.i.p.}$ the coefficient of effectiveness of information provision is determined by the expression:

$$Ke.i.p. = \frac{Ksim.false.pl.tr. \times K_{Mask.}(1+N_{\Sigma n.prot.})N\Sigma n.prot.}{tt.st.ADM\ (1-ti.c.)}, \quad (6)$$

where $K_{sim.false.pl.tr.}$ – the coefficient of similarity of false placements to true ones;

$K_{Mask.}$ – the coefficient of the masking of a strategically important object;

$N_{\Sigma n.prot.}$ – the total number of forces and means of protection (air defense and electronic warfare) of a strategically important object against unmanned aerial vehicles that carry out disinformation measures;

$N_{\Sigma i.m.}$ – the total number of information means as part of air defense and electronic warfare protection of a strategically important object from unmanned aerial vehicles, information flows participating in the collection process;

$t_{t.st.\ ADM}$ – time of stay of anti-aircraft defense means at the location;

$t_{i.c.}$ – time of information collection.

The destruction of unmanned aerial vehicles during the protection of a strategically important object from the air is considered as a probabilistic process characterized, first of all, by the ratio of the forces of the parties.

To evaluate the effective use of radioelectronic warfare means for the protection of a strategically important object, the mathematical expectation of the number of unmanned aerial vehicles that have been affected by radioelectronic warfare (suppression) by means of radio electronic warfare is used ($M_{UAV\ c.out.ADM}$):

$$M_{UAV_c.out.ADM} = N_{UAV_c.out.} \times \Delta Psav.SIO \quad , \quad (7)$$

where $N_{UAV_c.out.}$ – the number of unmanned aerial vehicles on which radioelectronic influence (suppression) was carried out;

$\Delta P_{sav.\ SIO}$ – an increase in the probability of saving a strategically important object, which is equal to the probability of conditional neutralization of the unmanned aerial vehicle(s). It is determined by the dependence of the number of conditionally neutralized unmanned aerial vehicles and is calculated according to the formula:

$$\Delta P_{sav.}SIO = P^{P}_{sav.ob} - P^{V}_{sav.ob}, \quad (8)$$

where $P_{sav.ob}^{P}$ – the probability of preserving a strategically important object in the conditions of countermeasures against means of electronic warfare;

$P_{sav.ob}^{V}$– the probability of preserving a strategically important object in the absence of countermeasures against radioelectronic warfare.

For the case of protecting a strategically important object only by means of electronic warfare, expression (8) can be transformed into the form:

$$P_{sav.SIO} = 1 - e^{-N_{UAV_SIO} P_{sav.SIO}/N_{UAV}} \quad (9)$$

where $P_{sav.SIO}$ – the probability of preserving a strategically important object by means of radioelectronic warfare;

N_{UAV_SIO} – the number of unmanned aerial vehicles of a strategically important facility;

N_{UAV} – the number of unmanned aerial vehicles.

The analysis of the ratios shows that when assessing the effectiveness of joint actions, only the capabilities of anti-aircraft defense or the capabilities of radioelectronic warfare are taken into account with a fixed number of unmanned aerial vehicles participating in an attack on a strategically important object (Lezik O. V., Ryazantsev S. S., Knysh D. V., 2015).

Therefore, as a result of this property, it is proposed to transform the dependence into the form, which allows determining the efficiency indicator of compatible actions into the form:

$$P_i = 1 - e^{-\left(\frac{M_{destr.UAV_ADM}}{N_{л.а.}} + K_{comp.}\frac{M_{destr.UAV_SIA}}{N_{л.а.}} + K_{op.real.}\frac{M_{destr.UAV_l.alt.}}{N_{л.а.}}\right)}, \quad (10)$$

where $M_{destr.UAV_ADM}$ – mathematical expectation of the number of destroyed unmanned aerial vehicles by means of air defense;

$K_{comp.}$ – compatibility factor of anti-aircraft defense and radioelectronic warfare;

$M_{destr.UAV_SIA}$ – mathematical expectation of the number of destroyed unmanned aerial vehicles by means of electronic warfare;

$K_{op.real.}$ – coefficient of opportunity realization;

$M_{destr.UAV_l.alt.}$ – mathematical expectation of the number of destroyed unmanned aerial vehicles at low altitudes.

Figure 3. Mathematical model of protection effectiveness assessment strategically important object from the number of destroyed unmanned aerial vehicles by air defense forces

Based on the results of the analysis, it can be concluded that to evaluate the effectiveness of the joint actions of the air defense and radio electronic warfare units, a generalized indicator was chosen in the form of a mathematical expectation of the number of means (unmanned aerial vehicles) of air attack that did not complete the combat mission, defined in the relative value (P_i) and calculated by formula (10). Based on the value of this indicator, it is possible to evaluate the expected results of combat operations of air defense units and electronic warfare, the level of losses by means of air attack (unmanned aerial vehicles) and the degree of their performance of combat missions.

To deploy the variant of the combat composition of the air defense unit in battle order, a methodical technique was used for the directed selection of possible variants of the combat composition of the air defense unit within the framework of the existing organizational and personnel structure, with the conditional deployment of the air defense unit in battle order at fixed distances between “pairs” (anti-aircraft missile battery-electronic warfare unit) of a relatively strategically

important object (Lezik O. V., Ryazantsev S. S., Knysh D. V., 2015).

To implement this technique, we will use the ratio:

$$D_{UAI-SIAmin} - = a \times \text{J}, \tag{11}$$

where $D_{UAV-SIAmin}$ – the minimum range of anti-aircraft defense and radioelectronic warfare from the center of a strategically important object, in which their given number is evenly spaced at intervals of J;

a – uniformity factor.

For means of air defense and electronic warfare relative to each other and to a strategically important object, we use the ratio:

$$D_{UAI-SIAmin} = D_{detec.} \leq 0{,}65 D_{rec.rang.ammun.min}, \tag{12}$$

where $D_{detec.}$ – detection range;

$D_{rec.rang.ammun.min}$ – the minimum recoil range of the ammunition, which is determined from the expression:

$$D_{rec.rang.ammun.min} = V_{UAV} T_{f.t.ammun.} - \Delta + V_{UAV} T_{destr.UAV}\ , \tag{13}$$

where V_{UAV} – the speed of the unmanned aerial vehicle, km/min;

$T_{f.t.ammun.}$ – fall time of ammunitions using an unmanned aerial vehicle, min (or fall time of an unmanned aerial vehicle of the "Shahed-136/139", min);

Δ – ammunition lag using an unmanned aerial vehicle, km;

$T_{destr.UAV}$ – the time of destruction of the unmanned aerial vehicle.

In order for a strategically important object to be protected by means of radioelectronic warfare, it is necessary to place means of radioelectronic protection at a distance $D_{El.v.}$, which should be less $D_{ADM-El.v.min}$ or at best was equal to zero. At the same time, the reduction of the removal of places of placement of means of radioelectronic warfare ($D_{El.v.}$) is limited to the possibility of destroying a strategically important object when using a weapon that is self-guided by radioelectronic warfare radiation. A condition that determines the minimum and at the same time optimal value $D_{El.v.}$ looks like this:

$$D_{El.v.} \geq D_{destr.ammun.} + d_{SIO} + 3\sigma_{r.m.}\ , \tag{14}$$

where $D_{destr.ammun.}$ – radius of damage by munitions of a strategically important object;

d_{SIO} – the radius of a strategically important object;

$\sigma_{r.m.}$ – root mean square error of homing weapons.

The task of calculating the distance between the locations of air defense means during the protection of a strategically important object from unmanned aerial vehicles is determined by choosing the locations of air defense in two stages:

1. Proposals are being developed for the placement of air defense equipment in accordance with the requirements of the governing documents and the practice of organizing the protection of a strategically important object without taking into account the topography of the area (Lezik O. V., Ryazantsev S. S., Knysh D. V., 2015);

2. Correction of the coordinates of the placement of air defense means is carried out, taking into account the relief and nature of the terrain, the location of local objects that affect the effectiveness of the use of air defense forces to neutralize the unmanned aerial vehicle, using the capabilities of digital maps of the area.

Discussions

The conducted analysis showed that it is necessary to have pre-equipped locations of anti-aircraft defense and radioelectronic warfare along the entire zone (perimeter) that is intended for preservation, or in the most important directions. In each specific case, these factors must be taken into account when building a system to protect a strategically important object from an unmanned aerial vehicle. The developed proposals were elaborated in a comprehensive model for evaluating the effectiveness of air defense measures (Yermoshin M. O., 2004; Volkov A. F., Yanenko O. A., Kravchenko S. A., 2019).

Conclusion

Using the proposed method of choosing the location of air defense and electronic warfare during the protection of a strategically important object from the terrorist actions of an unmanned aerial vehicle, it is possible to develop such proposals, the use of which will ensure a high degree of protection of a strategically important object.

To evaluate the effectiveness of the combined actions of air defense and radioelectronic warfare, a generalized indicator was chosen in the form of a mathematical expectation of the number of unmanned aerial vehicles that did not complete a combat mission, defined as a relative value (W*i*), by the value of which it is possible to evaluate the results of the actions of air defense and radio electronic warfare, the level of losses of unmanned aerial vehicles and the extent of their tasks.

Recommendations

The materials of the article are of practical value for management bodies that, when planning the use of troops (forces), perform calculations to determine the required number of means of protection against unmanned aerial vehicles.

Further research in this direction will be aimed at developing a holistic methodology for evaluating the effectiveness of air defense forces, in particular, performing simulations that will allow to obtain estimates of the probability of preserving a strategically important object in the event of terrorist actions from the air by typical unmanned aerial vehicles at different heights (“Shahed-136/139”, “Orlan-10”, FPV, etc.).

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Armed Forces of Ukraine's mission and vision

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Abstract. The article's relevance is determined by the need to define how the Armed Forces of Ukraine, as part of the Defence Forces of Ukraine, will operate in the future security environment to deter a potential enemy, namely the russian federation.

Based on the future security environment analysis at the global and regional levels, it is identified that the main players in the world will be the United States of America and China, which will continue to form a world's bipolar order system. At the regional level, in particular on the European continent, the EU's countries main efforts will be focused on developing their own armed forces' capabilities and finding mechanisms to counteract the russian federation's "hybrid actions". At the meantime, military actions in future military conflicts will be carried out in a multi-domain operational environment with

the use of various high-precision "smart" weapons systems of wide range applications, robotic and unmanned assets for conducting armed struggle on air, above-water (underwater), space and land combat platforms. Based on the security environment analysis and the nature of future military operations, there have been identified the main directions of science and technology development for the production of the latest systems, complexes and armaments samples, military and special equipment, as well as requirements for them. The article's materials are of practical importance for specialists responsible for the defence planning documents development, namely, the Joint Operational Concept, the Strategy for the Development of the Armed Forces of Ukraine and the branches and separate services of the armed forces.

Keywords: vision, mission, multi-domain operation.

Introduction

Ukraine may face a renewed threat of military force from the russian federation in the future. And then the question arises as to how, taking into account the changes in the future security environment, the character of warfare in future military conflicts and limited resources, the Armed Forces of Ukraine (AFU) should operate as part of the state defence forces to deter a potential aggressor.

The main principles for achieving the goal of preventing a military conflict and deterring the enemy from launching a renewed armed aggression against Ukraine are set out in the guiding documents on defence planning, namely the Strategy for the Development of the Armed Forces of Ukraine until 2035, the Joint Operational Concept, and the Vision of the General Staff of the Armed Forces of Ukraine on the Development of the Armed Forces of Ukraine for the next 10 years (General Staff of the Armed Forces of Ukraine's Vision for the Development of the Armed Forces of Ukraine for the Next 10 Years, 2020). One of the main principles of these documents is the purpose (mission) and the general vision and guidelines for the development of the Armed Forces of Ukraine (vision) to achieve the goal in future military conflicts.

Many countries-partners pay sufficient attention to defining their armed forces' purpose and determining their development in the future. The analysis results of the views on the armed forces mission and vision of the world's leading countries are presented in Table 1.

Table 1. World's leading countries' mission and vision

Document	Mission	Vision
Army Doctrine Publication 1 Headquarters Department of the Army (Army Doctrine Publication 1, 2019)	The United States Army's mission is to fight and win. .	. . . the key to this success is the American soldier's skill and courage, his leaders' quality, his equipment's superiority, and the army's ability to adapt and dominate in a challenging operational environment. . .
Defence in a competitive age, March 2021 (Defence in a competitive age, 2021)	The UK's defence policy is based on the armed forces ensuring a credible nuclear and conventional deterrent	The Integrated Operational Concept's implementation will allow the Ministry of Defence to continue fulfilling many of the tasks we have traditionally performed. We will develop a new doctrine, new working methods, new capabilities and new partners to deter and restrain our enemies in the grey zone between peace and conflict

Continuation of the table 1. World's leading countries' mission and vision

Document	Mission	Vision
Israel's National Security Doctrine (How Israel ensures the country's defence and security with the help of special forces, 2021)	The Israel Defence Forces' mission is to "defend the existence, territorial integrity and sovereignty of the State of Israel"	Israel's top military and political leadership assumes that the state cannot afford to have a large army in peacetime, nor can it participate in full-scale combat operations for a long time. Considering the above, the Israel Defence Forces must always have a qualitative advantage over a possible enemy by: adopting the most modern military equipment; implementing a more advanced command and control system; maintaining an effective mobilisation mechanism and a high level of personnel training (including the reserve)
Turkish Armed Forces (TSK) 2033 Vision (Türkiye's geopolitical and security plans and Ukraine's place in them, 2024)	The Turkish Armed Forces are designed to defend a state's freedom, independence and territorial integrity	To create a highly mobile army equipped with the most modern weapons and equipment and intended primarily for participation in regional conflicts

At the same time, the changing security environment, science and technology development, and the emergence of new armed conflict forms and methods require constant adjustment and improvement of the main defence planning documents.

Methodological Framework

Based on the security environment analysis, new trends in armed warfare and prospective directions of military science and technology development, and taking into account the russian-Ukrainian war experience, to shape the Armed Forces of Ukraine mission and vision for the Armed Forces of Ukraine Development Strategy until 2035.

Results and Discussions

The future security environment in the world and on the European continent will be challenging, unpredictable and unstable. russia's war against Ukraine has shown the inability of international security organisations and blocs (alliances) to ensure peace and security in the region. At the strategic level, the formation the bipolar world order system will continue. The main players in this process will be the United States and China, which will try to expand their influence in the world, form alliances and seek for allies (satellites). The main competition between these centres of influence will take place in the economic sphere, characterised by increased defence spending and increased military potential, especially in high-tech weapons production.

The North Atlantic Alliance will be the only effective system of collective defence and will continue to increase defence spending and finance programmes for the development and re-equipment of its armed forces. The greatest threat to NATO will be the russian federation. At the same time, China will be considered by the Alliance as a challenge to the interests, security and values of the organisation. NATO's priority will be to strengthen the defence capabilities of the Alliance's eastern flank. The EU, together with NATO, will focus on developing defence capabilities to neutralise threats in the region, including with the Ukraine's participation. The main threat to NATO

and the EU will remain the russian federation, which will continue to be an obstacle to Ukraine's European choice realisation and its path to NATO. The russian federation will continue to use various forms and methods of influence on Ukraine, namely energy terror, information warfare, cyberattacks on critical infrastructure, religious confrontation and other unconventional aggression methods. The Swiss Federal Intelligence Service's report "Swiss Security 2023" and the German Federal Office for the Constitutional Protection (Western countries' intelligence on the current security environment, 2023) highlight the "hybrid influence" trends, including the spread of disinformation, forming public opinion and political discourse in their favour, influencing political decision-making, undermining public confidence in democratic institutions and mechanisms with the active use of social media, influence agents and pro-russian activists. There is a rather high risk that the russian federation will continue its military expansion against Ukraine and Eastern Europe in the future.

It is worth noting that all players on the European continent will increase their armed forces' capabilities primarily by deploying modern weapons, increasing the number of land- and sea-based high-precision weapons platforms (including nuclear powered ones). In future military conflicts, the opposing parties will try to minimise direct personnel contact on the battlefield, destroy or disable enemy forces and assets at long distances long before the direct combat engagement. This is expected to involve the widespread combined use of highly precision "smart" weapons systems for a wide range of applications, the use of robotic and unmanned warfare systems on air, overwater (underwater), space and land combat platforms, which will ensure the tasks' fulfilment in difficult operational conditions with minimal risk to personnel's lives: missile and air defence systems, strategic electronic warfare, hypersonic, high-precision, electromagnetic, laser, infrasound weapons. At the same time, as the military conflict grows in scale, the difficulty of achieving minimal direct combat engagements will increase significantly. According to the analysts' opinion (Ivashchenko, Hordiichuk, Andriianova, 2022), military operations will be conducted in a multi-domain operational environment. Partner states are now actively developing the multi-domain operations concept as an option to countermeasure an aggressor whose potential far exceeds that of its' aggression victim (Army Unified Network Plan 2021, 2021; Army Futures Command Concept for Manoeuvre in Multi-Domain Operations 2028, 2020; Multi-Domain Operations: Future of Conflicts, 2021). Warfare's new methods will be driven by the availability of new weapons, military and special equipment, long-range precision weapons, various intelligence assets and long-range reconnaissance capabilities.

The main directions of science and technology development for the manufacture of the latest systems, complexes and armaments samples, military and special equipment are as follows:

Artificial intelligence. Recent years have seen a surge in artificial intelligence systems' development. There have already been a revolutionary number of breakthroughs. In particular, the implementation of artificial intelligence in military systems, which is already underway and will continue to spread, will radically change the course of warfare.

Robotisation. Development analysis of the latest defence technologies shows that autonomy technology is actively evolving. Over the past ten years, unmanned systems have become common tools employed in conflicts, including the war with the russian federation. In the future, robots and "swarm" systems will perform tasks that are currently considered too risky, complex or even impossible for humans to perform. They are likely to change the way we conduct operations (warfare) in the future. That is why, in order to strengthen the defence capability, the President of Ukraine has made a decision to create a separate branch of forces, namely the Unmanned Systems Forces of the Armed Forces of Ukraine (Decree of the President (51/2024), 2024).

Quantum communications. Quantum communications will have a dramatic impact on improving the communication channels' security. This technology blocks any hacking attempts. It guarantees the information storage and communication channels invulnerability. This is especially important in the military, where the information security affects the successful mission execution or even the operation.

Innovative substances and materials. Scientific and technological progress makes it possible to create fundamentally new materials and substances: ultra-strong and ultra-light, with programmable properties. In particular, these are composite polymers and the most promising area - additive materials. They can be used to synthesise and build up objects of various shapes and purposes in layers.

Cyberweapons. Cyber warfare has already become a reality. In the future, the struggle in the information space will only intensify. The use of artificial intelligence and machine learning will create a new generation of cyber weapons that can adapt and evolve to overcome defences. It will paralyse the enemy's critical infrastructure, destabilise political systems, and disrupt economic stability.

Nanotechnology. The development and implementation of nanotechnology in the military sphere will allow the creation of materials for secrecy and object protection, adaptive camouflage, as well as self-healing materials that will automatically repair damaged surfaces and structures.

It is clear that the list of promising technologies is not limited to the mentioned ones, but from a military point of view, they are among the most important.

As for the requirements for armaments and military equipment samples, the following can be highlighted by:

creation of new high-precision weapons and their increased range;

Increasing the strike force's firepower and munitions' combat power;

use of aerospace systems to solve the problems of collecting and processing remote Earth sensing data, control, navigation and direct targeting;

Increasing the special equipment role, first of all, reconnaissance, electronic warfare, communications and automated command and control;

creation of robotic, autonomous and remotely controlled models and systems of armaments, military and special equipment;

development of neurocomputer technologies and neural networks, which are adaptive systems for data processing, intellectual analysis and forecasting;

development and application of armaments samples, military and special equipment based on non-traditional (including non-lethal) operating principles;

development of highly efficient medium and long-range vehicles for the purpose of operational troops (forces) mobility;

Increasing the armaments protection, military and special equipment, infrastructure facilities from damage by conventional weapons and mass electromagnetic destruction weapons;

improving the reliability, effectiveness of the use and simplification of the maintenance of armaments, military and special equipment, ensuring their seasonal and round-the-clock operation;

improving the ability to record, store, generate and analyse large amounts of data.

