The object of research is the process of formation of a network structure and a new, non-hierarchical method of coordinating the links of assessing the society national security level, based on the triple helix concept. The triple helix (network interaction of science, business and the state) is presented as a universal institutional matrix for an innovative type of growth and conditions for continuous updates of the relationships of the political, social and economic part of the society national security level. From these positions, the concept of the triple helix allows to form the principles of managing the society national security level under the conditions of interaction of its parts. In this case, the main indicators of national security are taken into account. The economic and social situation at the local level directly affects the stability, manageability, civic cohesion and the country's ability to resist external and internal threats. The proposed models provide the formation of the national security level integrated indicator model through the main factors of the political, social and economic components. The conducted studies provide a more objective assessment of "preventive" security measures in the context of providing data from state bodies and operational information from law enforcement agencies. At the same time, both quantitative and qualitative assessments of the national security level are taken into account, which provides confidence in ensuring the national security level of the state as a whole. The proposed method for assessing the national security level is based on a model for calculating the integral indicator of the regional society national security level, which ensures timely intervention by authorities and state institutions in stabilizing and/or increasing the national security level. Thus, at the beginning of 2022 in Lviv (Ukraine) it was 65.75 (stable region), in Mariupol (Ukraine) – 32.75 (before occupation, risk to security)

Keywords: triple helix, clusters, national security system, integral assessment indicator

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DEVELOPMENT OF A METHOD FOR ASSESSING THE SOCIETY NATIONAL SECURITY LEVEL BASED ON THE TRIPLE HELIX CONCEPT

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1. Introduction

The mass distribution of modern information and communication systems (ICS) has significantly increased the information capacity of the world, which in turn has formed socio-cyber-physical systems. The emergence of such systems has significantly expanded the range of digital services, on the one hand. On the other hand, it has complicated their

organization, including the formation of security on each of the platforms (social, management and physical). Thus, their development on the basis of smart technologies, Internet of Things and classical ICS and technologies (ICST) forms the principles of building security (political, social, economic) of society, which as a result affects its national security. The main feature of the information society is not so much the dominance of information as the network logic of its use, which gives the disseminated information special qualities and functions. This approach requires continuous updates in the formation and provision of the necessary level of national security with a certain institutional environment, where horizontal network connections prevail. It is in such an environment that modern clusters are formed, designed to generate innovations in the formation of intellectual security systems for each of the components of national security. The concept of a triple partnership of universities (science), business and government, known as the Triple Helix Model, appeared in the mid-1990s as a synthesis of the institutional views of sociologists and biological analogy. In works [1, 2] the concept of the triple helix is presented as a hybrid social construction that has the advantages of the DNA molecule (cohesion of spiral structures) and increased adaptability to changes in the external environment. In work [3] the concept forms regional clusters and ensures the generation of innovations in national innovation systems. In addition, the concept of the triple helix is used in the decisions of the Baltic Development Forum and EU strategic documents as a new approach to the processes of integration and the creation of a single knowledge market [4]. Thus, the use of the concept of the triple helix in various areas allows for the formation of a new mechanism for achieving consensus, capable of ensuring the self-development of complex network systems in the conditions of globalization and digitalization of society. Mass online contacts have nullified social distances, giving rise to a situation of continuous changes, which is often perceived as the "tyranny of the moment" [4]. In [5], models based on systems of linear homogeneous and inhomogeneous differential equations with constant and variable coefficients, defined in interval form, which can be used in dynamic assessment systems, are considered. In [6], the possibilities of critical assessment of the relationship between geographical clustering and state policy are considered, which confirms the need for research into national security in the context of the development of socio-cyberphysical systems. Society within socio-cyberphysical systems forms a sharply increased dynamism of the social environment, an increased level of interdependence to constantly high levels of uncertainty within the framework of national security and their components. Adapting to these parameters, society forms a transition to a new, superplastic structure and a new way of coordinating relations, which significantly affects the formation of the national security level [1, 7]. In works [2, 8], research confirms the possibility of using the concept of a triple model based on the integration of political, social and economic aspects of regional society national security. Fig. 1 shows a cluster-network system of an open type society in the spectrum of regional society national security.

The basis of cluster-network systems of the open type society are socio-cyber-physical systems that allow dynamically forming the national security level under the determined conditions. In this case, the following types of coordination can be used: a hierarchical management system with administrative decision-making, a market system with a "chaotic" deviation from a strict hierarchy, as well as network coordination of connections with a more flexible and integrated hierarchy system.

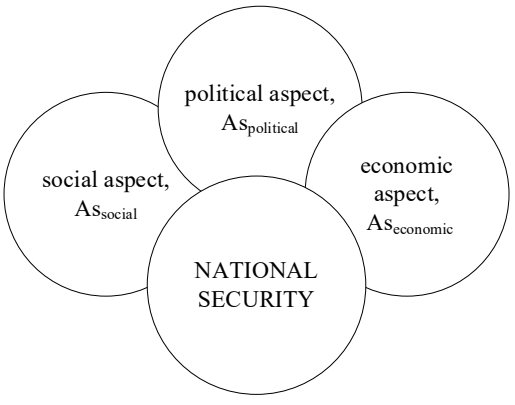

Fig. 1. Cluster-network systems of an open type society

Thus, it is necessary to form separate relations coordination centers in society, which are formed as distributed nodes of accumulation and transfer of knowledge. At the same time, a significant role in the formation of the level of national security should be ensured by the use of a network organizational order, which allows forming a dynamic model of assessing the level of security, both its individual components and security as a whole.

2. Literature review and problem statement

In [9], an innovative rethinking of the triple helix model in the context of city-centered entrepreneurial ecosystems (CEE) is proposed, which is an undoubted advantage. It successfully combines historical analysis with quantitative modeling, bringing depth to the assessment of path dependence. However, a significant number of generalizations, insufficiently substantiated assumptions about universities and their role in ecosystems, as well as a limited data set reduce the persuasiveness of the conclusions. The hypothesis of polycentric cooperation remains declarative, without clear mechanisms for its implementation. In addition, the article demonstrates a certain conceptual overload: excessive attention to many levels of interaction blurs the focus of the study. Limitations on data availability and insufficient analysis of the factors of CEE failures leave room for doubts about the practical value of the proposed recommendations.