All these components, namely the security environment, new trends in armed conflict and promising areas of military science and technology development, require clarification of the Armed Forces of Ukraine's mission and vision in the future.

According to the Constitution of Ukraine, the Armed Forces of Ukraine are a military formation entrusted with the defence of Ukraine, protection of its sovereignty, territorial integrity and inviolability. Thus, this will be relevant in the future, and **the Armed Forces of Ukraine's Mission will be** to deter and repel armed aggression against Ukraine, protect the state's airspace and underwater space within the territorial sea of Ukraine. In cases determined by law, the Armed Forces of Ukraine will participate in activities aimed at counter-terrorism, peace and security support within the framework of regional and international security organisations' efforts.

The Armed Forces of Ukraine's Vision aims to formulate a general vision and intentions, define the guidelines for the capabilities development of the Armed Forces of Ukraine in a whole and of the branches and individual arms (forces), as well as their activities for the next 10-15 years.

The main directions of the Armed Forces of Ukraine's capabilities development will be as follows:

To ensure the reliable defence of Ukraine, protection its sovereignty, territorial integrity and inviolability, the main priority for development will be granted to the Special Operations Forces, the Unmanned Systems Forces, the Missile and Artillery Forces and Army Aviation of the Land Forces, the Anti-Aircraft Missile Forces of the Air Forces and the Coastal Missile and Artillery Forces of the Navy of the Armed Forces of Ukraine, the Medical Forces and the Logistics Forces.

In the long term perspective, increasing the combat capabilities of the Armed Forces of Ukraine as a whole, the development of these particular branches and individual arms (forces) is the most important.

The foundation for building the Armed Forces of Ukraine as part of the defence forces will be operational adaptability, interoperability and cross-domain synergy of their components, which will provide the capabilities necessary to fulfil the state defence tasks to form an operational environment and effectively respond to a wide range of tasks and changing threats and situations with the help of relevant flexible and operational forces and assets, freedom of action, the ability to act jointly, effectively and efficiently as part of the joint troops (forces) groupings and use their capabilities in different domains in such a way that each of them will increase efficiency and compensate for the vulnerabilities of others to establish an advantage over the enemy.

The Armed Forces of Ukraine's composition, structure and size, and the capabilities they have gained will ensure activities in several operational environment domains, the ability to effectively oppose the enemy, quickly create the necessary joint force groupings with sufficient control, manoeuvrability and appropriate firepower to destroy the enemy, who has an advantage, in the fluid conditions of the future multi-domain operational environment, in particular:

the land component would ensure the decisive universal, sustainable power of the defence forces for rapid and long-term combat operations to destroy the enemy's land forces and defend the state's land territory by fulfilling a wide range of tasks in interaction with other defence forces components in the air, sea, space and cyber domains, supporting strategic and operational mobility, fire, close air support and other capabilities with such main forces and assets as mechanised and tank units, missile forces and artillery, air defence, army aviation, communications, intelligence, electronic warfare, logistics and medical support, chemical, biological, radiological, nuclear defence, engineering, geoinformation and hydrometeorological support;

the air component would ensure gaining air superiority, isolating warfare zones (areas), defeating its reserves, destroying munitions stockpiles and other material and technical assets, and complicating logistics through the widespread use of precision-guided and self-guided weapons, reconnaissance and reconnaissance-strike systems, unmanned combat robotic weapons systems to cause continuous fire damage to the enemy at the depth of its location;

the maritime component would ensure that the state maintains control over the sea within the internationally recognised boundaries of internal waters, the territorial sea, as well as its exclusive (maritime) economic zone and continental shelf, and the prohibition of such control by the enemy through joint measures of air defence, anti-missile, anti-boat and anti-submarine defence, mine and anti-mine operations, electronic warfare, missile strikes, artillery fire, use of above- and underwater unmanned systems, sea (river) assaults, conducting specific actions on the sea surface, in underwater space and above the sea;

the cyber component would ensure the operational reliability and security of the forces and weapons command and control systems, institutions, organisations and objects of the defence forces and would contribute to gaining an advantage over the enemy in other operational environment domains.

The Armed Forces of Ukraine's components would include an optimised and functional-balanced number of military command and control bodies, formations, military divisions, units,

institutions and organisations, which, depending on the timeframe for readiness to fulfil their tasks, would have an appropriate combat readiness level.

The Land Forces of the Armed Forces of Ukraine will continue to develop in such a way they could conduct joint operations and use combat systems in a comprehensive manner.

The Land Forces' armaments and military equipment will be developing with regard to the experience gained in combat actions, requirements for units' high manoeuvrability, autonomy of their actions, and enemy long-range firepower with precision weapons systems, the main delivery vehicles of which will be missile forces, artillery and land robotic systems.

The Air Forces of the Armed Forces of Ukraine will be developing in order to ensure the most secure protection of Ukraine's airspace, covering particularly important objects on the territory of Ukraine, and, most importantly, covering forces groupings during the operations.

Alert systems for warning forces of an air attack should be connected with similar partner countries' systems, integrated with them into a single system, and based on early detection of the air enemy while it is still operating at military sites.

Priority in armaments and military equipment development of the Air Force will be given to joint production with partners, procurement of new and modernisation of existing samples, and improvement of the air defence system's firepower and unmanned aerial systems.

The Navy of the Armed Forces of Ukraine will be developing to ensure the defence of Ukraine from the sea, the most reliable underwater space protection, and support for land forces groupings.

Priority in the Navy's development will be given to surface forces, coastal missile and artillery forces, and maritime unmanned systems. A sufficient number of high-armed, manoeuvrable boats and ships will be provided through the ship and boat depot construction and the procurement of such models from our partners.

The Navy will be equipped with a sufficient number of modern missile systems and maritime unmanned systems to strike enemy ships at sea. The availability of modern air defence systems in the Navy will ensure the reliability of striking the enemy from the sea direction.

The Air Assault Forces of the Armed Forces of Ukraine will be developing for rapid deployment to cover (defence) individual directions (areas), conduct offensive (assault) operations and conduct combat operations in its rear.

They would be characterised by high mobility, the ability to quickly achieve certain areas and frontiers, independently fulfil tasks in difficult conditions, in any direction, and a high level of training, motivation and combat spirit.

The airborne assault troops will be deployed depending on the situation as part of a force grouping in a particular direction or as brigades within force groupings.

The Special Operations Forces of the Armed Forces of Ukraine will be developing to respond asymmetrically to existing and potential threats to the state's security by organising and supporting resistance movement actions, conducting military informational and psychological operations in a hostile environment against an enemy with a number superiority in order to reduce its capabilities, and fighting terrorism and piracy.

The unmanned systems forces will be developing in order to preserve human resources through the measures system implementation by means of widespread application of unmanned (crewless) systems and artificial intelligence:

in the land domain, unmanned systems used to strike the enemy, transportation, mining, logistics and other tasks on the battlefield. In case of a shift to the long-term positional warfare format, the direction of underground digging drones will be developing, which will be able to reach enemy positions under the surface invisibly for the subsequent mining and destruction purposes, as well as counter assets against them;

in the air domain, the comprehensive use of unmanned aerial vehicles equipped with high-precision weapons. Expanding the practice of manned and unmanned aerial vehicle systems integrated use, including "swarm" tactics with a large number of smaller drones;

in the maritime domain, in future military actions, large-scale use of unmanned maritime systems, particularly autonomous reconnaissance, strike, anti-aircraft, anti-mine and other special underwater and above-water (semi-submersible) vehicles;

in cyberspace, the main targets of cyber attacks will remain state information resources, information and communication systems of government authorities and military command bodies, force and weapons' command and control systems, robotic and unmanned platforms, as well as data processing centres and the communication infrastructure that ensures their operation. Including, but not limited to, cyber assets, there would be extensive use of electronic warfare assets to disrupt reconnaissance, signalling and communication systems' assets, and to disable unmanned systems and weapons control systems.

The Logistics Forces of the Armed Forces of Ukraine will be developing to fulfil the logistics support tasks for the daily activities of the Armed Forces of Ukraine and defence forces' strategic activities.

The Logistics Forces of the Armed Forces of Ukraine, as a rationally organised and extensive system, will gain the ability to:

guaranteed fulfilment of the logistics support tasks for the state's defence forces;

meeting the need for armaments, military and special equipment, material and technical assets, works and services, defence forces military transportation ((transportation);

maintenance of armaments and military equipment strategic stocks and material and technical assets;

ensuring the engineering and infrastructure needs of the troops (forces);

compatibility with NATO member states' military logistics units (institutions).

The Medical, Support, Communications and Cybersecurity Forces will further gain the capability to support troops (forces) activities during multi-branch, multi-agency joint operations.

The realisation of these principles will allow to create the Armed Forces of Ukraine, which will be able to:

ensure successful aggressor deterrence, prevent military crises, conduct state armed defence, protect its sovereignty, territorial integrity and inviolability;

achieve NATO membership criteria and to participate in multinational operations.

Conclusion

This article presents the author's view on the Armed Forces of Ukraine's mission and vision. It is based on the analysis of: the future security environment, both in the world and on the European continent; the future military operations' nature; the main directions of science and technology development for the manufacture of the latest systems, complexes and weapons samples, military and special equipment, as well as requirements to them.

The Unmanned Systems Forces of the Armed Forces of Ukraine's mission and vision are presented separately from the existing branches and individual arms (forces).

Recommendations

The research results can be used in the Development Strategy of the Armed Forces of Ukraine until 2035 elaboration and serve as a basis for branches and individual arms (forces) missions and visions development. The article may be useful for specialists in defence planning, researchers and analysts involved in the development and justification of state decisions on the Armed Forces of Ukraine's development.

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The role of leverage in supporting the ability of private military companies to withstand financial risks

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Abstract. Financial leverage plays a crucial role in helping private military companies (PMCs) manage economic risks and maintain financial independence. In the context of enhancing the economic resilience of PMCs, the use of leverage improves the accumulation of own resources and capabilities, allowing them to better withstand the emergence of financial risks.

The authors consider that PMCs often operate in high-risk environments where they face various financial challenges, such as fluctuations in demand for their services, geopolitical uncertainty and regulatory changes, etc. By raising free cash, they can gain additional opportunities to expand their operations, invest in advanced technologies and diversify their service offerings. This increased financial flexibility can help them weather turbulent times and maintain their competitive edge in the industry. However, it is important for these companies to carefully manage their leverage levels to avoid excessive debt burdens that could potentially lead to financial difficulties.

The article presents the ontology of financial risks for private military companies: instability of

the geopolitical situation; legal and regulatory changes; liquidity support and cash flow management in a high-risk environment; variability of demand for security services; credit risk; operational risk. Some strategies to mitigate financial risks in PMCs (leverage effects) can be used to mitigate them, such as: diversification of services and geographic presence; implementation of strict credit control measures and due diligence; investment in robust operational infrastructure and risk management systems.

The authors provide an example of calculation of the financial leverage effect indicator for a potential private military company, which clearly reflects a possible general approach to assessing the financial capabilities of such companies (using the graphical method, the safe amount of borrowed funds is determined).

The results of using the financial leverage effect indicator for a potential private military company may include not only the current improvement of its operational performance, but also an increase in the realism of long-term planning.

Keywords: leverage, financial leverage, private military companies, financial risk, sustainability.

Introduction

The rational use of financial leverage can have a significant impact on the financial stability of PMCs, potentially supporting or undermining their operations. Private capital plays a crucial role in financing the development of PMCs in different countries, highlighting the positive aspect of leverage as a source of financing for their financial needs (Kohan, 2021). However, the use of leverage also creates financial risks that need to be carefully managed to maintain stability. Operating and production leverage indicators are important for the analysis of financial PMCs, which allows for a comprehensive assessment of potential risks and vulnerabilities (Prystash, 2022). When financial risks are not properly controlled, the risk profile is transformed from a locally managed one to a more widespread and influential level, which increases the vulnerability of these companies to financial shocks (Ilyashenko, 2017). In situations of armed conflict, PMCs are particularly concerned about maintaining their financial stability capabilities, which requires the assessment and implementation of best practices to effectively address these issues (Pushkarenko, 2023). Proper leverage management is crucial for these companies to ensure their financial resilience and sustainability in the face of diverse operational demands and risks.

Methodological Framework

The role of leverage in enhancing the financial stability of PMCs is closely linked to the broader financial ecosystem, how these firms manage and mitigate risk. Financial leverage, or the use of borrowed capital, can increase both potential returns and risks, making it a critical tool in the strategic arsenal of PMCs. The emergence and spread of financial shocks can seriously affect the financial stability of these companies, requiring a robust risk management system to navigate the controlled and uncontrolled financial environment (Bielova, 2015). This is especially true for PMCs operating in unstable regions where the geopolitical landscape can change rapidly, thus transforming their risk profile from localised manageable risks to widespread systemic threats. Effective risk management strategies, as described in the financial risk classification for insurance companies, can provide a valuable template for PMCs to develop their own methodologies. These strategies can help identify, assess, and mitigate various financial risks, thereby enhancing overall stability (Private Military Companies, 2007). In addition, the global and national contexts of financial stability, as outlined in the textbooks, highlight the importance of understanding the multifaceted nature of financial risks and the interconnectedness of global financial systems. By integrating these perspectives, PMCs can better anticipate and respond to financial disruptions, thereby ensuring the safety of their operations and long-term sustainability (Kaletnik, Kostiuk, Voznyi, 2021). Overall, the effective use of financial

instruments requires a keen understanding of both the macroeconomic environment and the specific operating environment in which PMCs operate. This dual focus can help to develop tailored financial strategies that not only enhance stability, but also promote growth and sustainability in an increasingly complex and interconnected world.

Therefore, there is a need to analyse the potential role of leverage in supporting the capability of PMCs to withstand the emergence of financial risks.

Results

Understanding the nature of financial risks for PMCs (Table 1) is the basis for good decision-making when it comes to their operations. They operate in complex, high-risk environments, often providing security and military services to clients in conflict zones or unstable regions. As such, they face a variety of financial risks that must be carefully managed to ensure their sustainability. One of the main financial risks faced by PMCs is the unpredictability of their revenue streams. Contracts with clients can be suddenly cancelled or modified, especially in unstable regions where the political situation can change rapidly. To reduce the impact of this risk, PMCs can diversify their client base and seek long-term contracts that provide greater stability. Another financial risk for PMCs is the high operational costs associated with providing security and military services in insecure environments. PMCs need to invest in training, equipment, logistics and insurance to ensure the safety and efficiency of their operations. These costs can rise quickly, especially if the security situation deteriorates or unexpected events occur.

Table 1. Ontology of financial risks for PMC

Potential risk	Brief description
Unstable geopolitical situation	As PMCs are increasingly used alongside national armed forces, their importance and vulnerability to geopolitical changes are growing (Kinsey, 2002). This dependence on an unstable geopolitical environment can lead to abrupt changes in the scale of operations, sudden withdrawal from regions or unexpected contract renewals, creating significant financial risks. Key points to consider include: the broad scope of PMCs means that they are deeply affected by geopolitical changes; the increasing use of PMCs as a complement to national armed forces increases their vulnerability to geopolitical risks; and financial implications may include sudden changes in contracts or adjustments to the scope of operations due to changes in the geopolitical situation.
Legal and regulatory developments	The legal frameworks governing PMCs are far from uniform and can change without prior notice, significantly affecting their global operations. Issues related to legitimacy and accountability are of paramount importance, as PMCs often operate in countries with weak legal systems and ineffective oversight (Renou, 2005). The absence of a standardised global regulatory environment for them leads to unpredictability and financial instability, as companies have to navigate disparate national laws and international regulations. This problem is highlighted by the fact that: PMCs face diverse legal and regulatory environments around the world; issues of legitimacy and accountability arise, especially in regions with weak legal oversight; and the constantly changing legal environment creates significant financial risks, requiring PMCs to adapt quickly.
Maintaining liquidity and managing cash flows in a high-risk environment	The nature of PMCs operations, often in volatile and unpredictable environments, makes effective liquidity risk management essential (Principles for Sound Liquidity Risk Management and Supervision, 2018). Techniques such as cash flow modelling and liquidity ratios are important tools to help PMCs navigate the uncertainty of their operating environment (Banks, 2005). Key strategies include: using cash flow modelling to forecast and manage liquidity positions; using liquidity ratios to assess a company's ability to meet short-term obligations; and adapting financial management practices to the unique challenges of operating in a high-risk environment.

Continuation of the table 1. Ontology of financial risks for PMCs

Potential risk	Brief description
Variability in demand for security services	This demand is inextricably linked to global security concerns, which, according to a recent annual report, are growing due to various threats to national security around the world (Permanent Select Committee on I. (house), 2024). The key role of PMCs, ranging from protecting infrastructure abroad to providing close protection to high-ranking officials, underscores their importance in the current geopolitical climate. However, this also exposes them to market risks, as their operational viability is largely dependent on the unpredictability of the global security landscape. The main argument in favour of privatising security companies is their cost-effectiveness and efficiency compared to traditional armed forces (Cumming, Mohammadi, Zambelli, 2021). However, the demand for their services remains sensitive to sudden geopolitical changes, regulatory shifts and economic downturns, which can significantly affect their financial stability. The report highlights the steady growth in demand for PMC services driven by increasing global security concerns (Vestner, 2019), but this demand is not immune to sudden downturns, which creates a significant market risk for PMCs.
Credit risk	Delayed payments or non-performance of contracts by clients can have a serious impact on the cash flow and overall financial position of a PMC. The concept of contract financing is vital in this context, as it allows government payments to contractors in advance of acceptance of supplies or services, mitigating some aspects of credit risk (Fama, 1990). However, this mechanism does not cover all scenarios or clients, especially in the private sector or in international contracts. In addition, the MoD's policy is to ensure that contractors, including PMCs, have a fair opportunity to succeed and are adequately compensated for their services (Defense Department awards synfuel contract, 2007). Despite these measures, PMCs still face significant financial risks if a client delays payment or fails to fulfil its obligations, which underscores the importance of careful risk assessment and mitigation strategies in financial planning.
Operational risk	Operational risk for PMCs covers a wide range of potential internal failures, including inefficiencies in processes, systems or human error, which can lead to significant financial losses. The Risk Management Association defines this type of risk as arising from inadequate or failed internal processes, people and systems (Aloqab, Alobaidi, Raweh, 2018). Operational risk management is crucial for PMCs, focusing on identifying, assessing and mitigating risks that arise during day-to-day operations (Association, 2008). This includes everything from logistical failures, cybersecurity breaches to regulatory violations, which can not only lead to financial losses but also damage reputation. Thus, operational risk summarises the many uncertainties that PMCs face during their operations, highlighting the need for robust risk management strategies to protect against these potential pitfalls (Raanan, Kenett, Pike, 2010).

Therefore, exploring strategies to mitigate financial risks in PMCs is crucial to ensure their sustainability and effectiveness in fulfilling their missions.

Some strategies for mitigating financial risks in the PMC (leverage effects):

1. Diversification of services and geographical presence is a strategic approach for PMCs to effectively mitigate risk. By offering a wide range of services, such as strategic planning, intelligence, investigations and operations on land, sea or air, PMCs can serve a broader client base and reduce their dependence on a single revenue stream. This diversification strategy also extends to geographic expansion, allowing PMCs to spread their risks across different regions. The benefits of adopting this approach include reduced exposure to local economic downturns; access to a wider range of contracts and opportunities; and reduced risks associated with political instability in certain regions. Expanding the range of services and geographical presence allows the PMC to build a more sustainable business model that can withstand various financial risks.