The study [10] provides a useful systematization of interaction models innovative – from the triple to the five-fold spiral, which is its main advantage. At the same time, the study is mainly descriptive in nature and is based exclusively on secondary sources, which significantly limits its scientific novelty and empirical validity. The lack of a deep analysis of the practical application of models in real innovation ecosystems reduces the applied value of the study. The authors do not provide a critical assessment of potential contradictions or challenges of expanding spirals, in particular the risk of excessive complexity or blurring of responsibility between actors. Despite mentioning Mode 3 and the environmental component, the content of the article leaves many open questions regarding the tools for implementing sustainable development innovations. As a result, the work informs more than it analyzes, and needs to be supplemented with empirical cases that would confirm the effectiveness of the proposed models.

The paper [11] examines the current topic of the relationship between food security and the broader context of national and human security in the context of the COVID-19 pandemic, which is its strength. However, the concept of the triple security helix seems more declarative than analytically developed – the authors do not provide a clear theoretical justification or a logically completed model of its application. The paper relies excessively on general judgments and examples without sufficient empirical data or comparative analysis. The claims about the "securitization" of food remain superficial and are not accompanied by a critical analysis of the potential consequences of such an approach. There is also a lack of clear criteria for assessing the effectiveness of the actions of state and non-state actors. As a result, the study formulates hypotheses rather than provides convincing conclusions, and requires deeper methodological reflection and structuring.

The study [12] raises the urgent question of the role of civil society groups in eco-innovation and attempts to theoretically justify the need for their inclusion in models such as the triple or quadruple helix. However, the conceptual apparatus of the study seems overloaded – terms such as "triple helix twins" are introduced without clear definitions or analytical development, which complicates the perception of the text. The main argument is based on only two case studies (Denmark and China), which creates a limited basis for generalizations and weakens empirical reliability. Important statements, in particular about "mixed organizations" or the role of NGOs, are not accompanied by a critical analysis of the risks, for example, the political instrumentalization of such structures. The article also avoids discussing conflicts of interest between civil society and industrial or government actors, although this is a key factor in the practice of eco-innovation. Overall, the study has theoretical value, but needs greater conceptual clarity and a broader empirical base for the conclusions to be convincing.

The paper [13] examines an important and complex topic – the adaptation of the triple helix model to the sphere of international security and defense, which is a bold and potentially innovative attempt. However, the study is mainly descriptive in nature and does not contain a clearly formulated analytical model or criteria for assessing the effectiveness of interaction between universities, the state and business in the security sphere. The involvement of only secondary sources, without empirical or quantitative data, weakens the validity of the conclusions. Generalizations about the "virtuous circle" between knowledge, technology and security remain at the level of hypotheses and are not confirmed by specific cases or comparative analysis of countries. In addition, the authors do not consider the ethical and legal risks of cooperation between universities and the military sector, which is critically important in the context of defense research. As a result, despite the relevance of the topic, the article requires a deeper methodological foundation and critical reflection on the potential contradictions of the application of the IMS in the military-defense context.

The study [14] addresses the important problem of insufficient participation of local government administrations in Triple Helix cooperation, which is relevant for increasing the efficiency of innovation processes. The use of a quantitative method with a survey in seven countries is positive, which provides a certain empirical basis. At the same time, the article is limited to describing trends without an in-depth analysis of the reasons for uneven readiness, in particular, there is a lack of attention to political, cultural and administrative factors that may influence the behavior of local authorities. Possible ways to overcome the identified obstacles are also insufficiently considered, which makes the study incomplete from a practical point of view. In addition, the sample is geographically limited, which calls into question the general representativeness of the findings for other regions. The authors do not pay due attention to potential internal conflicts of interest between different levels of government, which can significantly complicate cooperation. Overall, the study has valuable observations, but requires a deeper analytical approach and a broader context for practical application.

The work [15] explores the key topic of social potential as a fundamental resource of national security, which is an important contribution to understanding the complexity of this issue. At the same time, the work is too general and declarative in nature, without a clear methodological basis or empirical data to confirm the stated theses. The absence of specific mechanisms of interaction between state bodies and public institutions reduces the practical value of the study. There is also a lack of critical analysis of potential obstacles to the implementation of an active role of society, such as information inequality or distrust of authorities. Statements regarding the preparation of citizens for defense sound abstract and require detailing in view of modern challenges. In addition, the article does not consider the impact of digitalization and modern technologies on social potential in the security sector. In general, the text requires an in-depth analytical approach and empirical support to increase its scientific weight.

The paper [16] examines the important and topical issue of social tension surrounding the military conscription of ultra-Orthodox men in Israel, which has significant implications for national security and social cohesion. However, the analysis remains largely descriptive and does not offer an in-depth exploration of causal mechanisms or specific policy solutions that could resolve the conflict. The lack of empirical data or interviews with representatives of different parties limits the objectivity of the conclusions. The authors do not pay sufficient attention to the potential risks of increasing social polarization or the impact on internal security. The article also does not consider alternative service models or the possibilities of compromises in the context of contemporary security challenges. Despite the importance of the topic, the study has limited practical value without offering specific recommendations or strategies for government and society. Overall, the paper provides a basis for further in-depth study, but in itself is more of an introduction to the discussion than a thorough analysis.

The study [17] explores the important topic of cybersecurity and its impact on national security, which is relevant in the context of growing threats of cyberterrorism. At the same time, the study has significant limitations due to a narrow sample – the opinions of only students of two specialized universities, which limits the generalizability of the conclusions and their practical significance. The methodology does not provide for comparison with the opinions of other stakeholders, for example, cybersecurity specialists or government agencies, which reduces the complexity of the analysis. The concept of an "inclusive vision of a digital society" is presented rather vaguely, without a clear definition or systematic consideration. In addition, the article does not offer new strategies or recommendations, but mainly describes already known threats and basic countermeasures. The lack of quantitative analysis and in-depth consideration of the dynamics of cyber threats makes the study superficial. In general, the work is

rather informative and requires significant deepening for scientific and practical value.

The paper [18] makes an important contribution to the study of the dynamics of the Triple Helix model at the micro level, focusing on the role of hybrid organizations, which is a relevant direction in modern innovation research. However, the use of a single thematic case (Robotdalen) limits the possibility of generalizing the results to a broader context or other regions and sectors. The authors do not consider in sufficient detail the potential challenges and contradictions that may arise in the interaction between stakeholders, especially in issues of resource allocation or conflicts of interest. The analysis is mainly focused on positive aspects, which may create a certain idealized image of hybrid organizations. Methodologically, the lack of comparison with other similar initiatives reduces the depth of the study. In addition, the article does not pay sufficient attention to the role of external factors, such as political or economic conditions, which significantly affect the success of the Triple Helix. Overall, the paper offers valuable ideas, but needs a broader empirical base and critical analysis to strengthen its scientific weight.

In [19], a comprehensive framework for implementing a circular economy based on the triple helix model is proposed, which is an important contribution to the development of cross-sectoral strategies for sustainable development. However, its main methodology – an integrative review – does not provide empirical verification of the proposed recommendations, which limits the practical applicability of the results. Focusing only on three countries with a high level of development creates the risk of underestimating the challenges in developing countries or countries with different political systems. The lack of analysis of potential barriers to coordination between government, industry and academia reduces the depth of the study. The framework of recommendations seems rather generalized and may not take into account regional characteristics and the specifics of individual industries. In addition, the article does not consider the risks or failures of implementing circular strategies in the context of existing economic and political constraints. Overall, the work has theoretical value, but requires further empirical justification for practical implementation.

The study [20] proposes an ambitious concept of a unified theory of spiral architectures that attempts to integrate five key dimensions of modern sustainable democratic economies and societies. However, its approach remains largely theoretical and highly abstract, which complicates the practical application and verification of the proposed model. The lack of empirical data or specific cases gives the impression that the concept is more declarative than scientifically sound. In addition, the article pays little attention to the potential challenges of integrating different spiral models into a single framework, especially in conditions of geopolitical instability and technological inequalities. The mechanisms that would ensure the effective implementation of the ideas of Industry 5.0 and Democracy 5.0 in the real world are not sufficiently considered. It is worth noting separately that a significant part of the argumentation is based on political assumptions, which may narrow the audience. Overall, the work has great potential, but needs significant refinement to increase its practical value and scientific weight.

In [21], the problem of the separation of means and aims in the implementation of the Triple Helix model in Ukraine, which is an important topic for countries with oligarchic economies, is thoroughly examined. The authors successfully combine theoretical approaches of institutionalism with empirical data obtained from interviews, which strengthens the scientific weight of the work. However, the study has several significant limitations: first, the focus only on Ukraine limits the general generalizability of the conclusions to other countries with similar problems. Second, the use of exclusively qualitative methods and a small sample (four universities and science parks) do not allow to fully cover the diversity of experience in implementing the model. The work also lacks specific practical recommendations for overcoming the identified problems, which reduces its applied value. The most significant drawback is the insufficient analysis of the influence of external political and economic factors that could strengthen or weaken the gap between means and ends. Overall, the work makes an important contribution to understanding the barriers to implementing the Triple Helix in the context of countries with complex institutional structures, but requires an expansion of the methodology and deeper analysis for practical use.

The need to develop a method for assessing the national security of society is due to the actual presence of such influences on the assessments of the influence of individual agents (voters), positions and ratings of political forces, which significantly affects the national security of the state.

Thus, it is necessary to develop a method for applying the concept of the triple helix to substantiate and assess the impact of territorial communities or regional society on the level of national security of the state. The method should be based on the main factors of national security – political, social and economic, take into account the age groups of the population, their activity and loyalty to the authorities. For this purpose, it is proposed to use the cluster structure of systems, a direct connection between their members of society and a collective way of their response to the uncertainty of the external environment. This approach is ensured by combining resources and mass cooperation of social and political aspects with micro- and macro-aspects of the economic component.

3. The aim and objectives of the study

The aim of the study is to develop a method for assessing the society national security level based on the triple helix concept. This approach will allow for timely consideration of the change's dynamics in individual components of society national security, taking into account external and internal factors.

To achieve this aim, the following objectives were accomplished:

– to analyze the components of society national security;

– to develop a mathematical model for assessing the social stability of society;

– to develop a mathematical model for determining the regional security index;

– to develop a mathematical model for evaluating loyalty;

– to develop a mathematical model of an integral indicator of the regional society national security level.

4. Materials and methods

The object of the study is the process of formation of a network structure and a new, non-hierarchical way of coordinating the links of assessing the society national security level, based on the concept of the triple helix. In the

context of national security, the triple helix model is considered as an effective network mechanism for coordinating actions between key actors – the state, society and mechanisms of influence on the national security of the state.

Based on the principles of collaboration and non-hierarchical interaction, this model contributes to the development of sustainable public consensus in strategic decision-making. Its key advantage is the ability to provide a synergistic effect through continuous innovative transformations in the national security system. In [22], mathematical models for assessing the propensity for social influence of regional communities in terms of their attitude to political parties are considered and presented in Fig. 2, 3.