2. Implementing strict credit control measures and conducting thorough customer due diligence are crucial for managing financial risks in the activities of PMCs. Credit risk, liquidity risk and operational risk are serious issues that can be addressed through a comprehensive risk assessment (Spivack, 2001). Due diligence plays a vital role in this process, providing a clear understanding of the history, financial position and potential risks associated with doing business with PMCs and their

clients. The key aspects of an effective due diligence and credit control system are the following: comprehensive assessment of the creditworthiness and financial stability of clients; regular review of lending terms and conditions to bring them in line with current risk assessments; implementation of a risk-based approach to client verification, adjusting measures based on the assessed level of risk (Project Risks, 2016). These measures help the PMCs to minimise the risk of financial losses due to non-payments or contractual disputes, ensuring a more stable financial position.

3. Investing in a robust operational infrastructure and risk management systems is essential to effectively address and mitigate the financial risks of a PMC. An integrated approach to risk management involves assessing different types of risks (e.g. credit, liquidity, operational) and integrating risk assessment across different geographical regions, legal entities and business lines of the firm (Leverage, Financial Stability, and Deflation, 2016). This involves developing and implementing advanced risk assessment tools and methodologies; continuously monitoring and updating risk management practices to reflect the changing risk landscape; and training and raising awareness of staff on risk awareness and mitigation strategies. Such investments not only enhance the ability of a PMCs to manage risk, but also help build trust with clients and stakeholders, thereby supporting business continuity and financial stability.

All the above strategies are the consequences of the use of financial leverage, which plays a crucial role in strengthening the operational capabilities of PMCs, providing them with the necessary capital to expand their asset base and obtain a higher return on risk capital (Mahoney, Tkach, Rethmeyer, 2022). However, this leverage is associated with significant risks that may affect the financial stability of these companies. Empirical evidence suggests that defence contractors backed by private equity are more prone to bankruptcy, indicating that the use of debt capital can lead to financial difficulties under certain market conditions (Inspectorate, 2003). This is especially true in the context of PMCs, where the volatile nature of defence contracts and geopolitical changes can quickly alter their revenue streams. Thus, while financial leverage can enhance operational capabilities by allowing them to invest in advanced technologies and expand their range of services, it also requires sound financial management strategies to mitigate the associated risks. Thus, striking a balance between raising capital for growth and maintaining financial stability is essential for the continued operation of PMCs.

The benefit of calculating the leverage effect is that it allows PMCs to assess the impact of debt financing on their overall financial performance. By calculating the leverage effect, they can determine how changes in interest rates or operating income will affect their own profits and return on equity. Financial leverage refers to the use of debt to finance a PMCs operations and investments. While debt can increase profits when the business is booming, it can also increase losses during economic downturns. Therefore, understanding the effect of financial leverage is crucial for making informed decisions on capital structure and risk management. In addition, calculating the leverage effect can help the PMCs determine the optimal level of debt. By analysing different scenarios and modelling the impact of debt on profitability, PMCs can find a balance between maximising shareholder returns and maintaining financial stability.

The strategic use of financial leverage greatly enhances PMCs' capabilities by enabling them to invest in the most advanced military technologies and equipment. By borrowing capital, PMCs can acquire advanced weapons, surveillance systems and protective equipment that they would otherwise be unable to afford. This not only increases their operational efficiency, but also makes PMCs competitive in the global market for military and security services. In turn, the use of financial leverage is an important tool for modernising and expanding their technological assets without dispersing ownership in PMCs through equity financing (Andreopoulos, Brandle, 2012). The procurement of advanced technologies ensures that PMCs can offer higher-level services, such as high-tech surveillance and reconnaissance missions; advanced cybersecurity defences; and the deployment of sophisticated unmanned aerial vehicles. These technological advances, funded by

financial leverage, allow PMCs to conduct operations more efficiently and with greater accuracy, thereby increasing their attractiveness to potential customers, including governments and multinationals (Galai, 2019).

Financial leverage plays a key role in facilitating the global expansion of PMCs. With access to debt, they can scale their services across borders, establishing a presence in strategic locations around the world. This expansion is not only geographical, but also entails an increased portfolio of services to meet a variety of security needs. The use of debt allows PMCs to quickly mobilise resources, personnel and equipment to conflict zones or areas in need of immediate security assistance, thereby taking advantage of emerging opportunities (Fahn, Hadjer, 2015). Global expansion strategies that can be implemented with the help of financial levers include establishing operational bases in conflict-affected regions; diversifying services, including logistics support, training and consulting; and participating in international cooperation and security contracts. The ability to respond quickly to global security needs and participate in international operations enhances the reputation of PMCs and strengthens their position as key players in the international security landscape (O'Brien, 2008).

While financial leverage offers significant advantages, it also carries significant risks, especially in the volatile environment in which PMCs typically operate. High levels of debt increase their financial exposure, making them vulnerable to market fluctuations and economic downturns. In scenarios where contract operations are suddenly cancelled or reduced due to political or military events, PMCs may be unable to cover their debt obligations, leading to financial distress or even bankruptcy (Clauss, 2012). In addition, reliance on debt financing requires careful risk management strategies to mitigate interest rate risks, which can unexpectedly increase the cost of borrowing; liquidity risks, which affect the ability of an PMC to meet short-term financial obligations; and reputational risks, if financial instability jeopardises operational capabilities. The unstable balance between borrowing for growth and managing the associated risks highlights the difficulty of using financial leverage in a security environment characterised by uncertainty and rapid change (Nebolsina, 2019); (Armanious, Zhao, 2022).

Therefore, to clearly evaluate the financial performance of a PMC, we will present a step-by-step calculation of the financial leverage effect (ЕФВ) for a potential PMC (ПВКх). For this purpose, it is necessary to estimate the economic profitability (EP) and the average estimated rate of interest (CPCB):

$$ЕФВ = 2/3 (EP - CPCB) * ПК / ВК,$$

where PEI = net operating result of the investment / (Own funds + Borrowed funds),

CPCB = Interest expense / Borrowings * 100%.

PMCs Input data (ПВКх):

1. Revenue from operations - USD 1,231.8 million.
2. Variable expenses - USD 10970.5 million.
3. Fixed costs - USD 687.6 million.
4. Own funds (BK) - USD 1130.4 million.
5. Borrowed funds (ПК) - USD 180 million.
6. Financial costs on borrowed funds (ФВПК) - USD 32.4 million.

ПВКх performance indicators:

1. Profit - USD 573.7 million.
2. Net investment performance (PEI): financial expenses on borrowed funds (ФПК) + Profit - USD 606.1 million.
3. Gross margin (BM) - USD 1261.3 million.
4. Gross margin (BM/Revenue) - 0.103.
5. Share of fixed assets - 9.241%.
6. Profitability of services - 4.69%.

To calculate the **financial leverage effect** (ЕФВ), it is necessary to calculate the economic profitability (EP) and the average estimated interest rate (CPCB):
EP = PEI / Assets * 100 = 606.1 / (1130.4 + 180) * 100 = 46.25%.
СРСВ = ФПК/ ПК * 100 = 32.4 / 180 * 100 = 18%.
ЕФР = 2 / 3(ЕР - СРСП) * ЗС / СС = 2 / 3(46.25% - 18%) * 180 / 1130.4 = 3.0%.
РСС = 2/3 * ЕР + ЕФР = 2/3 * 46.25 + 3.0 = 33.84%.

The volume of ЕФВ reflects the increase in the return on equity resulting from the use of borrowed capital.

The ability of debt to leverage a company's assets for more significant projects is a strategic advantage that PMCs can take advantage of. By using debt capital, they can expand their operational capabilities and embark on larger and more ambitious projects, which are often integral to their growth and success in the highly competitive defence sector (Ilyashenko, 2017). This approach not only demonstrates the tactical use of financial instruments to achieve business goals, but also highlights the importance of managing the balance between raising assets and maintaining financial health. Strategic deployment of debt capital, when managed effectively, allows PMCs to maximise the use of their assets and project scale without compromising their financial stability.

In our case, the ЕФВ was 3.0%, and since the leverage is less than 1 (0.159), this ПВКх can be considered creditworthy.

Let's use the graphical method to determine the safe amount of borrowed funds. Typical differential curves are shown in Fig. 1.

The position of the potential ПВКх on the graph is determined: EP / CPCB = 46.25 / 18 = 2.57, then EP = 2.57CPCB.

With additional possible borrowing, it is necessary that the financial capacity of the ПВКх does not fall below the main curve (ПВКх is between EP = 3CPCB and EP = 2CPCB). Thus, at the level of tax neutrality at the point of ЕФВ/РСС = 1/3, the permissible leverage of the ПК/ВК is 1.0.

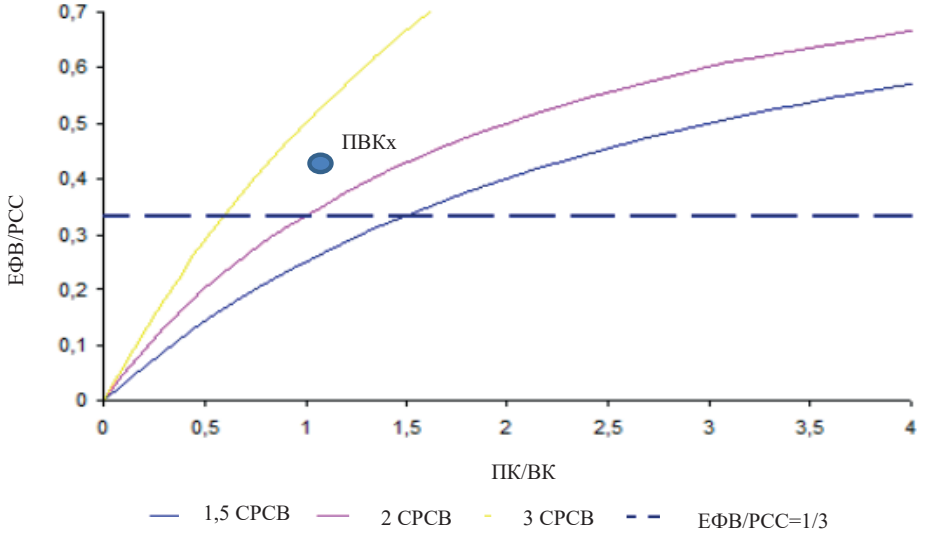


Figure 1. Differential curves (results of the authors' calculations)

Thus, borrowed funds can be increased by USD 950.4 million and reach USD 1,130.4 million.

Let us determine the upper bound of the cost of debt:

ЕР = 2СРСВ, i.e., СРСВ = 46.25% / 2 = 23.13%, and СРСВ = ФВПК / ПК.

Hence, ФВПК = СРСВ * ПК = 23.13% * 1130.4 = USD 261.422 million.

Thus, without increasing the level of economic risk, this ПВКх can borrow an additional USD 950.4 million. The additional borrowing will cost the ПВК $219.795 million if the average interest rate on the loan capital does not exceed 23.13%.

The critical value of the net investment performance is the value at which the ЕФВ = "0", and therefore the return on equity is the same for both the options with borrowed funds and using only equity. Then PEI critical = 1310.4 * 18 = USD 235.872 million.

In our case, the threshold value is passed, which indicates that it is profitable for the ПВКх to attract borrowed funds.

The correct interpretation of the results of the calculation of the financial leverage effect to counter financial risks can help the PMCs to make informed decisions about its operations and strategy. Financial leverage refers to the use of debt to finance operations and investments to increase the potential return on investment. However, this strategy is also associated with increased financial risks, as the company must pay regular interest on the debt, which can be a burden for reduced profits. By accurately calculating the impact of financial leverage on a PMC's operations, managers can assess the level of risk they are exposed to and adjust their financial structure accordingly. For example, if the calculations show that a PMCs is heavily reliant on debt financing, it may need to consider reducing its leverage to mitigate potential risks. On the other hand, if the calculations show that the company can comfortably manage its debt obligations while still achieving the desired profitability, it may decide to maintain or even increase its borrowing base. A clear understanding of the impact of financial leverage can also assist the PMCs in budgeting and forecasting. By incorporating this information into their financial planning, they can make more accurate forecasts of future cash flows and make strategic decisions that are more aligned with their goals.

Conclusion

Financial leverage plays a crucial role in the stability of a PMC, offering both opportunities and risks. Managing it effectively is essential to navigate the complexity of financial transactions in volatile regions. PMCs face financial risks such as unpredictable revenues and high operating costs, which require strategic planning and risk mitigation. Diversifying the customer base and securing long-term contracts can increase revenue stability, while prudent management of operating costs is vital to sustain operations in a challenging environment.

PMCs face a variety of financial risks due to an unpredictable geopolitical environment, legislative and regulatory changes, liquidity management challenges, demand volatility, credit risk and operational failures. To mitigate these risks, PMCs can diversify their services and geographic presence, implement strict credit control measures, conduct due diligence, and invest in robust operational infrastructure and risk management systems. These strategies help PMCs to overcome uncertainties, enhance financial stability and ensure business continuity in a high-risk environment.

Research shows that financial leverage plays a crucial role in increasing the operational capacity of a PMC, providing the necessary capital to expand and increase profits. However, it also creates significant risks, such as increased vulnerability to bankruptcy. By strategically using financial leverage, PMCs can invest in advanced technology, expand globally, and respond effectively to security needs. Balancing debt is essential for sustainable operations in the volatile security industry.

The use of the ЕФЛ involves considering the economic profitability and the average interest rate. Using the methodology presented in the article, PMCs can assess the impact of debt on their profitability. (In the example, the authors demonstrate a situation with a 3.0% increase in profitability

due to the use of borrowed capital.) The analysis also determined the company's creditworthiness and the safe amount of borrowed funds. Thus, the correct interpretation of the ЕФЛ helps to make informed decisions on financial risk management and optimisation of the financial structure of a PMC.

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The military purpose two-circuit turbo-jet engine with an afterburner turbine working blades thermocycle durability experimental research methodology

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Abstract. The relevance of this article is due to the fact that it is extremely important to maintain the technical condition of the military aircraft engine fleet to ensure a high level of reliability and flight safety. This, in turn, requires experimental studies of the thermal cyclic durability of working blades, which limit the service life of an aircraft engine. The purpose of the study is to justify the further development of the experimental research methodology of the working blades` of turbojet two-circuit engines with an afterburner combustion chamber thermocycle durability, which have exhausted their resource, to assess their residual strength. The main research methods are methods of analysis and synthesis, deduction and induction, as well as methods of experimental research. Ten samples of the working blades of the RD-33 aircraft engine were chosen as the object of the experimental study. The experimental research was carried out on a special installation that allows samples` testing for stretching and creep in an air environment under isothermal and thermocycling conditions. To study the residual resource of working blades samples, the experimental research method was used, that involves the three stages (preparatory, main, final) of implementation. The further development of the methodology consists in a new working blades samples preparing procedure, thermocycling modes and mechanical loads for testing samples parameters determining, establishing the duration of their exposure at the maximum temperature, expanding modern tools for analytical results processing of the experimental studies. When conducting an experimental study, the parameters of the test modes were determined in such a way that it was possible to investigate the influence of the main load factors on the residual durability of the material, namely: the mechanical stresses magnitude; maximum and minimum temperature of the sample in the cycle; heating and cooling time; sample exposure time at the maximum temperature. Based on the analysis of the obtained experimental data, a conclusion was made concerning the significant dependence of the durability of the working blade samples on the level of temperatures, stresses and exposure time at the maximum temperature value in the cycle. The main results of the article are the proof of the working blades` resource potential according to the residual creep deformation and durability criteria, that creates grounds for forecasting and justified extension of the established resource during the military aircraft engines` operation according to the technical condition. The proposed further development of the experimental research methodology on the thermocycle durability of the turbojet two-circuit engines with an afterburner combustion chamber working blades meets the requirements of the Aviation Rules in terms of airworthiness standards for aircraft engines in relation to the aircraft engines resource`s management strategy. The materials of the article may be useful for developers, manufacturers and operators of power plants, as well as scientists and researchers in the field of aircraft engine construction.

Keywords: aircraft engine, thermocycle durability, damage, working blade, experiment.

Introduction

The engine park technical condition maintenance and a high level of their reliability and flights safety ensuring is based on the experimentally obtained performances of the thermocycle durability of the turbines working blades` heat-resistant alloys, those limit the aircraft engine`s life. In this context, it is relevant to carry out complex studies of the thermal and stress-strain states of the working blades (WB) material, that allow to determine the main factors that affect the damage mechanism.

Materials and Methods

The domestic scientific school, founded by Pisarenko G.S., Karpinos B.S., Serensen S.V., Tretyachenko H.M. has made a significant contribution to the basic provisions` development of the strength reliability of aircraft engines` materials and structural elements, including thermocycle creep and long-term strength of the material of the aviation gas turbine`s working blades after working the issue out. Thus, the works (Serensen, Dulnev, Bychkov, 1961; Pisarenko, 1980; Tretyachenko, Karpinos, 1990) provide the durability of operating under extreme conditions structural elements studies analysis. In work (Karpinos, 2022), the residual creep during the thermal cycle and the durability of the WB material of a high-pressure turbine are determined by tests. The work (Kulyk, Kucher, Koveshnikov, Dubrovskyi, Petruk, 2009) proposes a studying method for the asymmetry of the thermomechanical load cycle influence on the heat-resistant materials durability during thermocycle tests. The work (Pityak, Bilyavin, Mahotkin, Rovkov, 2005) presents the experiment`s methodology and results for deformation detecting and tension in structural elements under the influence of temperature gradients.

Approaches to experimental and calculation methods for assessing damage accumulation in aircraft engine parts are being investigated by foreign scientists. In particular, S.S. Manson (Manson S.) (Manson, 1974) calculated the low-cycle durability of the blade, the final service life according to the law of linear interaction of creep and fatigue. S. Majumdar (Majumdar S.) (Majumdar, 1975) investigated the creep of the turbine`s WB, the dependence between creep and fatigue for the durability calculation, proposed a low-cycle fatigue and creep failures predicting method. A thorough analysis of the phenomenon of creep and its calculation models for various components of aircraft engines is given in the Lin Yuan`s work (Lin Yuan, Wang Chenglong, Sun Yongchao, Sun Mingbo, Yuan Yu, Gao Zhan & Xiao Yiwen, 2023).

However, the previously researched problematic issues of the thermocycle durability evaluating the of WB material of the turbojet two-circuit engines with an afterburner combustion chamber (TJTCEACC) of military use, require further development of the scientific and methodological apparatus for the experimental studies conducting.

In accordance with the abovementioned, the purpose of the article is to substantiate the further experimental research methodology development of the TJTCEACC`s WB thermocycle durability, that have exhausted their resource, to assess their residual strength and present the results of its implementation.

The turbine`s WBs work at different engine operating modes, under the influence of high temperatures and in a wide range of power loads, while the damage accumulation in them occurs according to the mechanisms of both thermal fatigue and creep.

The WB`s destruction mechanism in operation is activated due to the nucleation of a fatigue crack, which increases its size under the action of acting stresses. The crack, acting as a stress concentrator, reduces the WB`s cross-sectional area, at a certain value of which it can no longer withstand the operating loads and is destroyed under the action of cyclic and static loads (Fig. 1).

The fatigue crack development and fracture zones at the alloy`s grain boundaries are observed on the destroyed WB. Of course, the destruction processes develop over time and, first of all, depend on the dominant influencing factors (temperature, load and time of their action).

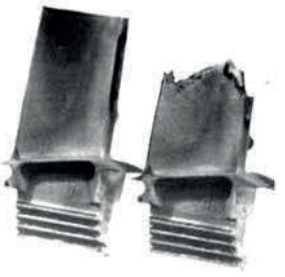


Figure 1. Destruction of the WB (Karpinos, Samuleev, Lyashenko, Lais'ke, Rutkovs'kyi, 2013)

Methods of the WB samples experimental research. The organization and conduct of experimental research requires the experiments planning based on the principles of a minimally sufficient number of factors to ensure the maximum possible impact on their result detection. To study the residual resource of WB samples, a method of experimental research is proposed (Fig. 2), which involves the implementation of three stages: preparatory, main, and final.