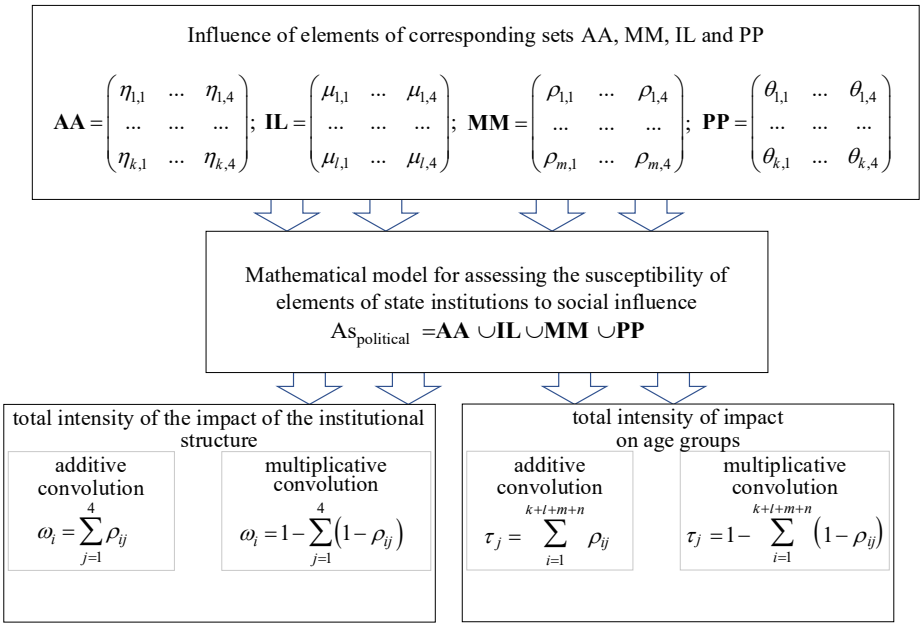

Fig. 3. Structural diagram of the method for assessing the total intensity of the influence of a particular institutional structure

Source data

$AA=\{AA_1, AA_2, \ldots, AA_k\}$ – a set of state power institutions;

$\lambda_i \in \{1, 0.75, 0.5, 0.25\}$ – weighting coefficient of the level of government;

$PP=\{PP_1, PP_2, \ldots, PP_n\}$ – a set of political forces;

weighting coefficient reflecting its rating – $\theta_i \in [0, 1]$;

$IL=\{IL_1, IL_2, \ldots, IL_l\}$ – a set of informal leaders of regional society;

$MM = \{M_1, M_2, \ldots, M_m\}$ – set of media elements;

$SS = \{SS_1, SS_2, SS_3, SS_4, SS_5\}$ – regional community (society), with age ranges (in years) (18–29), (30–39), (40–49), (50–59), (60+);

$\psi_i \in \{0.75, 1, 0.5, 0.25\}$ – political activity coefficient;

$\mu_{ij} \in \{1, 0.75, 0.5, 0.25\}$ – weighting coefficients reflecting the strength of the social influence of elements of state institutions, media and informal leaders on the attitude of regional communities towards political parties

$$\text{As}_{\text{political}} = \mathbf{AA} \cup \mathbf{IL} \cup \mathbf{MM} \cup \mathbf{PP},$$

Assessment of the total intensity of the impact of the institutional structure:

additive convolution:

$$\omega_i = \sum_{j=1}^{4} \rho_{ij},$$

multiplicative convolution:

$$\omega_i = 1 - \sum_{j=1}^{4} \left(1 - \rho_{ij}\right),$$

where

$$\rho_{ij} = \mu_{ij} \times \sigma_j, \sigma_i = w_i \times \psi_i, \quad i = \overline{1,4}, w_i = \frac{N_i}{N_0},$$

N_0 – total number of territorial communities;
N_i – size of the age category of the territorial community

Assessment of the total intensity of impact on age groups:

additive convolution:

$$\tau_j = \sum_{i=1}^{k+l+m+n} \rho_{ij}$$

multiplicative convolution:

$$\tau_j = 1 - \sum_{i=1}^{k+l+m+n} \left(1 - \rho_{ij}\right)$$

In the range from $k+1$ to $k+l$ – informal, ranging from $k+l+1$ to $k+l+m$ – media personalities, ranging from $k+l+m$ to $k+l+m+n$ – political forces

Fig. 2. Mathematical model for assessing susceptibility to social influence

The main hypotheses are related to obtaining operational information from law enforcement agencies, which ensure the formation of appropriate weighting factors for individual indicators of each of the components. The presence of operational information from various state/law enforcement and other sources only increases the level of the input data objectivity.

At the same time, the hypotheses take into account the weighting coefficients of the age strata of regional society, territorial affiliation, income of regional society, as well as qualitative indicators of loyalty to government bodies.

For practical implementation, it is proposed to use four independent neural networks. Main components of the dataset:

1. Input features (33 columns): These are the raw primary metrics that are the input to the neural network. They include a wide range of socio-economic indicators, such as:

1. 1. Economic: GDP per capita (gdp_per_capita), volume of local budgets.

1. 2. Social: Education and healthcare indices, crime rate (crime_rate), level of trust in government.

1. 3. Demographic: Population size and structure (population_total, youth_pct).

1. 4. Geospatial: Distance to borders, travel time to the regional center.

1. 5. Military: indicators of community presence in a combat zone (war_zone_*).

2. Target variables are the columns, which values of the neural network is trying to predict. Four separate models are created for training, each for a different purpose:

3. RSI (Regional Security Index): A numerical value between 0 and 100 that integrates economic, social, infrastructure, and risk factors. Used for regression purposes.

4. LI (Loyalty Index): A numerical value from 0 to 100 that measures the level of trust, well-being, and social engagement. Used for regression purposes.

5. RSI_label: A categorical label ('risk', 'stable', etc.) assigned based on the RSI value. Used to perform classification.

6. LI_label: A categorical label ('low_loyalty', 'high_loyalty') that is assigned based on the LI value. Used to perform classification.

Essentially, each of these models is a digital analyst who has learned to find complex and non-obvious connections between 33 different indicators, from the economy and crime to social media activity.