PREPARATORY STAGE: The experimental equipment preparation (E 1.1), test samples (E 1.2), determination of their test modes (Fig. 2), namely the required temperature and stress levels based on the results of modeling the thermal stress-strain state of WB turbines (E 1.3).

MAIN STAGE: The sample is heated to the specified temperature with the help of the special installation, using the method of high-temperature tests (E.2.1). Exposure of the sample at the specified (maximum) temperature during the specified time (E.2.2).

Then, the sample is cooled to the specified (minimum) temperature, and it is held on the sample for the specified time (according to the program) (E.2.3). The process of thermocycle loading according to the test program is repeated until the technical shutdown of the experimental installation for its maintenance.

Performing technical maintenance (replacing the graphite rod, quartz glass, seals, washing mirrors in the heating and cooling chambers, checking the functionality of the installation on a technological sample, etc.) (E.2.4). Continuation of tests of samples for thermocycle creep until sample failure.

FINAL STAGE: Analytical processing of the experimental studies results (E.3.1), those involves the calculation of the values of: operational factors damage accumulated from the "High Temperature Mode" (HTM); plasticity and strength of the WB material residual resource for unsteady and accelerated stages; steady stage (half-cycles of heating and cooling), as well as to obtain a regression full curve.

In contrast to existing methods, it is proposed to improve the quality of WB samples tests by introducing determining procedures for test modes and the duration of exposure setting, as well as the analytical processing of the results of experimental studies improving.

Thus, the determination of WB samples test modes (E 1.3) is performed with the help of mathematical models, those are meaningfully considered in the article [6]. Tensile stresses in the WB sample should have values that occur in the real WB under the action of centrifugal forces, namely, σ=(100...126) MPa. The temperature of the WB sample must correspond to the calculated maximum temperature of the WB in the elevated temperature mode (ETM) T=9650C and the cyclic temperature change T=9650C↔5000C over time. The time of heating and cooling of the blade in transient modes of operation of the engine corresponds to the values t=180 sec, t=90 sec.

The introduction procedure for establishing the duration of WB samples exposure at the maximum temperature (E.2.2) is necessary to identify the impact of exposure time at different forms of cycles, that will indicate the degree of thermal fatigue and change in durability.

The results of the analytical processing experimental studies (E.3.1) involves expanding the use of modern data processing tools.

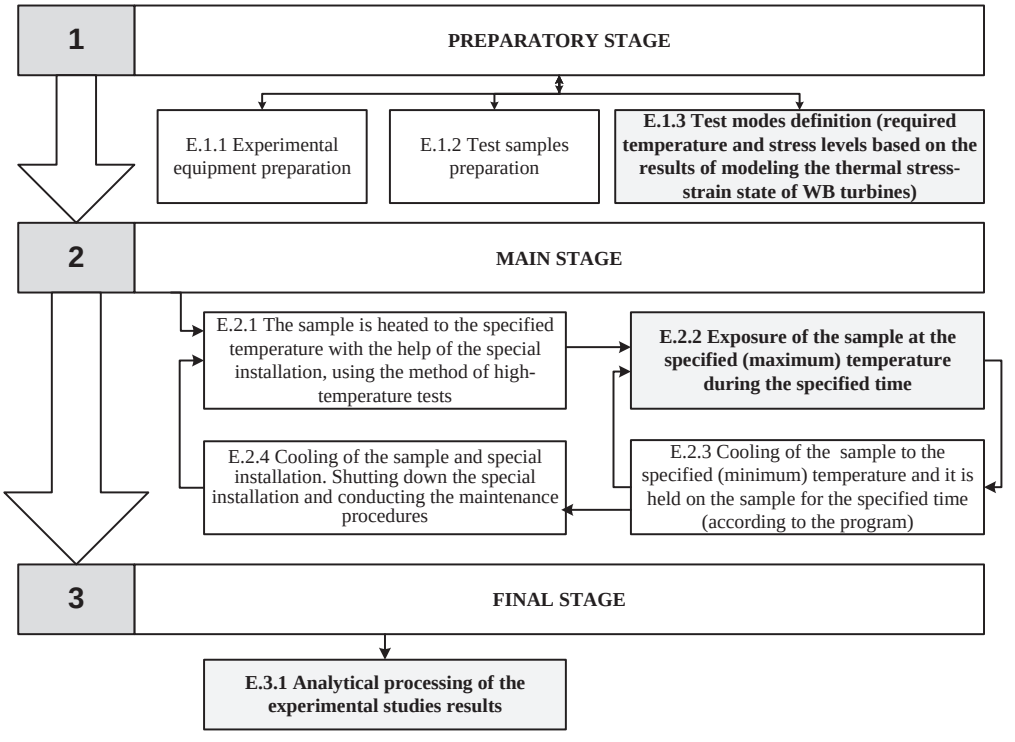


Figure 2. The experimental research methodology of WB samples for thermocycle durability block diagram

Results

The purpose of the experimental study is to assess the residual strength of the WB of the high-pressure gas turbine TJTCEACC RD-33 based on the study of changes in the mechanical properties/behavior of the material under external thermomechanical loading.

10 samples from the WB of the high-pressure gas turbine of the RD-33 engine were chosen as the object of the experimental study.

The experimental research was carried out at the special installation "Luskunchyk" of the Institute of Strength Problems named after H.S. Pisarenko of the National Academy of Sciences of Ukraine, which allows you to study samples for stretching and creep in an air environment under isothermal and thermocycle regimes.

When conducting an experimental study according to the proposed methodology, the parameters of the test modes were determined in such a way that it was possible to investigate the influence of the main load factors on the residual durability of the material, namely: the magnitude

of mechanical stresses; maximum and minimum temperature of the sample in the cycle; heating and cooling time; sample exposure time at the maximum temperature.

In accordance with this, a classic plan of a multifactorial experiment was adopted (Table 1).

Table 1. The plan of the multivariate experiment by modes

Regime	Test temperature, Tmax	Average holding time, τvytr.sr	Load, σ	Deformation, ε	Time to destruction of the sample τruyn.	Number of cycles, N cycle
Mode 1	const	180 p	var	var	var	var
Mode 2	const	3 hours	const	var	var	var
Mode 3	const	90 p	const	var	var	var

Each mode of the multifactorial experiment has its own character of test cycles of WB samples for durability (Fig. 3).

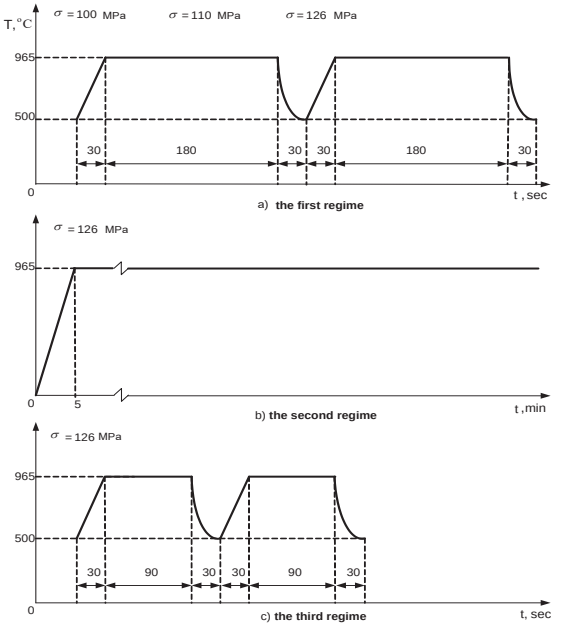


Figure 3. Modes of WB samples testing for durability

When conducting an experimental study, it was supposed to test the following hypotheses regarding confirmation/refutation:

Hypothesis 1: the existence of a linear dependence of the thermocycle damage of the WB turbine on stress and the number of cycles;

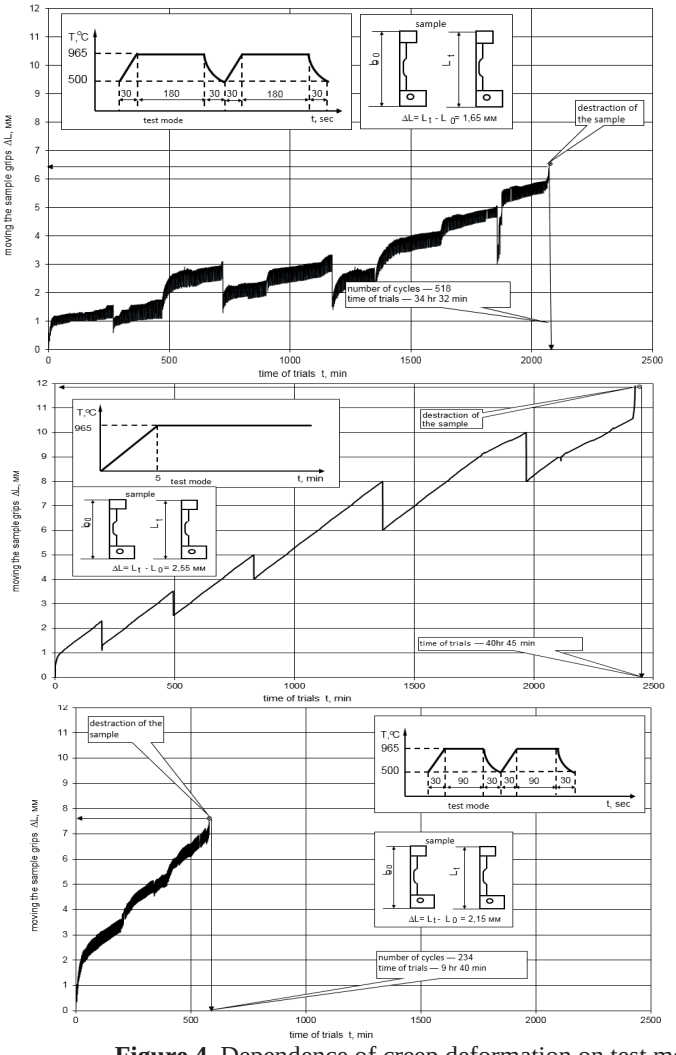
Hypothesis 2: the influence of the form of the cycle and the exposure time at the maximum temperature regime on the time and number of cycles to destruction.

Hypothesis 3: the decrease in long-term strength is associated with the exhaustion of the WB resource at the stage of engine operation.

Hypothesis 4: presence of dependence of creep deformation on cyclic temperature changes.

Hypothesis 5: there is a margin of safety in the WB for further operation of the engine.

The specified hypotheses verification is carried out during tests of WB samples for the purpose of characterizing the material behavior under the loads action under conditions of high temperatures with the special experimental equipment application. According to the experiment results, the dependences of the deformation of the sample were obtained (Fig. 4).



a) the first regime

b) the second regime

c) the third regime

Figure 4. Dependence of creep deformation on test modes

It was established that the creep curves for all test regimes have three stages: unstable creep, stable creep and intense avalanche deformation. The main part of the deformation accumulated in the stable stage. Unsettled and established stages took place after a test break. The results of experimental studies according to test modes are shown in Fig. 5.

To evaluate the residual strength, the deformation index of the WB material (half cycles and full) is used:

$$\varepsilon_n = a + bt - ct^2 + dt^3, \quad (1)$$

where ε_n – complete deformation.

t – time

Based on statistical processing of the experimental data, the kinetic equations for the complete curve of the WB sample were obtained, according to

the first mode is sample WB No. 1:

$$\varepsilon_n = 0{,}738 + 1{,}2 \cdot 10^{-3} t - 3 \cdot 10^{-6} t^2 + 1{,}1 \cdot 10^{-9} t^3, R^2 = 0{,}935 \quad (2)$$

the second mode, sample WB No. 3:

$$\varepsilon_n = 2{,}26 + 3{,}7 \cdot 10^{-3} t - 3{,}9 \cdot 10^{-6} t^2 + 3{,}5 \cdot 10^{-9} t^3, R^2 = 0{,}962 \quad (3)$$

the third mode is sample WB No. 8:

$$\varepsilon_n = 1{,}11 + 2{,}6 \cdot 10^{-3} t - 3{,}8 \cdot 10^{-6} t^2 + 2{,}3 \cdot 10^{-9} t^3, R^2 = 0{,}962 \quad (4)$$

Adequacy of the proposed dependencies was confirmed with reliability $R^2 \geq 0{,}93$. The results of the experiments were within the constructed 95% confidence intervals. The spread of the values of the limit characteristics of the materials is insignificant and amounts to an average of 5%.

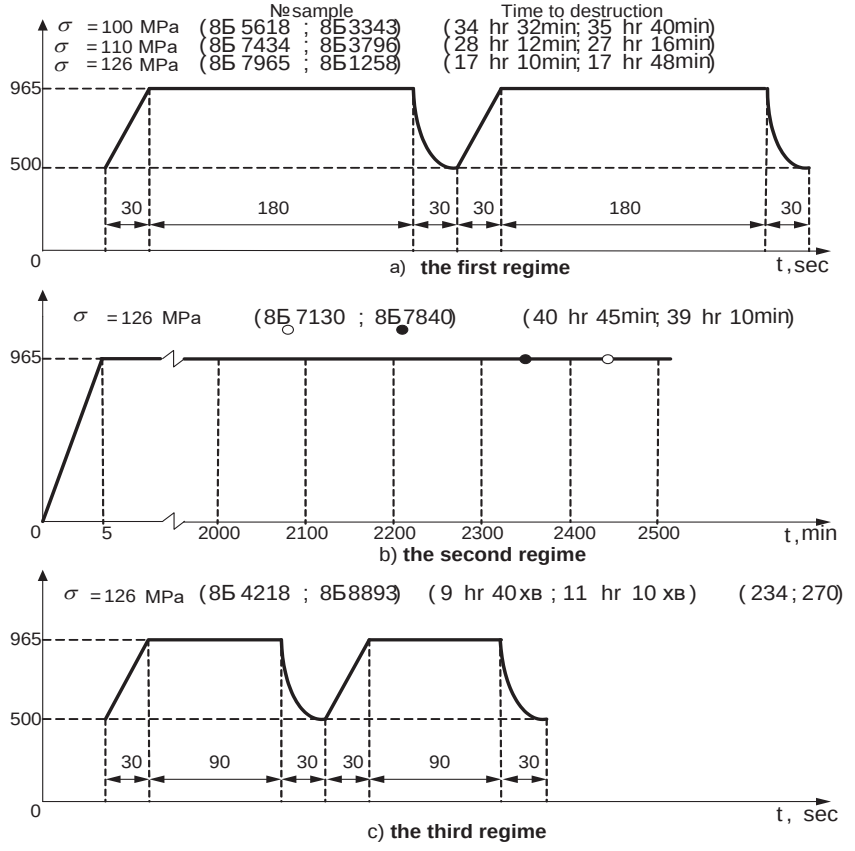


Figure 5. Results of experimental studies by test modes

Therefore, the form of the test cycle, the amount of stress, the value of the maximum temperature significantly affect the time and number of cycles to failure:

an increase in the stress level in the cycle, under other equal conditions of the experiment, leads to a decrease in durability by almost two times, while the ultimate deformation does not change significantly (hypotheses 1-4 are confirmed for regime 1);

at a constant maximum temperature, the maximum number of cycles and time to failure is ensured (according to mode 2, hypotheses 2 and 3 are confirmed);

reducing the length of exposure time in the cycle at the maximum temperature sharply reduces the durability (according to mode 3, hypotheses 3-5 are confirmed).

Discussions

The conducted experimental study has been performed for one of the six resource-limiting modes of operation of a military aircraft engine, namely, the mode of elevated temperatures, which has a significant impact on the level of the residual resource of the engine. Conducting further research under other regimes with a potential reserve of residual resource from 20% to 90% raises the issue of developing a scientific and methodological apparatus for mutual calculation of resource indicators. It is quite possible to adopt a single resource indicator taking into account the damage of resource-limiting parts of the engine, when the resource will be presented in two dimensions: static and thermocycle. Calculating damage for all resource-limiting elements would make it possible to set individual resources to engine modules and, if their replacement in military units is provided, to operate the engines practically without removing them from service. However, the transition to a new resource indicator is debatable and requires additional resource tests of aircraft engines with simulation of resource-limiting modes of operation in flight conditions on the stand.

Conclusion

Thus, the method of experimental research on the thermocycle durability of the WB of the high-pressure TJTCEACC`s turbine received further development, the feature of that, unlike the existing ones, is the thermocycle regimes and mechanical loads parameters determination, taking into account the duration of WB samples exposure at the maximum temperature, expanding the toolkit of the results` analytical processing, which allows to evaluate the thermocycle creep, long-term strength of the material and the residual resource of the WB turbine samples.

The residual creep deformation and durability of the WB calculation proved the resource potential existence, based on the margin of safety and creates grounds for forecasting and a reasonable extension of the established resource when operating the engines according to the technical condition.

The further development of the methodology for experimental research on the thermocycle durability of the TJTCEACC high-pressure turbine WB meets the requirements of the Aviation Rules in terms of airworthiness standards for aircraft engines regarding the resource management strategy of aircraft engines, namely the establishment and increase of the designated resource of the main engine parts based on the use of experimentally substantiated calculation methods and databases given curves of low-cycle fatigue and operation of the engine without mandatory removal for repair before reaching the designated resource of any of the main parts (Aviation regulations, 2004).

The materials of the article may be useful for developers, manufacturers and power plants operators, as well as scientists and researchers in the field of aircraft engine construction.

Recommendations

The proposed method for experimental research of the turbine`s WB thermocycle durability was tested on the RD-33 engine of the MiG-29 aircraft and can be recommended for other types of TJTCEACC of fighter aircraft. Such a technique may serve as a basis for the technique of resource management improving for the military aircraft engines fleet, that will allow to carry out a

comprehensive analysis of TJTCEACC operational parameters, the technical condition monitoring and residual resource control for managing the aircraft engines life cycle.\

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The author declares that he has no competing interests in the subject of the article.

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“Таймлайн”-мобілізація – шлях від примусу до популяризації військової служби в умовах війни: право вибору – спосіб ефективного комплектування людськими ресурсами

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Анотація. Актуальність статті, тематика якої – підвищення ефективності мобілізації в Україні, ні в кого сьогодні не викликає сумніву. Запровадження авторами так званих принципів “timeline”-мобілізації полягає в аналізі змін у підходах щодо мобілізації під час війни, зокрема щодо переходу від примусової мобілізації до популяризації військової служби та надання права вибору військовозобов’язаним формату проходження служби за принципом: “чим більше ти ризикуєш, тим менше ти служиш, але маєш найбільший фінансовий та соціальний пакет для себе та своєї родини, і навпаки”. Це дослідження підкреслює важливість забезпечення права вибору для громадян, що сприяє ефективному комплектуванню людськими ресурсами та підвищенню морального духу військовослужбовців. В умовах російсько-української війни, що триває, для України цей підхід є критично важливим, оскільки дозволяє зміцнити обороноздатність країни завдяки залученню мотивованих та свідомих добровольців. Тому головною метою статті було обрано виявлення існуючої проблематики мобілізаційних процесів у нашій державі та пошук шляхів удосконалення механізмів комплектування Збройних Сил України людськими ресурсами в умовах війни. Одним зі шляхів автори вважають запровадження системи “timeline”-мобілізації в Україні, яка, на їхню думку, сприятиме формуванню позитивного іміджу військової служби, підвищенню мотивації до добровільного вступу та забезпеченню ефективного комплектування людськими ресурсами в умовах війни. Основними методами досліджень є методи “мозкового штурму”, аналізу і синтезу, дедукції та індукції. Головними результатами статті є те, що в ній: сформовано актуальну проблематику діючих механізмів комплектування Збройних Сил України людськими ресурсами під час мобілізації в умовах війни; запропоновано методичний підхід щодо проведення досліджень за напрямом підвищення ефективності мобілізації в Україні; запропоновано проєкт новітньої моделі проходження військової служби за контрактом за принципом “timeline”-мобілізації; сформовано варіанти проходження військової служби за контрактом під час дії воєнного стану; запропоновано підхід щодо визначення додаткових соціальних гарантій військовослужбовцям під час проходження служби за контрактом за принципом “timeline”. Матеріали статті можуть бути корисними керівництву складових Сил оборони України та держави в цілому, а також науковцям і дослідникам за напрямами досліджень питань щодо комплектування людськими ресурсами та мобілізації у Збройних Силах України.

Ключові слова: варіанти проходження військової служби, ефективність мобілізації та комплектування, Збройні Сили України, інформаційний вплив, людські ресурси, модель системи “timeline”-мобілізації, методичний підхід, збройна агресія, соціальний захист військовослужбовців, обороноздатність, мобілізація, національна безпека, російсько-українська війна, ротація, рекрутинг, сили оборони держави.

“Не можна силою примусити людину щиро виконувати свій обов’язок, тільки право вибору майбутніх перспектив особистого існування та рідних дає шанс на щирість та свідомість” – Олег Семененко

Вступ (Introduction)

В умовах сучасних збройних конфліктів і гібридних війн ефективне комплектування збройних сил людськими ресурсами стає однією з найважливіших задач для будь-якої держави. В Україні, з огляду на військовий конфлікт, що триває, питання щодо мобілізації набуло особливого значення (Статистичні дані для якісного опрацювання науково-дослідної роботи “Рампа-М”; Закон України № 3633-IX, 2024; Талалай, 2014; Можаровський, 2014; Семененко, Воронченко, Москаленко, Абрамова, Харитонов, 2021).

Традиційна примусова мобілізація хоч і залишається необхідним заходом у воєнний час, пов'язана з численними викликами, такими як психологічний стрес, соціальна несправедливість та емоційне вигорання військовослужбовців.

Водночас, люди дедалі більше розуміють, що добровільна служба і надання громадянам права вибору можуть значно підвищити ефективність мобілізації. Добровольці зазвичай більш мотивовані, мають вищий бойовий дух і краще підготовлені до виконання завдань. Таким чином, перехід від примусу до популяризації військової служби та впровадження прав вибору стає не лише морально етичним, а й стратегічно доцільним.

Дослідження різних підходів щодо мобілізації та їхній вплив на ефективність функціонування сил оборони держави, а також аналіз міжнародного досвіду в цій сфері є надзвичайно важливими для України в її прагненні забезпечити надійну оборону та безпеку. Вивчивши часові параметри мобілізаційних процесів, так званий "таймлайн" ("timeline"), їхню трансформацію від примусу до добровільної служби, можна отримати цінні уроки для створення більш збалансованої та ефективної системи комплектування сил оборони України, а особливо Збройних Сил України (ЗС України) (Статистичні дані для якісного опрацювання науково-дослідної роботи "Рампа-М"; Закон України № 3633-IX, 2024; Талалай, 2014; Можаровський, 2014; Семененко, Воронченко, Москаленко, Абрамова, Харитонов, 2021; Романченко, Талалай, 2017; Череп, 2023; Павловський, 2023; Уроки російсько-української війни 2022 року, 2022; Наказ Верховного Головнокомандувача Збройних Сил України від 22.02.22 № 2, 2022; Указ Президента (69/2022), 2022; Указ Президента (342/2022), 2022; Указ Президента (574/2022), 2022; Указ Президента (758/2022), 2022; Закон України № 235-VIII, 2015; Військові запропонували мобілізувати додатково до 500 тисяч людей. Зеленський; Результати опитування КМІС в рамках проєкту "MOBILISE"; Романченко, Талалай, 2016; Соломицький, Семененко, Онофрійчук, Слюсаренко, Баранов, Мітченко, 2022).

Таким чином, дослідження за цим напрямом не лише розглядає важливу тему для поточного військового контексту України, а й сприяє формуванню нових ефективних підходів щодо мобілізації в Україні в умовах війни, що триває.

Materials and Methods (Матеріали та методи)

Нині, на третьому році війни, в Україні досі мобілізаційні процеси непрозорі, що обумовлено невизначеністю населення під час призову на військову службу. Основними напрямами такої невизначеності є (Статистичні дані для якісного опрацювання науково-дослідної роботи "Рампа-М"; Закон України № 3633-IX, 2024; Талалай, 2014; Можаровський, 2014; Семененко, Воронченко, Москаленко, Абрамова, Харитонов, 2021; Романченко, Талалай, 2017; Череп, 2023; Павловський, 2023; Уроки російсько-української війни 2022 року, 2022; Наказ Верховного Головнокомандувача Збройних Сил України від 22.02.22 № 2, 2022; Указ Президента (69/2022), 2022; Указ Президента (342/2022), 2022; Указ Президента (574/2022), 2022; Указ Президента (758/2022), 2022; Закон України № 235-VIII, 2015; Військові запропонували мобілізувати додатково до 500 тисяч людей. Зеленський; Результати опитування КМІС в рамках проєкту "MOBILISE"; Романченко, Талалай, 2016; Соломицький, Семененко, Онофрійчук, Слюсаренко, Баранов, Мітченко, 2022):

місця проходження служби та її перспективи;

тривалість проходження служби, а також інформація щодо залучення чи не залучення до бойових дій;

наслідки для військовослужбовців та членів їхніх сімей у разі поранення або смерті під час виконання бойових завдань, тобто досі немає чіткої відповіді на запитання: "Якщо зі мною щось станеться, що далі ….?";

інформація щодо прав та свобод, які надає проходження військової служби, а також обмежень, заборон і наслідків у разі відмови від неї тощо.

Це породжує низку негативних моментів під час продовження мобілізації в Україні, а саме:

зменшуються показники ефективності мобілізації;

зростає кількість осіб, котрі ухиляються від військової служби;

представники територіальних центрів комплектування та соціальної підтримки (ТЦКіСП) здійснюють спроби силою та примусом набрати недостатню кількість людських ресурсів, що викликає зростання негативного ставлення до людей у формі та силових структур узагалі;

значно знижується морально-психологічний стан тих, хто служить, та населення країни загалом;

знижується ефективність застосування військ (сил) через відсутність вмотивованості призваного за мобілізацією особового складу;

збільшується негативний інформаційний контент стосовно керівництва силових структур та політичного керівництва держави тощо.

Усе це змушує керівництво ЗС України та держави в цілому негайно переглянути існуючий стан справ з цього питання та здійснити трансформацію системи комплектування складових сил оборони. Це можливо тільки у разі зміни стратегії комплектування Сил оборони держави та розроблення дієвого всеохоплюючого методичного підходу щодо підвищення ефективності мобілізації в Україні в умовах війни.

Одним із дієвих елементів такого підходу є запровадження динамічної системи так званої “timeline”-мобілізації, яка створить можливі варіанти проходження служби з певними особливостями контракту, що є альтернативою наявним негативним наслідкам для населення у разі ухиляння від проходження військової служби, яка є обов’язком кожного громадянина України у віці від 18 до 60 років (Статистичні дані для якісного опрацювання науково-дослідної роботи “Рампа-М”; Закон України № 3633-IX, 2024; Талалай, 2014; Можаровський, 2014; Семененко, Воронченко, Москаленко, Абрамова, Харитонов, 2021; Романченко, Талалай, 2017; Череп, 2023; Павловський, 2023; Уроки російсько-української війни 2022 року, 2022; Наказ Верховного Головнокомандувача Збройних Сил України від 22.02.22 № 2, 2022; Указ Президента (69/2022), 2022; Указ Президента (342/2022), 2022; Указ Президента (574/2022), 2022; Указ Президента (758/2022), 2022; Закон України № 235-VIII, 2015; Військові запропонували мобілізувати додатково до 500 тисяч людей. Зеленський; Результати опитування КМІС в рамках проєкту “MOBILISE”; Романченко, Талалай, 2016; Соломицький, Семененко, Онофрійчук, Слюсаренко, Баранов, Мітченко, 2022).

Динамічна система “timeline” передбачає гнучкий підхід до мобілізації, відповідно до якого громадяни зможуть вибирати різні форми служби залежно від своїх особистих обставин та готовності. Це можуть бути короткострокові контракти з можливістю подовження, служба в резерві, а також альтернативні форми виконання військових обов’язків, такі як цивільна служба на підтримку збройних сил тощо. Такий підхід не лише знижує соціальну напругу, а й підвищує мотивацію громадян до участі в обороні країни, що, у свою чергу, позитивно впливає на загальну мобілізаційну готовність та ефективність ЗС України.

Упровадження цієї системи також передбачає покращення умов для військовослужбовців та членів їхніх сімей, зокрема забезпечення належного соціального захисту, медичної допомоги, реабілітації та інших необхідних послуг, що дозволить знизити побоювання та невизначеність, пов’язані з можливими ризиками служби, та сприятиме створенню позитивного іміджу військової служби в суспільстві. Отже, запровадження динамічної системи “timeline”-мобілізації є ключовим кроком у реформуванні мобілізаційних

процесів в Україні, що дасть можливість значно підвищити ефективність комплектування збройних сил та забезпечити надійну оборону держави в сучасних умовах.

Results (Результати)

Удосконалення діючих механізмів комплектування ЗС України людськими ресурсами в умовах війни передбачає запровадження низки заходів, а саме:

вивчення проблем, які вкрай негативно впливають на проведення мобілізації, та вироблення стратегії їх вирішення;

налагодження комунікацій (діалогу) з цивільним населенням держави та військовослужбовцями, які безпосередньо виконують бойові (спеціальні) завдання на лінії бойового зіткнення;

вдосконалення системи ротації військовослужбовців, комплектування ЗС України людськими ресурсами;

підвищення ефективності інформаційного впливу на думку населення країни;

підвищення якості соціального захисту військовослужбовців;

удосконалення системи бронювання;

генерування нових ідей (інновацій) та обмін ними з питань пошуку шляхів підвищення ефективності мобілізації людських ресурсів та прийняття громадян України на військову службу за контрактом тощо.

Методичний підхід щодо проведення досліджень за напрямом підвищення ефективності мобілізації в Україні наведено у табл. 1, у якій розкрито проблематику цього питання та відповідні напрями дослідження, а також показано основні проблеми, що негативно впливають на процес мобілізації, і запропоновано конкретні дослідницькі заходи для їх вирішення.

Перший етап досліджень слід присвятити вивченню основних проблем мобілізації, яка проводиться в державі (рис. 1). Вісімнадцятого травня 2024 року набрав чинності новий закон про мобілізацію, який протягом останніх місяців був предметом запеклих суперечок в українському політичному середовищі та у суспільстві. Головним завданням закону є посилення мобілізаційних процесів, проте наразі немає впевненості в тому, що підсумковий документ впорається із цим завданням. У будь-якому разі, він формально посилює правила військового обліку, посилює санкції проти так званих “ухилянтів” та конкретизує положення про відстрочку від мобілізації. Новації, прописані у новому законі, стосуються саме посилення правил військового обліку для українських призовників, а найголовніше – вони не спонукають населення країни добровільно вступати до лав ЗС України для боротьби із загарбником саме за власним бажанням. Зазначений закон передбачає цілком примусовий характер дій.

Оскільки під час підготовки згаданого вище законопроєкту не враховувалась думка цивільного населення та військовослужбовців, які безпосередньо виконують бойові (спеціальні) завдання на лінії бойового зіткнення, пропонується провести соціальне опитування цивільного населення країни та військовослужбовців, щоб зрозуміти, як до цього ставиться саме ця категорія людей. Основні заходи, яких треба вжити під час проведення досліджень щодо визначення проблем мобілізації в Україні після ухвалення закону про мобілізацію, продемонстровано на рис. 2.

Однією з головних проблем комплектування ЗС України в умовах війни залишається побудова системи прозорої ротації (рис. 3). Ротація під час війни означає заміну особового складу, що виконує певне бойове завдання або несе службу в складних умовах, на інших військовослужбовців, які були на інших позиціях (ППД, у районах, де не ведуться бойові дії, тощо). Це регулярна заміна або взаємозаміна особового складу, підрозділів (частин), що виконують завдання у важких, складних або несприятливих умовах, через певний час.



Рисунок 1. Ілюстрація порядку визначення основних проблем мобілізації



Рисунок 2. Ілюстрація реалізації заходів із визначення проблематики мобілізації в Україні

Одним із важливих заходів, що допоможе вирішити проблеми із комплектуванням військових організаційних структур людськими ресурсами, є запровадження нових форм строкових контрактів для проходження військової служби у ЗС України за принципом "timeline" (рис. 4), які будуть становити суттєву альтернативу призову військовозобов'язаних на військову службу за мобілізацією, що, у свою чергу, дасть можливість значно знизити соціальну напругу в суспільстві.

Таблиця 1. Методичний підхід щодо проведення досліджень стосовно підвищення ефективності мобілізації в Україні (проблематика та напрями)

№	Проблеми мобілізаційних заходів (негативні фактори)	Напрями дослідження
Етап 1. Визначення основних проблем мобілізації		
1.	Небажання цивільного населення бути призваними до лав ЗС України	1. Розробити анкети та провести соціальне онлайн-опитування цивільного населення в різних регіонах України з визначення причин небажання бути призваними до лав ЗС України
		2. Провести онлайн-анкетування (опитування) військовослужбовців з визначення причин небажання цивільного населення бути призваними до лав ЗС України та його думки стосовно того, які необхідно здійснити зміни, щоб вирішити цю проблему. (Особливу увагу звернути на тих військовослужбовців, які призвані за мобілізацією та безпосередньо виконували (виконують) бойові (спеціальні) завдання на лінії бойового зіткнення).
		3. Здійснити аналіз результатів соціальних опитувань цивільного населення і анкетувань (опитувань) військовослужбовців та на підставі висновків з аналізу підготувати пропозиції щодо підвищення ефективності виконання мобілізаційних заходів.
Етап 2. Дослідження проблем комплектування Збройних Сил України		
2.	Недосконала система ротацій військовослужбовців і недостатньо інформативна та якісна система рекрутингу, недосконаліть процедур вибору військової частини для проходження військової служби	1. Вивчити та проаналізувати підходи щодо залучення військовослужбовців до ведення бойових дій в інших країнах (США, Ізраїль, росія). 2. Дослідити проблематику організації та порядку проведення ротацій військовослужбовців, які залучаються до виконання бойових (спеціальних) завдань на лінії бойового зіткнення в Україні.
		3. Дослідити пропозиції та сформувати рекомендації щодо створення прозорої системи ротацій військовослужбовців різних штатно-посадових категорій за напрямами: регламентування тривалості перебування особового складу на лінії бойового зіткнення та військової служби; визначення принципів рівномірності військової служби залежно від ступеня її інтенсивності у Збройних Силах України; формування чітких правил проходження служби за різних умов (із залученням до безпосередніх бойових дій та без залучення); удосконалення процедур вибору військової частини для проходження військової служби; розроблення чітких правил грошового заохочення та забезпечення мобілізованих; формування варіантів проходження військової служби за контрактом під час дії воєнного стану (особливого періоду) за принципом “timeline”-мобілізації. 4. Розробити пропозиції стосовно формування проєкту наказу Міністерства оборони України щодо впровадження системи ротації у Збройних Силах України та інших складових сил оборони України та підготувати пропозиції щодо затвердження на законодавчому рівні.
		5. Сформувати пропозиції щодо удосконалення нормативно-правової бази України з метою врегулювання питань, що стосуються комплектування ЗС України, за умов створення прозорої системи ротацій.

Продовження таблиці 1. Методичний підхід щодо проведення досліджень стосовно підвищення ефективності мобілізації в Україні (проблематика та напрями)

№	Проблеми мобілізаційних заходів (негативні фактори)	Напрями дослідження
Етап 3. Дослідження питань щодо підвищення ефективності інформаційного впливу		
3.	Недосконалість інформаційного впливу на свідомість громадян України щодо незворотності мобілізації	1. Проаналізувати способи і методи ведення інформаційної пропаганди (ІПСО) передових країн світу та країни-агресора з метою розширення спектра методів боротьби у медіа- та кіберпросторі. 2. Вивчити пропозиції та розробити рекомендації щодо підвищення якості інформаційного впливу на свідомість громадян України стосовно незворотності мобілізації: формування загальних правил зміни інформаційної політики; визначення заходів з удосконалення інформаційного простору щодо популяризації мобілізації та її незворотності. 3. Провести круглий стіл із залученням представників ЗМІ. 4. Сформувати пропозиції щодо залучення PR-компаній (агенцій) до розроблення PR-стратегій та їх супроводження з питань підвищення репутації бойових підрозділів та популяризації військової служби у ЗС України.
4.	Недостатня обізнаність громадян України щодо відкриття та роботи рекрутингових центрів при ЦНАП	5. Сформувати пропозиції щодо популяризації та підвищення якості реклами в ЗМІ стосовно завдань рекрутингових центрів при ЦНАП та порядку їхньої роботи.
Етап 4. Дослідження питань щодо підвищення якості соціального захисту військовослужбовців		
5.	Недосконалість процедур соціального захисту військовослужбовців та членів їхніх сімей, які призвані за мобілізацією	1. Провести порівняльний аналіз досвіду інших країн щодо соціального забезпечення військовослужбовців, які призвані за мобілізацією. 2. Привести їх у відповідність до норм, які поширюються на військовослужбовців за контрактом.
Етап 5. Дослідження та удосконалення питань щодо бронювання		
6.	Немає переліку підприємств, які є критично важливими для функціонування національної економіки та забезпечення життєдіяльності держави, недосконалість переліку професій для бронювання	1. Розробити пропозиції щодо визначення переліку підприємств, які належать до об'єктів критичної та енергетичної інфраструктури і є важливими для функціонування національної економіки та забезпечення життєдіяльності населення, що приведе до спрощення порядку бронювання військовозобов'язаних.
		2. Розробити рекомендації щодо внесення зміни до ПКМУ від 27.01.2023 № 76.

Запропонований принцип комплектування ЗС України надає право військовозобов'язаним вибирати посади для проходження служби у вибраній ними військовій організаційній структурі, а також можливість вибрати вид строкового контракту, який найбільше їх влаштовує. Проходження військової служби та безпосередня участь у бойових діях на лінії бойового зіткнення передбачають додаткові соціальні пільги та надають можливість комплектувати ЗС України більш вмотивованими громадянами, а також зняти моральну напругу в сім'ях майбутніх військовослужбовців та вирішити їхні соціальні проблеми практично від самого початку служби. Особливо це стосується громадян, які виберуть форми контрактів за принципом "timeline".



Рисунок 3. Ілюстрація реалізації заходів з визначення проблематики прозорої ротації в умовах війни

Умови контракту за принципом Timeline 1 та соціальні гарантії військовослужбовцям за визначеною формою контракту.

Цю форму контракту можуть вибрати військовозобов'язані, які мають досвід участі в бойових діях (статус УБД), але були звільнені з військової служби впродовж останніх 5 років за різних обставин. Військовозобов'язані матимуть право вибирати військову частину, яка безпосередньо виконує бойові завдання, та бути направленими до неї для проходження військової служби за прямою ВОС, без додаткової підготовки у навчальних центрах (підрозділах). Термін дії контракту за принципом Timeline 1 становитиме 1 рік з моменту його підписання і може бути продовжений тільки за згодою військовослужбовця та командира військової частини. Перед закінченням дії контракту передбачається надання можливості військовослужбовцям вибирати та укладати інші види контракту за принципом Timeline 1–Timeline 5. Умови проходження військової служби за контрактом за принципом Timeline 1:

• 1–9 місяців військової служби за контрактом – участь у бойових діях безпосередньо на лінії бойового зіткнення, використовуючи систему ротацій всередині підрозділу;

• 10–11 місяців військової служби за контрактом – гарантована відпустка після участі в бойових діях;

• 12-ий місяць – проходження військової служби в ППД військової частини, проходження ВЛК перед звільненням з військової служби та звільнення з військової служби.