Thus, it is proposed:

1. Classifier models (predict category).

These two neural networks answer the question, "Which group does this society belong to?" They act as a sorting center that assigns a specific label to each society.

Neural network for RSI_label (Security Classifier): analyzes all data about the community and makes a verdict on which of the four risk categories it belongs to:

– high_security (high security level);

– stable (stable);

– potential_vulnerability (potentially vulnerable);

– risk (in the risk zone).

Neural network for LI_label (Loyalty Classifier): analyzes similar data, but with a focus on trust and well-being indicators to assign one of three labels:

– high_loyalty (high loyalty);

– moderate_loyalty (moderate loyalty);

– low_loyalty (low loyalty).

2. Regression models (predicting exact numbers). These two neural networks answer the question "How safe or loyal is this community?" They provide not just a category, but a specific numerical score on a scale from 0 to 100.

Neural Network for RSI (Resilience Index Predictor): Based on input data, the exact value of the regional security index is calculated. For example, it may give not just "stable", but 72.5 points out of 100.

Neural Network for LI (Loyalty Index Predictor): Calculates an accurate numerical score for the Loyalty Index. For example, 65.8 points out of 100.

These four neural networks create a tool for:

1. Early risk identification – helps authorities and analysts see which regions need additional attention or support before problems become apparent.

2. In-depth analysis – allows to understand which factors (for example, low education levels or high crime rates) have the greatest impact on safety in a particular community.

These models allow to take into account the hierarchical structure of state institutions and its influence on the political worldview of individual social age groups, informal leaders on political parties, and also to take into account social age groups. They also allow to use the mathematical apparatus in the formal description of mathematical models according to the components of social and economic national security of regional society.

5. Results of the development of a method for assessing the national security of society based on the triple helix concept

5. 1. Analysis of the society national security components

In modern conditions, the national security of the state depends not only on military power and foreign policy, but also on the internal stability of regional communities. The economic and social situation at the local level directly affects the stability, manageability, civic cohesion and the country's ability to resist external and internal threats. Thus, an analysis of the key factors determining the impact of communities on national security is carried out, and an analytical model is proposed for assessing this impact.

National security is not only the army and external threats, but also the ability of the state to ensure stability, prosperity, and development at all levels.

Regions with chronic problems can become hotbeds of separatism, crime, information vulnerability, and critical infrastructure risks.

In turn, strong, capable communities provide: a mobilization reserve, economic stability, civic activity, and positive demographic dynamics.

In Ukraine, the war showed that communities with strong local economies, developed infrastructure, and cohesive populations coped better with the challenges of war. At the same time, underdeveloped regions (especially border regions) became areas of increased risk (Table 1).

Table 1

An example of communities' impact on security in Ukraine

Example	Security impact
Decentralization (since 2014)	The transfer of powers and finances to communities has strengthened local resilience and allowed for a rapid response to military and humanitarian challenges
Communities in Donbas and frontline zones	Socio-economic vulnerability before 2014 contributed to destabilization and pro-Russian movements
Cohesive communities (e.g. Ternopil, Volyn regions)	A high level of population mobilization, support for the Armed Forces of Ukraine, and volunteerism are key contributions to national defense
IDPs and social integration programs	Successful communities create an environment for the integration of IDPs – reducing tensions and preventing radicalization

Similar processes are characteristic not only for Ukraine, but also for the countries of the European Union (Table 2) and the member states of the NATO bloc (Table 3).

One of the most important components of the national security of the state is the social and economic satisfaction and stability of the population of territorial communities (regions). It is this component that primarily forms the

commitment of the population to the current government and, accordingly, determines the degree of risk of threats to national security in the relevant regions or territorial communities. Economic and social factors and their impact on security are given in Tables 4, 5.

Table 2

Examples of community influence on security in European Union countries

Example	Security impact
France: «Banlieues» – Depressive Suburbs	High unemployment and social marginalization have caused surges in protests, conflicts, and radicalization (terrorism)
Germany: refugee integration (2015–2018)	The social and economic adaptation of migrants is a critical factor for stability. Successful integration reduces the risks of tension
Italy: regional imbalances South/North	The economic weakness of the southern regions contributes to the shadow economy and organized crime – challenges to national security

Table 3

Examples of community influence on security in NATO countries (Poland, Baltic countries, USA)

Example	Security impact
Poland: development of eastern regions (near Belarus/Ukraine)	Support for rural communities, transport infrastructure, and security has reduced border risks
Latvia and Estonia: Integration of the Russian-speaking minority	State policies to strengthen civic identity through education and the media increase resilience against information attacks
USA: Urban inequality as a factor of internal security risk	Mass protests (2020) showed that social injustice in communities can have nationwide consequences

Table 4

Economic factors of territorial communities' influence on national security

Factor	Security impact
Employment rate	High unemployment in communities increases the risk of social tension, increased crime, migration, and radicalization
Investment attractiveness	Insufficient investment in the regions reduces the resilience of the economy, undermines stability, and complicates defense mobilization
Infrastructure (roads, energy, digital networks)	Weak infrastructure complicates emergency response and weakens control over territories
Budgetary provision of communities	Insufficient budget limits the ability to provide basic services, contributing to social discontent
Level of the shadow economy	The spread of illegal business undermines trust in the state, creates corruption risks, and finances criminal/separatist groups

Table 5

Social factors of territorial communities' influence on national security

Factor	Security impact
Education quality	Low levels of education contribute to disinformation and reduce public resilience to information threats
Access to health services	Poor health of the population reduces defense capabilities and exacerbates humanitarian crises
The level of trust in the authorities	The lack of dialogue between citizens and local/central authorities contributes to protest sentiments
Integration of minorities and internally displaced persons (IDPs)	Marginalization of IDPs or national minorities can lead to social instability
Patriotism and social solidarity	Weak identity and low levels of solidarity are "soft targets" for external influence and destabilization

Thus, the proposed analysis of Tables 1–5 showed that the main factors influencing the components of national security are political, social and economic. In this case, it is necessary to take into account the main indicators of each of the components, which provides a scientific basis for "preventive" measures to ensure stability and/or increase the level of regional society national security. In addition, this provides an objective assessment of both government bodies and political forces during election campaigns, as well as the impact on rating indicators.