Наприклад, додаткові соціальні гарантії військовослужбовцям під час проходження служби за контрактом за принципом Timeline 1 (табл. 2):

• одноразова грошова виплата військовослужбовцям у розмірі 100 000 грн за умови підписання контракту на проходження військової служби в ЗС України за принципом Timeline 1. Нарахування та виплата цієї грошової виплати здійснюється військовою частиною протягом 10 діб з моменту прийняття їх на військову служу за контрактом;

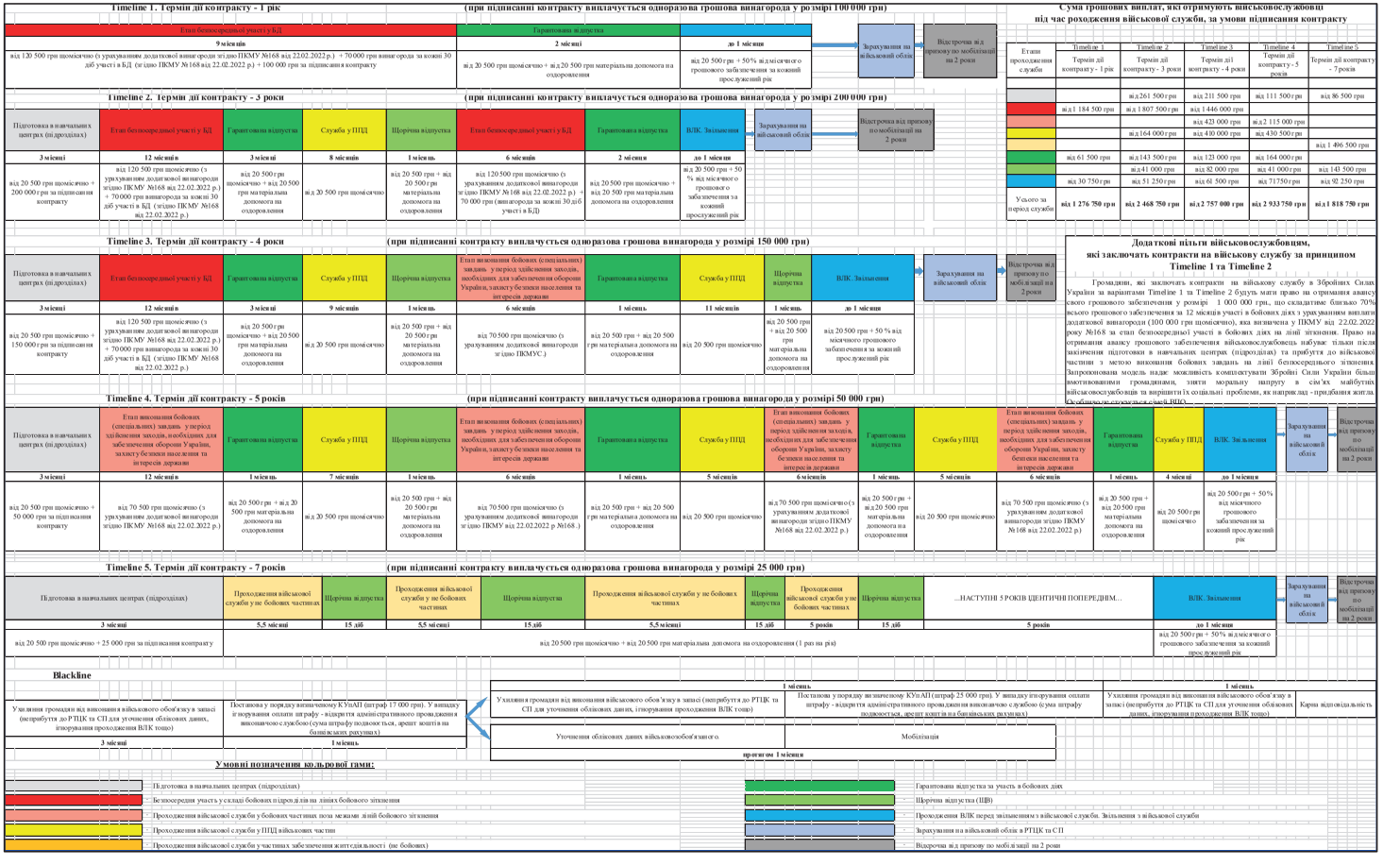


Рисунок 4. Проєкт новітньої Моделі проходження військової служби за контрактом за принципом TIMELINE

• військовозобов'язані, які укладуть контракт на військову службу в ЗС України за принципом Timeline 1, будуть мати право на отримання авансу свого грошового забезпечення у розмірі 500 000 грн, що становитиме близько 50% всього грошового забезпечення за 9 місяців участі в бойових діях з урахуванням виплати додаткової винагороди (100 000 грн щомісячно), яка визначена у ПКМУ від 22.02.2022 року №168, за етап безпосередньої участі в бойових діях на лінії бойового зіткнення. Право на отримання авансу грошового забезпечення військовослужбовець набуває тільки після отримання бойового розпорядження на виконання бойових завдань на лінії безпосереднього зіткнення. Запропонована модель надає можливість комплектувати ЗС України більш вмотивованими громадянами, зняти моральну напругу в сім'ях майбутніх військовослужбовців та вирішити їхні соціальні проблеми, наприклад, щодо придбання житла;

• гарантована відпустка за участь у бойових діях строком на 60 діб з виплатою військовослужбовцю матеріальної допомоги на оздоровлення у розмірі одного місячного грошового забезпечення. Як варіант, пропонується надання можливості військовослужбовцю (за рішенням командира) розділяти гарантовану відпустку за участь у бойових діях на дві частини. Першу частину гарантованої відпустки – після 6 місяців служби строком на 30 діб, а другу частину гарантованої відпустки строком на 30 діб надавати за 2 місяці перед звільненням з військової служби.

Таблиця 2. Види грошових виплат та їх орієнтовні суми, які будуть отримувати військовослужбовці у разі проходження військової служби за контрактом за принципом Timeline 1 (без урахування надбавки за вислугу років)

№ п/п	Види грошових виплат	Стрілець (грн)	Командир відділення (грн)	Командир взводу (грн)	Командир роти (грн)
1	Одноразова виплата за підписання контракту	100 000	100 000	100 000	100 000
2	Щомісячне грошове забезпечення				
	- за місяць	20 586	22 677	28 229	31 224
	- за рік	247 032	272 124	338 748	374 688
3	Додаткова винагорода за безпосередню участь у бойових діях				
	- за місяць	100 000	100 000	100 000	100 000
	- за 9 місяців	900 000	900 000	900 000	900 000
4	Одноразова додаткова винагорода за виконання бойових завдань під час ведення бойових дій на лінії бойового зіткнення за кожні 30 днів (сумарно обчислених)				
	- за кожні 30 днів	70 000	70 000	70 000	70 000
	- за 150 днів	350 000	350 000	350 000	350 000
5	Матеріальна допомога на оздоровлення (1 раз на рік під час використання відпустки)	20 586	22 677	28 229	31 224
6	Матеріальна допомога для вирішення соціально-побутових питань (1 раз на рік)	до 20 586	до 22 677	до 28 229	до 31 224
7	Вихідна допомога при звільненні (50% від місячного грошового забезпечення)	10 293	11 339	14 115	15 612
	Усього за рік:				
	- без урахування п. 4 таблиці	948 847	1 328 817	1 409 321	1 452 748
	- з урахуванням п. 4 таблиці	1 298 847	1 678 817	1 759 321	1 802 748
	Право на отримання авансу свого грошового забезпечення	500 000	500 000	500 000	500 000

Умови контракту за принципом Timeline 2 та соціальні гарантії військовослужбовцям за визначеною формою контракту.

Цю форму контракту можуть вибрати військовозобов'язані та громадяни України, які не перебувають на військовому обліку військовозобов'язаних (призовники, жінки). Громадяни зазначеної категорії матимуть право вибирати військову частину, яка безпосередньо виконує бойові завдання, та бути направленими до неї для проходження подальшої військової служби

після їх підготовки у навчальних центрах (підрозділах). Термін дії контракту за принципом Timeline 2 становитиме 3 роки з моменту його підписання та може бути продовжений тільки за згодою військовослужбовця та командира військової частини. Перед закінченням дії контракту передбачається надання можливості військовослужбовцям вибирати та укладати інші види контракту за принципом Timeline 1–Timeline 5.

Умови проходження військової служби за контрактом за принципом Timeline 2:

• 1–3 місяці військової служби за контрактом – підготовка в навчальних центрах (підрозділах) ЗС України та на базах військової підготовки країн – членів НАТО;

• 4–15 місяців військової служби за контрактом – участь у бойових діях безпосередньо на лінії бойового зіткнення, використовуючи систему ротацій всередині підрозділу;

• 16–18 місяців військової служби за контрактом – гарантована відпустка після участі в бойових діях;

• 19–26 місяців військової служби за контрактом – проходження військової служби в ППД військової частини;

• 27-ий місяць військової служби за контрактом – щорічна відпустка;

• 28–33 місяці військової служби за контрактом – участь у бойових діях безпосередньо на лінії бойового зіткнення, використовуючи систему ротацій всередині підрозділу;

• 34–35 місяців військової служби за контрактом – гарантована відпустка після участі в бойових діях;

• 36-ий місяць військової служби за контрактом – проходження військової служби в ППД військової частини, проходження ВЛК перед звільненням з військової служби та звільнення з військової служби.

Умови контракту за принципом Timeline 3 та соціальні гарантії військовослужбовцям за визначеною формою контракту.

Таку форму контракту можуть вибрати військовозобов'язані та громадяни України, які не перебувають на військовому обліку військовозобов'язаних (призовники, жінки). Громадяни зазначеної категорії матимуть право вибирати військову частину, яка безпосередньо виконує бойові завдання, та бути направленими до неї для проходження подальшої військової служби після їх підготовки у навчальних центрах (підрозділах). Термін дії контракту за принципом Timeline 3 становитиме 4 роки з моменту його підписання та може бути продовжений тільки за згодою військовослужбовця та командира військової частини. Під час проходження військової служби військовослужбовцю буде надаватися право розірвати контракт тільки за умови підписання ним нового контракту за принципом Timeline 2, а перед закінченням дії контракту передбачається надання можливості військовослужбовцям вибирати та укладати інші види контракту за принципом Timeline 1–Timeline 5.

Умови проходження військової служби за контрактом за принципом Timeline 3:

• 1–3 місяці військової служби за контрактом – підготовка в навчальних центрах (підрозділах) Збройних Сил України та на базах військової підготовки країн – членів НАТО;

• 4–15 місяців військової служби за контрактом – участь у бойових діях безпосередньо на лінії бойового зіткнення, використовуючи систему ротацій всередині підрозділу;

• 16–18 місяців військової служби за контрактом – гарантована відпустка після участі в бойових діях;

• 19–27 місяців військової служби за контрактом – проходження військової служби в ППД військової частини;

• 28-ий місяць військової служби за контрактом – щорічна відпустка;

• 29–34 місяці військової служби за контрактом – виконання бойових (спеціальних) завдань у період здійснення заходів, необхідних для забезпечення оборони України, захисту безпеки населення та інтересів держави;

• 35-ий місяць військової служби за контрактом – гарантована відпустка після участі в бойових діях;

• 36–46 місяців військової служби за контрактом – проходження військової служби в ППД військової частини;

• 47-ий місяць військової служби за контрактом – щорічна відпустка;

• 48-ий місяць військової служби за контрактом – проходження військової служби в ППД військової частини, проходження ВЛК перед звільненням з військової служби та звільнення з військової служби.

Умови контракту за принципом Timeline 4 та соціальні гарантії військовослужбовцям за визначеною формою контракту.

Цю форму контракту можуть вибрати військовозобов'язані та громадяни України, які не перебувають на військовому обліку військовозобов'язаних (призовники, жінки). Громадяни зазначеної категорії матимуть право вибирати військову частину, яка безпосередньо виконує бойові завдання, та бути направленими до неї для виконання бойових (спеціальних) завдань на 2-ій лінії бойового зіткнення після їх підготовки у навчальних центрах (підрозділах). Термін дії контракту за принципом Timeline 4 становитиме 5 років з моменту його підписання та може бути продовжений тільки за згодою військовослужбовця та командира військової частини. Під час проходження військової служби військовослужбовцю буде надаватися право розірвати контракт тільки за умови підписання ним нового контракту за принципом Timeline 2–Timeline 3, а перед закінченням дії контракту передбачається надання можливості військовослужбовцям вибирати та укладати інші види контракту за принципом Timeline 1–Timeline 5.

Умови проходження військової служби за контрактом за принципом Timeline 4.

1–2-ий роки проходження військової служби:

• 1–3 місяці військової служби за контрактом – підготовка в навчальних центрах (підрозділах) Збройних Сил України та на базах військової підготовки країн – членів НАТО;

• 4–15 місяців військової служби за контрактом – виконання бойових (спеціальних) завдань у період здійснення заходів, необхідних для забезпечення оборони України, захисту безпеки населення та інтересів держави;

• 16-ий місяць військової служби за контрактом – гарантована відпустка після участі у виконанні бойових (спеціальних) завдань у період здійснення заходів, необхідних для забезпечення оборони України, захисту безпеки населення та інтересів держави;

• 17–23 місяці військової служби за контрактом – проходження військової служби в ППД військової частини;

• 24-ий місяць – щорічна відпустка;

3–4 роки ідентичні за формою проходження служби, а саме:

• 6 місяців – виконання бойових (спеціальних) завдань у період здійснення заходів, необхідних для забезпечення оборони України, захисту безпеки населення та інтересів держави;

• 1 місяць – гарантована відпустка після участі у виконанні бойових (спеціальних) завдань на 2-ій лінії бойового зіткнення;

• 5 місяців – проходження військової служби в ППД військової частини;

5-ий рік проходження служби:

• 6 місяців – виконання бойових (спеціальних) завдань у період здійснення заходів, необхідних для забезпечення оборони України, захисту безпеки населення та інтересів держави;

• 1-ий місяць – гарантована відпустка після участі у виконанні бойових (спеціальних) завдань на 2-ій лінії бойового зіткнення;

• 5 місяців – проходження військової служби в ППД військової частини;

• останній місяць військової служби за контрактом – проходження військової служби в ППД військової частини, проходження ВЛК перед звільненням з військової служби та звільнення з військової служби.

Умови контракту за принципом Timeline 5 та соціальні гарантії військовослужбовцям за визначеною формою контракту.

Таку форму контракту можуть вибрати військовозобов'язані та громадяни України, які не перебувають на військовому обліку військовозобов'язаних (призовники, жінки). Громадяни зазначеної категорії матимуть право вибирати для проходження служби не бойову військову частину, яка безпосередньо не виконує бойові завдання, та бути направленими до неї після їх підготовки у навчальних центрах (підрозділах). Термін дії контракту за принципом Timeline 5 становитиме 7 років з моменту його підписання та може бути продовжений тільки за згодою військовослужбовця та командира військової частини. Під час проходження військової служби військовослужбовцю буде надаватися право розірвати контракт тільки за умови підписання ним нового контракту за принципом Timeline 1–Timeline 4, а перед закінченням дії контракту передбачається надання можливості військовослужбовцям вибирати та укладати інші види контракту за принципом Timeline 1–Timeline 5.

Умови проходження військової служби за контрактом за принципом Timeline 5.

• 1–3 місяці військової служби за контрактом – підготовка в навчальних центрах (підрозділах) ЗС України та на базах військової підготовки країн – членів НАТО;

• решта служби – проходження військової служби у не бойових частинах з правом отримання щорічної відпустки строком на 30 діб;

• останній місяць військової служби за контрактом – проходження військової служби в ППД військової частини, проходження ВЛК перед звільненням з військової служби та звільнення з військової служби.

Формування чіткої прозорої системи вибору способу проходження військової служби, тобто виконання свого конституційного обов'язку кожним громадянином, за визначеним підходом "timeline" є привабливою альтернативою наслідкам, які виникають у разі ухиляння від проходження військової служби, так званим "blackline" (штрафи, обмеження життєдіяльності, блокування рахунків у разі несплати штрафів, відсутність можливості перетину кордону та відпочинку за межами України, відсутність пільг та низький рівень соціального захисту родини тощо).

Надання громадянам України чітких, прозорих правил вибору проходження військової служби є ефективним способом комплектування людськими ресурсами в умовах війни.

Право вибору залишається за людиною, хочеш менше служити, більше заробляти та мати повний соціальний пакет від держави для себе, членів своєї сім'ї, тоді "timeline" 1 та 2 з найбільшими ризиками, але найбільшими свободами та прозорими перспективами. Якщо вибираєте менше ризиків для життя – тоді "timeline" 3, 4 та 5, які мають найдовші терміни служби, нижчі показники грошового забезпечення та мінімальну кількість свобод і привілей, але й ці варіанти проходження військової служби є конкурентоспроможною альтернативою потрапляння у ситуацію "blackline".

Третій етап методичного підходу (табл. 1) присвячений дослідженням щодо підвищення ефективності інформаційно-психологічного впливу на аудиторії як росії, так і України. Найважливішою умовою перемоги в сучасних війнах (збройних конфліктах) є завоювання переваги в інформаційній сфері з метою забезпечення переваги в морально-психологічному стані власних військ над військами противника. Перевага в морально-психологічному стані досягається насамперед завдяки більш ефективним заходам зі здійснення інформаційно-психологічного впливу на власні війська та війська противника.

Інформаційно-психологічний вплив – цілеспрямоване інформаційне втручання у свідомість (підсвідомість) цільової аудиторії з метою корекції її поведінки та (або) світогляду,

зміни морально-психологічного стану. Засобами інформаційно-психологічного впливу є ЗМІ, спеціальна друкована продукція, публічна голосова агітація, агентурна діяльність, спеціальні інформаційні технології тощо. Недосконалість інформаційно-психологічного впливу на свідомість громадян України дуже сильно впливає на проведення мобілізації в державі. Необхідно повністю змінити інформаційну політику шляхом підвищення її "агресивності" стосовно дій рф, періодичності, бажаності перегляду населенням країни певних ток-шоу (програм), створення принципу очікуваності новин про війну та противника, зниження пропаганди та актуалізації інформативності, відходу від однобічності та принципів звикання до однотипності подання інформації тощо. Основними заходами із забезпечення переваги над противником в інформаційно-психологічному впливі можуть бути:

аналіз способів і методів ведення інформаційної пропаганди (ІПСО) передових країн світу та країни-агресора з метою розширення спектра методів боротьби у медіа- та кіберпросторі;

вивчення пропозицій та розроблення рекомендацій щодо підвищення якості інформаційного впливу на свідомість громадян України, особливо щодо незворотності мобілізації, тобто:

формування загальних правил зміни інформаційної політики;

визначення заходів з удосконалення інформаційного простору щодо популяризації мобілізації та її незворотності;

розроблення механізмів залучення PR-агенцій для популяризації військової служби у ЗС України та рекламації (висвітлення традицій, бойового духу, професіоналізму тощо) окремої бойової частини (підрозділу);

створення відповідного контенту для ЗМІ та комунікаційної стратегії, спрямованої на формування попиту відповідної бойової частини (підрозділу).

Четвертий етап методичного підходу (табл. 1) передбачає дослідження щодо підвищення якості соціального захисту військовослужбовців. В умовах російської збройної агресії, що триває, економічної нестабільності та систематичної й планомірної трансформації України як держави європейського зразка питання щодо соціального захисту військовослужбовців постає досить гостро. Право на соціальне забезпечення як усього населення України, так і специфічних його верств є одним із непорушних і фундаментальних прав людини, що передбачене не лише Конституцією України, а й міжнародними нормативно-правовими актами, згода на обов'язковість яких надана Верховною Радою України.

Водночас, з огляду на особливості механізму соціального забезпечення, що передбачене низкою нормативно-правових актів, окремого дослідження потребує питання стосовно аналізу засад, що закладені у відповідних документах, а також щодо окремих особливостей їх застосування в процесі реалізації військовослужбовцями свого права на соціальний захист.

П'ятий етап методичного підходу (табл. 1) передбачає дослідження щодо удосконалення питань стосовно бронювання життєво необхідних для економіки та соціальної сфери України об'єктів критичної та енергетичної інфраструктури (критичною інфраструктурою вважаються стратегічно важливі підприємства та установи, які необхідні для функціонування суспільства та економіки країни (наприклад, підприємства енергетичної галузі, банківських установ, підприємства, які забезпечують безпосередньо виробництво озброєнь).

До критично важливих належать і ті установи, що забезпечують діяльність місцевої інфраструктури, наприклад, комунальні підприємства.

Повний перелік об'єктів державної власності, що мають стратегічне значення для економіки і безпеки держави, є в постанові Кабінету Міністрів № 83 від 4.03.2015 р. Крім підприємств, зазначених у переліку, до критично важливих можуть бути зараховані й інші підприємства.

Критерії визначення підприємств, які є критично важливими для функціонування економіки та забезпечення життєдіяльності населення в особливий період, зазначені у постанові Кабінету Міністрів № 76 від 27.01.2023 р. Проте наразі немає переліку підприємств, які є критично важливими для функціонування національної економіки та забезпечення життєдіяльності держави, перелік професій для бронювання є недосконалим.

Через те, що немає такого переліку, деякі посадові особи вдаються до маніпулювання щодо віднесення тієї чи іншої організації до критичної інфраструктури, що призводить до зайвого бронювання людей, і, як наслідок, зменшення потенціалу людських мобілізаційних ресурсів.

Для вирішення зазначеної проблеми пропонується розробити пропозиції щодо визначення переліку підприємств, які належать до об'єктів критичної та енергетичної інфраструктури, що є важливими для функціонування національної економіки та забезпечення життєдіяльності населення. Це спростить порядок бронювання військовозобов'язаних.

Обговорення (Discussions)

Запровадження концепції "timeline"-мобілізації в ЗС України є ключовим кроком у переході від примусової мобілізації до популяризації військової служби, що забезпечує право вибору для громадян в умовах війни. Цей підхід дозволяє більш ефективно комплектувати сили оборони України людськими ресурсами, підвищуючи мотивацію та знижуючи соціальну напруженість.

Висновок (Conclusion)

Основними висновками щодо реалізації технології "timeline"-мобілізації можна вважати те, що в силових структурах і в країні в цілому відбудеться:

підвищення мотивації через добровільність. Надання можливості громадянам добровільно вступати на військову службу та самим вибирати вид контракту сприятиме зростанню їхньої мотивації та готовності до захисту країни;

розширення інформаційних кампаній. Масштабні інформаційні кампанії та освітні програми формуватимуть позитивне ставлення до військової служби, особливо у молоді;

запровадження соціальних пільг. Додаткові соціальні пільги та бонуси стануть потужним стимулом для добровільного вступу на службу;

прозорість процедур мобілізації. Забезпечення прозорості процесу мобілізації підвищить довіру до військових інституцій та знизить рівень суспільної напруженості;

поліпшення умов служби. Підвищення якості умов служби та підготовки військовослужбовців збільшить привабливість військової кар'єри;

індивідуальний підхід до рекрутів. Якщо враховувати індивідуальні особливості та навички новобранців, можна більш ефективно використовувати людські ресурси;

психологічна підтримка. Надання психологічної підтримки військовослужбовцям та їхнім сім'ям сприятиме збереженню морального духу;

визнання заслуг. Система визнання та нагородження підвищить мотивацію та гордість за службу. Свідомий вибір контракту створює умови для того, щоб людина розуміла: чим більше вона ризикує, тим менше термін контракту, і водночас це найбільший фінансовий та соціальний пакет;

залучення ветеранів. Використовуючи досвід ветеранів, можна покращити підготовку новобранців і зміцнити зв'язок між поколіннями військовослужбовців. Створення дієвих ветеранських ХАБів;

підвищення соціального статусу військових. Формування позитивного образу армії та популяризація свідомого вибору контракту через медіа та громадські заходи сприятимуть підвищенню престижу військової служби;

гнучкість мобілізаційних планів. Адаптивні мобілізаційні плани допоможуть більш ефективно реагувати на змінні потреби армії. Упровадження “timeline”-мобілізації сприятиме створенню сучасної, мотивованої та ефективної армії, здатної забезпечити національну безпеку та захист інтересів України в умовах війни.

Recommendations (Рекомендації)

Нині слід зрозуміти: забезпечивши право вибору для громадян України у разі вступу на військову службу, можна підвищити мотивацію та знизити напруженість у суспільстві. Але цього вдасться досягти не тільки шляхом удосконалення системи залучення на військову службу (мобілізації), потрібна масштабна трансформація всього середовища призову та проходження військової служби як на рівні складових сил оборони України, так і на державному рівні.

Подальшими напрямами досліджень за тематикою статті є детальне розроблення пропозицій щодо удосконалення грошових виплат, які будуть отримувати військовослужбовці під час проходження військової служби за контрактом за принципом “timeline”-мобілізації, а також дослідження питань, що стосуються перегляду контрактів військовослужбовців, які вже виконують свій громадянський обов’язок у ЗС України та інших складових сил оборони держави.

На думку авторів, упровадження підходу на основі “timeline”-мобілізації сприятиме формуванню позитивного іміджу військової служби, підвищенню мотивації до добровільного вступу та забезпечить ефективне комплектування людськими ресурсами в умовах війни, бо за такого принципу підвищиться прозорість проходження військової служби.

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"Timeline"-mobilization – the path from coercion to the popularization of military service in war conditions: the right to choose – a method of effective staffing with human resources

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Abstract. The relevance of the article on the topic of increasing the effectiveness of mobilization in Ukraine is beyond doubt today. The introduction of the so-called "timeline" principles of mobilization by the authors consists in the analysis of changes in the approaches to mobilization during the war, in particular, the transition from forced mobilization to the popularization of military service and giving conscripts the right to choose the format of service according to the principle: "the more you risk, the less you serve, but you have the largest financial and social package for yourself and your family, and vice versa." This study highlights the importance of providing citizens with choice, which contributes to effective staffing and increasing the morale of military personnel. In the conditions of the ongoing Russian-Ukrainian war, this approach is critically important for Ukraine, as it allows strengthening the country's defense capabilities through the involvement of motivated and conscious volunteers. That is why the main goal of the article was chosen - to identify the existing problems of mobilization processes in Ukraine today and to find ways to improve the current mechanisms of equipping the Armed Forces of Ukraine with human resources in war conditions. One of the ways the authors have chosen is the implementation of the "timeline"-mobilization system in Ukraine, which, according to the authors, will contribute to the formation of a positive image of military service, increase the motivation for voluntary enlistment, and ensure effective staffing with human resources in conditions of war. The main methods of research are the methods of "brainstorming", analysis and synthesis, deduction and induction. The main results of the article are that it: formed the actual problems of the current mechanisms of staffing the Armed Forces of Ukraine with human resources during mobilization in war conditions; a methodical approach to conducting research in the direction of increasing the effectiveness of mobilization in Ukraine is proposed; the project of the latest model of military service under a contract based on the "timeline"-mobilization principle is proposed; variants of military service under a contract during martial law have been created; an approach to determining additional social guarantees for military personnel during service under a contract based on the "timeline" principle is proposed. The materials of the article can be useful for the leadership of the components of the Defense Forces of Ukraine and the state as a whole, as well as for scientists and researchers in the areas of research on issues of staffing and mobilization in the Armed Forces of Ukraine.

Keywords: military service options, effectiveness of mobilization and recruitment, Armed Forces of Ukraine, information influence, human resources, model of the "timeline"-mobilization system, methodical approach, armed aggression, social protection of servicemen, defense capability, mobilization, national security, Russian-Ukrainian war, rotation, recruiting, state defense forces.

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Analysis and assessment of economic losses during the Russian-Ukrainian war

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Abstract. The relevance of the article is stipulated by the need to study the issues of Ukraine's economic losses as a result of russia's aggression with a view to further developing recommendations for Ukraine's post-war recovery.

The article analyses the main indicators which, in the authors' opinion, are crucial for determining the country's economic losses in the long-term perspective. In particular, the first significant indicator that can describe economic losses is the loss of territory. The loss of territory as a result of hostilities and its occupation has an immediate and long-term impact on the country's economy, as it reduces its potential for development and wealth creation. Another indicator that is closely related to the loss of territory is human losses. This can occur due to death, injury or migration of the population. The negative demographic situation affects the labour market, as there is a lack of personnel, in particular for the security and defence forces, and thus our resilience to the enemy is weakened; and the budget structure, which will change, as it will be necessary to increase expenditures for the older population's maintenance, etc. This is important when determining the country’s GDP, as this indicator shows the market value of all final goods and services produced in a year in all economy’s sectors in the state’s territory for consumption, export and accumulation. In

other words, GDP is largely determined by the country's population and land area. To provide a more comprehensive picture of Ukraine's economy and its losses, the article presents the dynamics of Ukraine's public debt compared to GDP.

The identified trends have made it possible to identify three sharp deterioration waves in the economic situation in Ukraine over the past ten years, which are associated with both a decrease in Ukraine's population and loss of territory, as well as a reduction in GDP. The first period was in 2014, and is associated with the occupation of Crimea and certain areas of Donetsk and Luhansk regions. The second period (2020) is the COVID-19 pandemic result. The third period (2022) is mainly caused by russia's full-scale invasion of Ukraine.

Areas for further research could include formalising the relationship between GDP and the country's population and the area of lost territory, as well as developing recommendations for improving the economic situation in Ukraine during the reconstruction period after the cessation of hostilities.

Keywords: national debt, demography, economic losses, GDP, loss of territory, population.

Introduction

The economic losses of a country as a result of war can be described by various indicators that cover a wide range of economic aspects. In particular, such indicators include: the growth or decline in gross domestic product (hereinafter - GDP), which will be determined by the intensity of production, investment and consumption; budget deficit, which may occur due to increased defence spending and reduced tax revenues; inflation, which may be significant due to higher prices for goods and services due to reduced supply and disruption of logistics chains; unemployment, which may increase due to the destruction of enterprises, loss of jobs and evacuation of the population; the volume of direct foreign investments which may decrease due to the increasing risks and uncertainty; trade balance which may worsen due to the decreasing export and increasing import of necessary goods (for example military materials and supplies); external debt which may increase due to the necessity to involve financial resources to cover the budgets` deficiency and defence financing; infrastructure damages which may be considerable due to the destruction of transport, energetic and municipal infrastructure, what requires significant spends for reconstruction; economic structure which may change if the reorientation of manufacture and economic activity happens for war-time needs that may lead to the degradation of civil economy sectors, etc.

It should be noted that, according to the authors, the main factors that affect the economic losses of a country are human losses that can occur due to death, injury or migration of the population, as well as the loss of territory as a result of hostilities.

Therefore, in order to assess economic losses, the authors believe that a detailed study of such factors as the number of people, the area of lost territories and GDP is necessary, which will allow to assess the overall impact of the war on the country's economy.

The current situation in the world prompted the study of determining losses problems in Ukraine. In general, quite a few publications have been devoted to this issue. In particular, since 2022, the analytical team of the Kyiv School of Economics has been periodically assessing the damage to Ukraine's economy caused by the destruction resulting from russia's armed aggression against Ukraine. This assessment is carried out within the framework of the National Council for the Recovery of Ukraine from the Consequences of Armed Aggression jointly with the Ministry of Community Development, Territories and Infrastructure, the Ministry of Economy, the Ministry of Health of Ukraine, under the coordination of the Ministry for the Reintegration of the Temporarily Occupied Territories of Ukraine and in cooperation with other relevant ministries and the National Bank of Ukraine (Damage to Ukraine's infrastructure as of 2022, 2022; Damage to the infrastructure of Ukraine as of 2023, 2023; Damage to the infrastructure of Ukraine as of 2024, 2024; Report on

direct infrastructure damage, indirect economic losses from the destruction caused by russia's military aggression against Ukraine, and a preliminary assessment of Ukraine's needs for financing the recovery, 2022; Report on direct losses of infrastructure from destruction as a result of russia's military aggression against Ukraine as of 1 September 2022, 2022; Report on direct losses of infrastructure from destruction as a result of russia's military aggression against Ukraine for the year since the beginning of the full-scale invasion, 2023; Report on direct infrastructure damage and indirect economic losses from destruction as a result of russia's military aggression against Ukraine as of June 2023, 2023; Report on direct infrastructure losses from destruction as a result of russia's military aggression against Ukraine as of the beginning of 2024, 2024). The assessment is based on the World Bank's methodology, which provides for the determination of direct damages - a cost estimate of the damage caused to Ukraine's physical infrastructure as a result of armed aggression (complete or partial destruction), as well as indirect damages – a cost estimate of changes in economic flows as a result of armed aggression, namely: loss of income in various sectors of the economy, additional costs associated with the war, and future losses incurred by the economy as a result of the war.

In addition, the Government of Ukraine, together with the World Bank, conducted a number of damage assessments and reconstruction needs in Ukraine due to russian aggression and presented their vision of losses and their cost estimates (Ukraine First Rapid Damage and Needs Assessment (RDNA1), 2022; Ukraine Second Rapid Damage and Needs Assessment (RDNA2), 2023; Ukraine Third Rapid Damage and Needs Assessment (RDNA3), 2024).

It should be noted that in 2022, the Cabinet of Ministers of Ukraine adopted Resolution

No. 326 of 20.03.2022 "On Approval of the Procedure for Determining Damage and Losses Caused to Ukraine as a Result of the Armed Aggression of the russian federation" (Resolution of the Cabinet of Ministers of Ukraine of 20.03.2022. № 326, 2022), and the Ministry of Economy of Ukraine, accordingly, developed a methodology for determining economic losses related to human losses, including Indirect economic losses associated with a decrease in population and a corresponding decrease in the country's economic indicators caused to Ukraine as a result of the armed aggression of the russian federation (Order of the Ministry of Economy of Ukraine of 02.11.2022. № 4363, 2022). These regulations are designed to determine damage and losses in monetary terms and establish general approaches to assessing economic losses related to human losses, including indirect economic losses associated with a decrease in population and a corresponding decrease in the country's economic performance caused to Ukraine as a result of the armed aggression of the russian federation.

In addition to reports, studies, and regulations at the state level, there are many other publications devoted to the analysis of the country's losses during the hostilities (Nykoliuk, Pyvovar, Nazarkina, Stolnikovych, Bohonos, 2023; Semenenko, Chernyshova, Taran, Kaplia, Musiienko, VPoberezhets, 2022; Khomutenko, Khomutenko, 2023; Bohdan, 2024; Marko, Chernyshova, 2019). However, the study of Ukraine's economic losses in terms of the relationship between human losses, losses of the country's territory and its GDP is not fully disclosed and needs to be clarified.

Thus, the purpose of this study is to examine Ukraine's economic losses in terms of the interconnection of human losses, losses of the country's territory and GDP.

Methodological Framework

The proposed study is based on empirical research methods, such as comparison, analysis, synthesis, induction and deduction. An economic and statistical analysis of the demographic situation in Ukraine, its territory and key economic indicators is carried out: GDP and national debt. The author constructed a series of dynamics of these indicators and identified the main trends in their change, which made it possible to comprehensively study the change in Ukraine's economic losses and draw appropriate conclusions about the current situation in the country. To illustrate the results, the author

uses the graphical method and builds relevant diagrams and graphs.

Results and Discussions

It is clear that the loss of territories has a significant impact on the state's economy, since the loss of territory means: loss of natural resources, namely access to minerals, forests, water resources and other natural resources that could bring economic benefits; loss of agricultural land, which can reduce the production of food and other agricultural products; loss of infrastructure (infrastructure facilities), namely, roads, bridges, power plants, water pipes, etc., which are important for economic activity; loss of production facilities, namely, plants, factories and other production facilities located on the lost territory; loss of housing stock, namely residential buildings and other real estate, which affects the real estate market and living conditions of the population; loss of businesses and enterprises, namely the loss of small, medium and large businesses that operated in the occupied territory, which leads to a decrease in tax revenues and overall economic activity; loss of tourism (tourist sites and territories), which leads to a decrease in tourism revenues; loss of markets and logistics routes, which requires reconfiguring economic ties and logistics routes due to the loss of territories, which may lead to additional costs. Thus, the loss of territory has an immediate and long-term impact on a country's economy, reducing its potential for development and wealth creation.

The total area of Ukraine's territory is 603,628 km², i.e. 5.7% of Europe and 0.44% of the world (Website of the State Service of Ukraine for Geodesy, Cartography and Cadastre). In terms of this indicator, it is the largest country located entirely in Europe and the second largest among the continent's countries after the russian federation. The territory of Ukraine stretches from west to east for 1316 km and from north to south for 893 km. Table 1 shows Ukraine's territory and population by region as of 2001 (Website of the State Statistics Service of Ukraine. Population). This year was chosen because it was the year of the All-Ukrainian Population Census. It was carried out in accordance with the resolution of the United Nations Economic and Social Council of 19.07.1995 on the conduct of national population censuses by UN member states in the period 1995-2004. It was the first national census since the previous one was conducted in 1989, on the eve of Ukraine's independence.

Thus, the total population of Ukraine, according to the All-Ukrainian Population Census, was 48 million 457 thousand people (Website of the State Statistics Service of Ukraine. Population). As can be seen from the table, Ukraine is characterised by a high population density, according to the All-Ukrainian Census, with a national average of 80 $^{people/km2}$. The lowest population density is in the north-west and south of the country, where it was less than 60 $^{people/km2}$. This figure is particularly low in Chernihiv region – 39 $^{people/km2}$. The eastern industrial regions are the most densely populated, with a population density of over 90 $^{people/km2}$, and in Donetsk region it reached 183 $^{people/km2}$. A decrease in population in 2001 compared to 1989 occurred in the vast majority of the country's regions, with the exception of Volyn, Zakarpattia, Rivne, and Kyiv, where this indicator remained almost at the level of 1989.

Unfortunately, since March 2014, certain parts of the territory of Ukraine have been occupied by the russian federation, namely: The Autonomous Republic of Crimea and Sevastopol and part of Kherson region (part of the Arabat Spit, the Ad Peninsula (Chaplynka district), Chonhar Peninsula (Henichesk district)). In April 2014, Ukraine's control temporarily ceased to extend to parts of Donetsk and Luhansk regions. After the full-scale russian invasion in February 2022, other territories were added to these areas, including parts of Kherson, Kharkiv, Zaporizhzhia, Mykolaiv, Dnipro, Sumy and Odesa regions.

By the end of autumn 2023, representatives of the Commander-in-Chief of the Armed Forces of Ukraine's Office released information that the aggressor state had occupied 109,000 ^{km2} of Ukraine's territory out of 603,600 ^{km2}, while the Armed Forces of Ukraine had liberated about 39,000 ^{km2} since the beginning of the full-scale invasion (Taranenko, 2023).

The dynamics of the loss of Ukrainian territory as a result of russia's occupation is shown in Table 2. Thus, five regions of Ukraine and the Autonomous Republic of Crimea are currently under partial occupation. In particular, Luhansk (26.3 thousand km^2, or 98% of the territory), Zaporizhzhia (19.6 thousand km^2, or 73%), Kherson (20.5 thousand km^2, or 72%), Donetsk (15.07 thousand km^2, or 57%), and Kharkiv (603 km^2, or 2%). russia also maintains full control over the Ukrainian peninsula of Crimea, which is 26.9 thousand km^2 of territory (Taranenko, 2023). We should also note the de-occupied territories that were occupied by russia at the beginning of the full-scale invasion and later returned by Ukrainian troops, namely 14 thousand km^2 - parts of Chernihiv and Sumy regions; 12 thousand km^2 - north and east of Kharkiv region; 7 thousand km^2 - north of Kyiv region; 6 thousand km^2 - parts of Mykolaiv region and the right-bank part of Kherson region. In total, 39 thousand km^2 have been cleared. The change in the territory of Ukraine occupied by russia since its independence is shown in Fig. 1.