5. 2. Development of a mathematical model for assessing the social stability

Social stability level (As_{social}) for regional society in terms of social loyalty to state institutions and the state as a whole depends on the population's satisfaction with their income level. The following factors significantly influence the formation of income levels: age and territorial affiliation.

The following sets of elements and their characteristics are introduced for consideration.

Let:

– $AC = \{AC_1, AC_2, ..., AC_k\}$ – a set of voters of the regional society by age categories. For the convenience of further calculations, let's represent the set in the form of a vector of the same name $\overline{A} = AC_1, AC_2, \ldots AC_k$. Each of these elements corresponds to an age category: AC_1 – 18–29 years, AC_2 – 30–39 years, AC_3 – 40–49 years, AC_4 – 50–59 years, 60 years and older. Each age group of voters can be assigned a weighting factor that reflects its rating – $\psi_i \in [0, 1]$. The values of the weighting factors of these age groups are as follows: $\psi_i \in \{0.13, 0.2, 0.22, 0.23, 0,22\}$.

TA (territorial affiliation) – $TA = \{TA_1, TA_2, ..., TA_k\}$ – a set of regional society by territorial affiliation, represented as a vector of the same name $\overline{T} = TA_1, TA_2, \ldots TA_k$, where TA_1 – a large city (from 150 thousand people (for example, Kyiv, Kharkiv, Odesa, Dnipro, Lviv)), TA_2 – medium-sized city (from 50 to 150 thousand people (for example, Bila Tserkva, Kremenchuk, Uman, Mukachevo, Drohobych)), TA_3 – small town (from 10 to 50 thousand people (for example, Korosten, Chortkiv, Yavoriv, Smila, Berezhany)); TA_4 – township (from 5 to 10 thousand people), TA_5 – village

(up to 5 thousand people). Each group is assigned weighting factors: $\lambda_i\{0.38, 0.25, 0.15, 0.08, 0.14\}$;

– $SI = \{SI_1, SI_2, ..., SI_k\}$ – the set of incomes of a regional society, represented as a vector of the same name $\vec{S} = SI_1, SI_2, \ldots SI_k$. The regional society's income is divided into five key groups: SI_1 – high, SI_2 – above average, SI_3 – average, SI_4 – below average, SI_5 – low. The value of income weighting coefficients by key groups is as follows: $\partial_i\{0.05, 0.1, 0.2, 0.35, 0.3\}$. In Ukraine, the vast majority of the population has low and below-average incomes. There is a middle class, but it does not dominate. The share of the population with incomes above the average is relatively small. A very small share of the population has high incomes, but their difference compared to other categories is enormous.

Indicator of income stability by age category (ω) is defined as

$$\omega_{ii} = \psi_i \times \partial_i, \quad (1)$$

where ψ_i – weighting coefficients of age groups of regional society; ∂_i – weighting coefficients of income of regional society.

An analysis of the correspondence of income levels to age categories of regional society is presented in Table 6.

Table 6

Correspondence of income levels to age categories of regional society

∂_i		ψ_i				
		AC_1	AC_2	AC_3	AC_4	AC_5
		0.13	0.2	0.22	0.23	0.22
SI_1	0.05	0.0065	0.01	0.011	0.0115	0.011
SI_2	0.1	0.013	0.02	0.022	0.023	0.022
SI_3	0.2	0.026	0.04	0.044	0.046	0.044
SI_4	0.35	0.0455	0.07	0.077	0.0805	0.077
SI_5	0.3	0.039	0.06	0.066	0.069	0.066

Analysis of Table 6 gives grounds to assert that the highest shares of the population of all categories of regional society receive incomes below average and low. This trend indicates significant socio-economic vulnerability of the population. In particular, this is a consequence of limited opportunities to meet basic needs and use necessary services (education, health care). There is an urgent need to support groups with incomes below average (the most numerous among them are AC_4 – 50–59 years). The distribution of age categories of the regional society by income level is shown in Fig. 4, where μ – income dependence by age category.

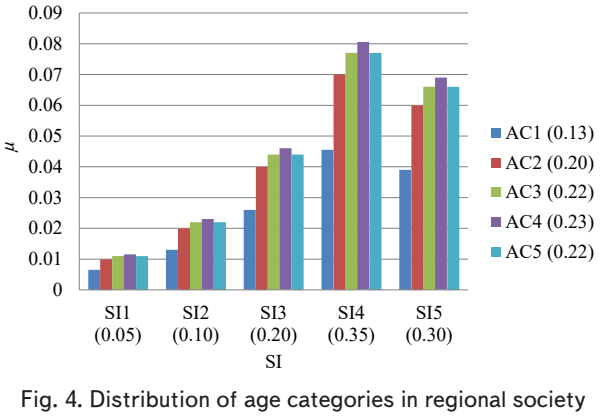

Fig. 4. Distribution of age categories in regional society by income level

Age category stability indicator by territorial affiliation (ϕ) is defined as

$$\phi = \psi_i \times \lambda_i, \quad (2)$$

where ψ_i – weighting coefficients of age groups in regional society; λ_i – weighting coefficients of groups by territorial affiliation.

An analysis of the correspondence of territorial affiliation to age categories of regional society is presented in Table 7.

Table 7

Correspondence of territorial affiliation to age categories of society

λ_i		ψ_i				
		AC_1	AC_2	AC_3	AC_4	AC_5
		0.13	0.2	0.22	0.23	0.22
TA_1	0.38	0.0494	0.076	0.0836	0.0874	0.0836
TA_2	0.25	0.0325	0.05	0.055	0.0575	0.055
TA_3	0.15	0.0195	0.03	0.033	0.0345	0.033
TA_4	0.08	0.0104	0.016	0.0176	0.0184	0.0176
TA_5	0.14	0.0182	0.028	0.0308	0.0322	0.0308

Analysis of Table 7 showed that the largest proportion of the population is concentrated in the group TA_1 – large cities. In groups TA_4 and TA_5 the population is the smallest. This is explained by the fact that with the decrease in the territorial group, additional restrictions appear for the population in terms of realizing their labor potential. These may be, for example, the peculiarities of rural areas (seasonality of work, low wages, remoteness from district centers, limited opportunities for obtaining educational and medical services). The consequence of this may be the migration of the first two age groups to cities or abroad, in order to obtain higher incomes. The distribution of age categories by territorial affiliation groups is shown in Fig. 5, where β – dependence of territorial affiliation of age category.

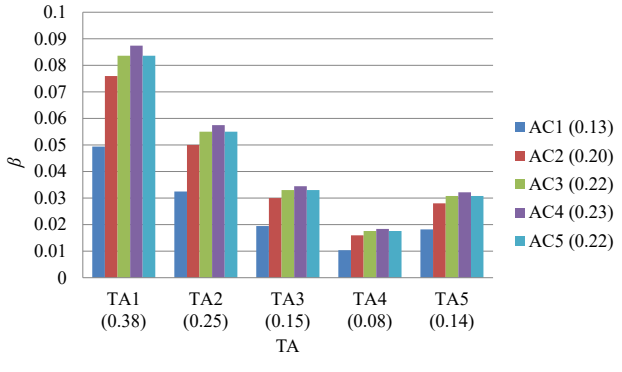

Fig. 5. Distribution of age categories by territorial affiliation groups

Analysis of vectors $\vec{A}$ (age categories), $\vec{T}$ (territorial affiliation) and $\vec{S}$ (income level) showed that the largest share of social activity in the region will belong to representatives of the age category 50–59 years (AC_4). Since the level of social activity depends on the level of income satisfaction in different territories of the region, was conducted a comparative analysis of all income levels (SI) for each territorial group (TA) by age category 50–59 years (AC_4). Thus, it is possible to determine

what level of income representatives of this category have in different territories and where the greatest potential for increasing income is (Table 8).

Using the floating preference method, the values of the criteria vectors are determined (C_i)

$$C_i = \eth_i \times \lambda_i, \quad (3)$$

where $\eth_i$ – weighting coefficients of income of regional society, λ_i – weighting coefficients of groups of territorial affiliation.

Table 8

Comparative analysis of income level and territorial affiliation for the age group 50–59

SI	TA	$\eth_i$	λ_i	C_i
SI_1	TA_1	0.05	0.38	0.019
SI_1	TA_2	0.05	0.25	0.0125
SI_1	TA_3	0.05	0.15	0.0075
SI_1	TA_4	0.05	0.08	0.004
SI_1	TA_5	0.05	0.14	0.007
SI_2	TA_1	0.1	0.38	0.038
SI_2	TA_2	0.1	0.25	0.025
SI_2	TA_3	0.1	0.15	0.015
SI_2	TA_4	0.1	0.08	0.008
SI_2	TA_5	0.1	0.14	0.014
SI_3	TA_1	0.2	0.38	0.076
SI_3	TA_2	0.2	0.25	0.05
SI_3	TA_3	0.2	0.15	0.03
SI_3	TA_4	0.2	0.08	0.016
SI_3	TA_5	0.2	0.14	0.028
SI_4	TA_1	0.35	0.38	0.133
SI_4	TA_2	0.35	0.25	0.0875
SI_4	TA_3	0.35	0.15	0.0525
SI_4	TA_4	0.35	0.08	0.028
SI_4	TA_5	0.35	0.14	0.049
SI_5	TA_1	0.3	0.38	0.114
SI_5	TA_2	0.3	0.25	0.075
SI_5	TA_3	0.3	0.15	0.045
SI_5	TA_4	0.3	0.08	0.024
SI_5	TA_5	0.3	0.14	0.042

Analysis of Table 8 shows that high income is observed in large cities. Thus, the correspondence between income and expenditure on meeting needs is greatest in this case.

However, to maintain this relevance, it is necessary to review opportunities and promote income growth, as the standard of living in large cities is high. Analysis of incomes of the age group 50–59 years (AC_4) in different groups of territorial affiliation is shown in Fig. 6. This makes it possible to determine exactly where to direct material incentives for employees to increase social activity in the region.

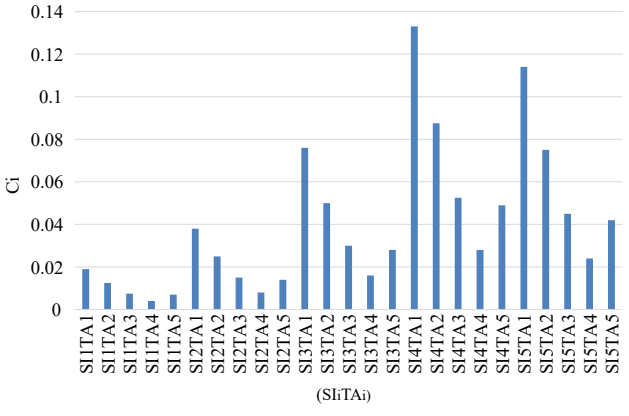

Fig. 6. Income analysis of the age group 50–59 years (AC_4) in different groups by territorial affiliation

Thus, the analysis of incomes of the age group 50–59 years (AC_4) in different territorial groups (Fig. 6) showed that with a decrease in the size of territorial groups, the level of income also decreases (for example, SI_3/TA_4, SI_5/TA_4 etc.). These areas may become the most promising space for increasing incomes and improving the standard of living in the region as a whole. Directing resources to increase incomes from SI_5, SI_4 to SI_2, SI_1 in small remote areas will significantly improve social activity in regional society.