Table 1. Ukraine`s territory and its population by regions

Region	Area		Population			
	year 1992 (km^2)	% of the total area	year 2001 (thousand people)	% of the total in 2001	year 1989 (thousand people)	2001 in % to 1989
Autonomous Republic of Crimea	26 081	4,32%	2033,7	4,20%	2063,6	99%
Vinnytsia oblast	26 513	4,39%	1772,4	3,66%	1932,6	92%
Volyn oblast	20 144	3,34%	1060,7	2,19%	1061,2	100%
Dnipropetrovsk oblast	31 974	5,30%	3567,6	7,36%	3881,2	92%
Donetsk oblast	26 517	4,39%	4841,1	9,99%	5332,4	91%
Zhytomyr oblast	29 832	4,94%	1389,5	2,87%	1545,4	90%
Zakarpattia oblast	12 777	2,12%	1258,3	2,60%	1252,3	100%
Zaporizhzhia oblast	27 180	4,50%	1929,2	3,98%	2081,8	93%
Ivano-Frankivsk oblast	13 928	2,31%	1409,8	2,91%	1423,5	99%
Kyiv oblast	28 131	4,66%	1827,9	3,77%	1940	94%
Kirovohrad oblast	24 588	4,07%	1133,1	2,34%	1239,4	91%
Luhansk oblast	26 684	4,42%	2546,2	5,25%	2862,7	89%
Lviv oblast	21 833	3,62%	2626,5	5,42%	2747,7	96%
Mykolaiv oblast	24 598	4,08%	1264,7	2,61%	1330,6	95%
Odesa oblast	33 310	5,52%	2469	5,10%	2642,6	93%
Poltava oblast	28 748	4,76%	1630,1	3,36%	1753	93%
Rivne oblast	20 047	3,32%	1173,3	2,42%	1169,7	100%
Sumy oblast	23 834	3,95%	1299,7	2,68%	1432,7	91%
Ternopil oblast	13 823	2,29%	1142,4	2,36%	1168,9	98%
Kharkiv oblast	31 415	5,20%	2914,2	6,01%	3195	91%
Kherson oblast	28 461	4,71%	1175,1	2,43%	1240	95%
Khmelnytska oblast	20 645	3,42%	1430,8	2,95%	1527,1	94%
Cherkasy oblast	20 900	3,46%	1402,9	2,90%	1531,5	92%
Chernivtsi oblast	8 097	1,34%	922,8	1,90%	938	98%
Chernihiv oblast	31 865	5,28%	1245,3	2,57%	1415,9	88%
Kyiv	839	0,14%	2611,3	5,39%	2602,8	100%
Sevastopol	864	0,14%	379,5	0,78%	395	96%
Total	603 628	100%	48457,1	100%	51706,6	94%

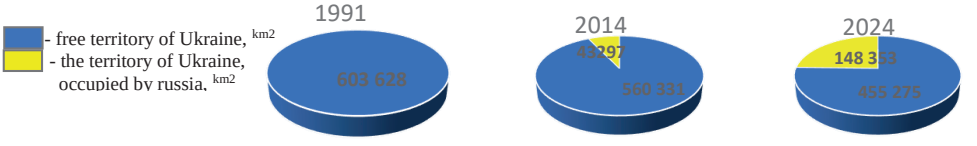


Figure 1. Dynamics of changes in Ukraine's territory

Thus, the data analysis shows that in 2014, 43,300 km², or 7% of Ukrainian territory, was under temporary russian occupation. After the full-scale russian invasion in 2022, this area increased by 2.9 times (Taranenko, 2023).

To get a full picture of the losses, let's analyse the dynamics of population losses in Ukraine compared to 2001. Table 3 shows the change in population in 2010, 2015 and 2022 compared to 2001 (Website of the State Statistics Service of Ukraine. Population).

Table 2. Dynamics of losses of the territory of Ukraine as a result of the russian occupation

Region	Occupation date	Area (km²)	% losses by area of the region	% loss of total area
Autonomous Republic of Crimea	20.02.2014–	26 945	100%	4,46%
Donetsk oblast (ORDLO)	07.04.2014–	15 075	57%	2,5%
Luhansk oblast (ORLO)	29.04.2014–	26 256	98%	4,35%
Kharkiv oblast	24.02.2022–	603	2%	0,10%
Zaporizhzhia oblast	24.02.2022–	19 861	73%	3,29%
Kherson oblast	24.02.2022–	20 492	72%	3,39%
Chernihiv and Sumy oblasts	24.02.2022–06.04.2022	13 996	25%	2,32%
North and east Kharkiv oblast	24.02.2022–08.09.2022	12 024	38%	1,99%
North of Kyiv oblast	24.02.2022–04.04.2022	7 096	25%	1,18%
Parts of Mykolaiv oblast and the right-bank part of Kherson oblast	26.02.2022–11.11.2022	6 005	11%	0,99%
Returned		39 121		6,48%
Lost and not returned		109 232		18,10%
Total lost		148 353		24,58%

The dynamics of population change is shown in the form of a graph in Fig. 2 (Website of the State Statistics Service of Ukraine. Population).

Thus, over the past 10 years, Ukraine's population has declined by almost 40%. In particular, in 2013, the population of Ukraine was probably 45.5 million people. This figure is likely to be overestimated by several million, as no census was conducted and many factors were not taken into account. After 2013, there were events that had a negative impact on the population of the country. These events can be divided into three periods. The first period (2014-2016): the number of people decreased as a result of the occupation of Crimea and part of Donbas, as well as the first wave of migration abroad. The second period (2019-2021): the decline in Ukraine's population was caused by the pandemic and intense migration. The third period began with russia's full-scale invasion of Ukraine. Taking into account the research of the Institute of Demography on the migration of the

Ukrainian population (Website of the Ministry of Social Policy of Ukraine), it can be argued that in 2016 the population of Ukraine decreased to 42.7 million people, in 2021 the country had 37 million people. Thus, from 2013 to 2021, the country's population decreased from 45 million to 37 million, or by 8 million people, or 18%. From 2021 to 2024, Ukraine's population decreased from 37 million to 31 million, or by another 6 million people, or 12%. In other words, in total, over the past ten years, Ukraine is likely to have lost 14.5 million people, or a 30% decline in its population. The main reasons for this decline are natural decline, migration, population under occupation, pandemic, and losses during hostilities. It should also be noted that the decline in the economically active population is faster than the decline in the country's population as a whole. This is natural, as active and able-bodied people migrate. Pensioners tend to stay at home. Thus, russia's full-scale invasion has worsened Ukraine's demographics and intensified the negative trends in Ukraine's population that were observed even before the military aggression.

Table 3. Population change in Ukraine by regions

Region	year 2001	year 2010	2010 as a % of 2001	year 2015	2015 as a % of 2001	year 2022	2022 as a % of 2001
Vinnytsia oblast	1772,4	1649,48	93%	1610,6	91%	1507,74	85%
Volyn oblast	1060,7	1036,52	98%	1042,9	98%	1020,77	96%
Dnipropetrovska oblast	3567,6	3353,53	94%	3276,6	92%	3093,15	87%
Donetsk oblast	4841,1	4463,08	92%	4297	89%	4056,41	84%
Zhytomyr oblast	1389,5	1285,04	92%	1256	90%	1177,56	85%
Zakarpattia oblast	1258,3	1244,88	99%	1259,6	100%	1243,72	99%
Zaporizhzhia oblast	1929,2	1810,39	94%	1765,9	92%	1636,32	85%
Ivano-Frankivsk oblast	1409,8	1380,55	98%	1382,6	98%	1350,57	96%
Kyiv oblast	1827,9	1721,04	94%	1729,2	95%	1795,54	98%
Kirovohrad oblast	1133,1	1017,05	90%	980,6	87%	902,28	80%
Luhansk oblast	2546,2	2309,49	91%	2220	87%	2101,65	83%
Lviv oblast	2626,5	2548,90	97%	2537,8	97%	2476,11	94%
Mykolaiv oblast	1264,7	1188,92	94%	1164,3	92%	1090,49	86%
Odesa oblast	2469	2390,03	97%	2396,4	97%	2349,75	95%
Poltava oblast	1630,1	1498,47	92%	1449	89%	1350,56	83%
Rivne oblast	1173,3	1151,69	98%	1161,2	99%	1140,90	97%
Sumy oblast	1299,7	1171,03	90%	1123,4	86%	1034,36	80%
Ternopil oblast	1142,4	1088,32	95%	1069,9	94%	1020,95	89%
Kharkiv oblast	2914,2	2767,46	95%	2731,3	94%	2596,25	89%
Kherson oblast	1175,1	1092,83	93%	1067,9	91%	1000,37	85%
Khmelnytskyi oblast	1430,8	1333,15	93%	1301,2	91%	1227,47	86%
Cherkasy oblast	1402,9	1294,39	92%	1251,8	89%	1159,20	83%
Chernivtsi oblast	922,8	904,19	98%	910	99%	889,93	96%
Chernihiv oblast	1245,3	1108,63	89%	1055,7	85%	957,67	77%
Kyiv	2611,3	2785,29	107%	2888	111%	2950,70	113%
Autonomous Republic of Crimea	2033,7	1964,99	97%				
Sevastopol	379,5	380,5	100%				
Total	48475,1	45939,82	95%	42928,9*	93%*	41130*	89%*

* - without the population of the temporarily occupied territory of the Autonomous Republic of Crimea and the city of Sevastopol.

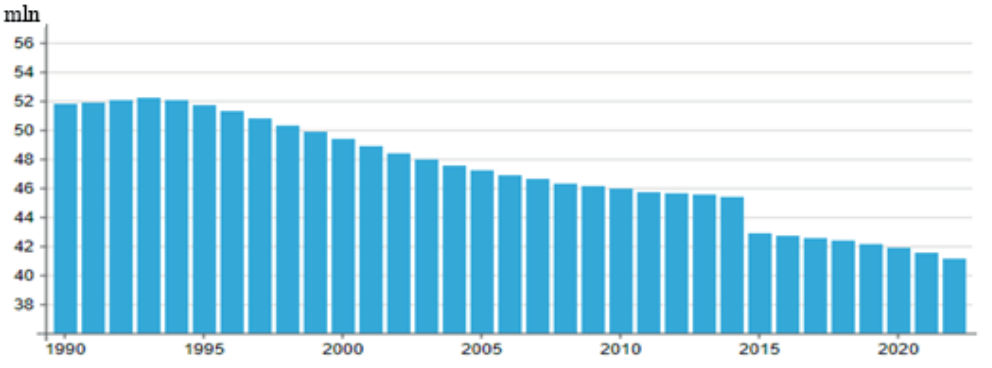


Figure 2. Dynamics of changes in the population of Ukraine

As of 2024, according to the Institute of Demography, 31 million people live in the government-controlled territory of Ukraine. Another 4.1 million live in the territories temporarily occupied by russia, about 4.9 million in the European Union and North America, and deportees to russia and Belarus (Website of the Ministry of Social Policy of Ukraine).

The demographic situation in Ukraine as of 2024 is shown in Fig. 3 (Website of the Ministry of Social Policy of Ukraine).

Thus, Ukrainians go abroad primarily because of hostilities on the territory of their country. And a significant number of them do not plan to return. According to various estimates, between 1.4 and 2.3 million Ukrainians plan to stay abroad. The negative impact of the current demographic situation is already evident. It affects the labour market, in particular, the shortage of personnel for the security and defence forces, which means that our resilience to the enemy is weakening; as well as the budget structure, which will change as it will be necessary to increase spending on the maintenance of older people, etc.

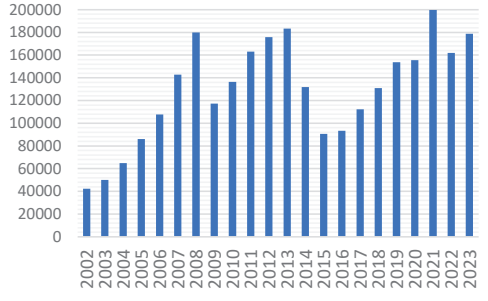


Source: Institute of Demography and Social Studies. Centre for Economic Strategy

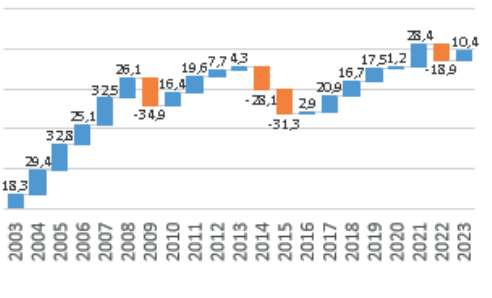
Figure 3. Distribution of the population of Ukraine as of 2024

The next step is to study changes in Ukraine's GDP. In general, gross domestic product (GDP) refers to a macroeconomic indicator that shows the market value of all final goods and services produced in a year in all sectors of the economy in the territory of a state for consumption, export, and accumulation, regardless of the nationality of the factors of production used (Website of the Ministry of Finance of Ukraine). A distinction is made between nominal and real GDP. Nominal, or absolute, GDP is determined in current (actual) prices of a given year. Real GDP (adjusted for inflation) is determined in the prices of the previous (or any other base) year. Real GDP thus takes into account the extent to which GDP growth is reflected in real output growth rather than price growth. If necessary, a country's GDP can be additionally converted into a foreign currency (most often into US dollars). The dynamics of nominal GDP in dollars, according to the World Bank and the IMF (Ukraine Third Rapid Damage and Needs Assessment (RDNA3), 2024), is shown in Fig. 4. Also, Fig. 4 also shows the change in GDP as a percentage of the previous year.

The full-scale invasion caused large-scale damage to the Ukrainian economy and led to a rapid decline. In 2022, the national product shrank by almost a third (28.8% of real GDP). The biggest drop occurred in the second quarter of 2022, when parts of Kyiv region and northern Ukraine were temporarily occupied. At that time, GDP fell by 36.9%. This was due to the loss of production capacity, human capital, and national savings. As already mentioned, more than 6 million refugees fled to other countries, almost 5 million people became internally displaced, and more than a million men were mobilised into the Armed Forces of Ukraine. This resulted in job losses, lower incomes, and a decrease in the purchasing power of the population. However, the economy began to show signs of recovery in the third quarter of 2022. This was primarily due to businesses and households adapting to the changes and resuming consumption. As a result, in 2023, the Ukrainian economy grew by 10% after falling by 19% in 2022. The receipt of sufficient external financial assistance helped to resolve the issue of currency stability. The main driver of economic growth in the first half of 2023 was a strong recovery in private consumption amid stabilisation in the foreign exchange market and expectations of a successful counter-offensive. In the second half of the year, the economy was supported by a good harvest, no electricity shortages, and a recovery in seaport exports.



Nominal GDP of Ukraine for 2002-2023, million USD



Change in Ukraine's GDP compared to the previous

Figure 4. Nominal GDP growth in Ukraine in 2002-2023

It is worth noting that, alongside the gradual recovery of Ukraine's economy, there is another problem, namely the changing structure of the economy. In recent years, the share of public spending has been increasing in the overall picture. While in 2021, the share of public administration in our country's economy was only 7%, last year it reached approximately 26%. At the same time, the share of the extractive industry fell by about half - from 8% to 4%, agriculture dropped from 12% to 8%, and even IT and telecommunications declined from 5% to 3%. Thus, a significant share of GDP is

provided by government spending, which, in turn, is supported by aid and loans from partners, amounting to USD 42 billion in 2023 (Website of the Ministry of Finance of Ukraine). The simultaneous economic downturn and rising borrowing have led to a rapid change in the volume of public debt.

Public debt is the total debt obligations of the state to all creditors (legal entities and individuals, foreign states, international organisations, etc.) The public debt consists of the debt of the central government, regional and local authorities, as well as the debt of all corporations with state participation, in proportion to the state's share in their capital (Website of the Ministry of Finance of Ukraine).

In particular, in 2023, the public debt is already 85% of GDP, while in 2021 the debt was less than 49%. The total amount of public debt at the beginning of 2024 reached USD 145.3 billion, which is about UAH 5.6 trillion. According to IMF predictions, Ukraine's public debt will continue to grow and may reach 100% of GDP in 2025. The dynamics of Ukraine's public debt is shown in Figure 5 (Website of the Ministry of Finance of Ukraine).

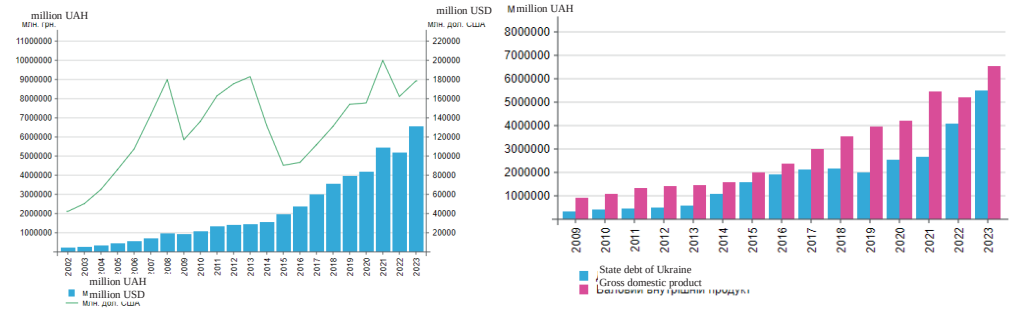


Figure 5. Dynamics of Ukraine's public debt in 2002-2023

As international experience shows, in general, debt is not a problem in itself. However, foreign borrowing should be linked to real investment and aimed at solving the country's off-budget problems. Unfortunately, foreign borrowings in Ukraine are currently used to solve defence and social problems that are directly related to the budget. Therefore, in the future, there is likely to be a need for new loans to service the external debt. This will have negative consequences for both financial sustainability and debt security of the state.

Conclusion

In summary, the analysis of Ukraine's economic losses over the past ten years has shown that:

firstly, there have been three waves of sharp deterioration in the economic situation in Ukraine, which are associated with both a decline in Ukraine's population and loss of territory, and a decline in GDP. The first period began in 2014 and is associated with the occupation of Crimea and certain districts of Donetsk and Luhansk regions. The second period (2020) is the result of the COVID-19 pandemic. The third (2022) is the full-scale russian invasion of Ukraine;

secondly, Ukraine's economic losses are mainly caused by active hostilities. The consequence of such actions is not only actual destruction or direct damage to Ukraine's physical infrastructure, but also a decrease in the country's territory and population, which directly affects Ukraine's GDP;

thirdly, in order to eliminate the negative consequences in Ukraine in the form of a deteriorating economic situation, it is necessary to comprehensively address the current problems.

In our opinion, the rapid development of Ukraine's economy is possible only if, on the one hand, the hostilities cease and most of the occupied territories are returned, which should be implemented

both militarily and through the art of diplomacy; on the other hand, the demographic problems in Ukraine are resolved, which requires not only the cessation of hostilities but also the search for ways to create conditions for increasing the birth rate in the country and reducing premature mortality, as well as changing the migration trend and ensuring migration growth.

Further research could be aimed at formalising the relationship between GDP and the country's population and lost territory, as well as developing recommendations for improving the economic situation in Ukraine during the post-conflict reconstruction period.

Recommendations

The materials of the article can be used as an integral part of the analysis of the economic situation in Ukraine over the past ten years, as well as in the formation and implementation of the country's economic, demographic and military-economic policies. The article may be useful to scholars and analysts involved in the development of forecasts, elaboration and justification of decisions on the development of the state.

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