Mathematical model for assessing social stability (SA) of regional society from the point of view of social loyalty to state institutions and the state as a whole is formally set

$$As_{social} = AC \cup TA \cup SI, \quad (4)$$

where the matrix SA – generalized matrix of the influence of income and territorial affiliation on the corresponding age categories of regional society (Fig. 7)

$$\varpi_i = \sum_{i=1}^{5} \rho_i, \quad (5)$$

where $\rho_i = \phi_i \times w_i$.

Multiplicative convolution

$$\varpi_i = \prod_{i=1}^{5} \rho_i, \quad (6)$$

where $i \in \{0.25...1\}$.

Thus, the proposed weighting coefficients provide the formation of the mathematical apparatus of the social stability assessment model, which ensures the consideration of the possible impact on the activity of age groups of the population (voters). In addition, the proposed assessment module allows for timely intervention by state authorities in stabilizing and/or increasing the level of population activity during election campaigns and forming an objective rating of political forces in the region (community).

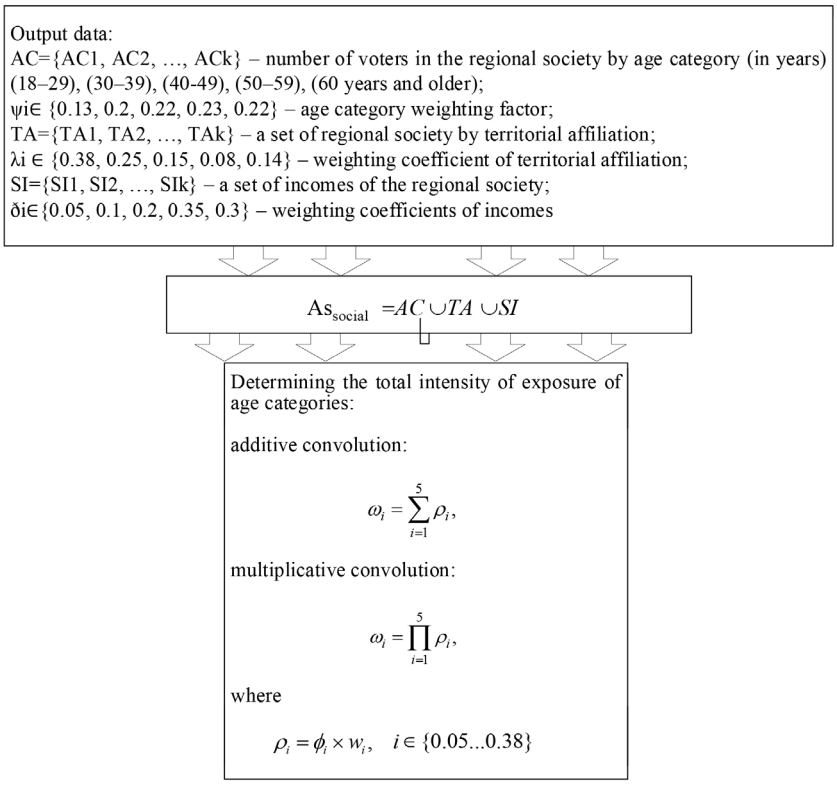

Fig. 7. Mathematical model for assessing social stability with additive convolution

5. 3. Development of a mathematical model for determining the Regional Security Index

To determine the impact of territorial communities on the national security of the state, a mathematical model for determining the Regional Security Index (RSI) is proposed. The model is based on the main socio-economic factors that shape the loyalty of the population of the region to the existing government and power structures. The specified model takes into account the age structure of the population in accordance with participation in the electoral process.

The model is formed from the following steps:

1. Construction of the RSI component matrix (by age)

$B \in \mathbb{R}^{n\times m}$ – RSI component matrix,

where n – number of age groups (5 according to the age structure of voters), m – number of safety components (E, S, I, C, R), each element β_{ij} – evaluation of the component j for the age group i.

2. Construction of voter loyalty matrix (LI)

$L \in \mathbb{R}^{n\times p}$,

where p – number of loyalty parameters (T, W, P, I, A), L_{ij} – estimation of the parameter j for the age group i.

3. Formation of a vector of age group weights

$v \in \mathbb{R}^{n\times n}$, share of the region's population in each age group.

4. Data integration:

a) the integral score for RSI is given by the expression

$$RSI_{per} = v \times B \times w_B, \quad (7)$$

where RSI_{per} – integral indicator of the regional security index, w_B – vector of security component weights (0.25, 0.20, 0.15, 0.25, 0.15).

b) similarly, for voter loyalty

$$LIV_{per} = v \times L \times w_L^T, \quad (8)$$

where LIV_{per} – integral indicator of voter loyalty, w_L – vector of loyalty parameter weights (0.3, 0.25, 0.15, 0.15, 0.15).

5. Construction of an integral indicator of national security of the region

$$As_{economic} = \\ = \alpha \times RSI + (1 - \alpha) \times LIV_{per}, \quad (9)$$

where $\alpha \in [0, 1]$ – priority coefficient (0.5 in case of equivalence of components, or varies depending on the objectives of the study).

To systematize the obtained estimates, it is necessary to apply the structuring of indicators according to the age groups of voters.

In statistical studies of electoral processes, it is customary to divide voters by age into 5 groups [23] (Table 9).

Table 9

Age groups and specificity of influence

–	Probable traits	Modifiers (for analytics)
18–29	Active in social networks, critical, less confidence in the system	Greater influence of critical media, less participation in programs
30–39	Economically active, critically rational	Strong emphasis on welfare, less on ideology
40–49	Balanced, socially inclusive	Often choose stability
50–59	Active TV consumers, experience of changing regimes	Higher loyalty in case of stability
60+	High level of traditionalism, dependence on the state	High participation in programs, inclination towards power structures

Model: Regional Security Index (RSI).

To determine the impact of regional communities on national security, it is necessary to identify the main factors of influence that form the *RSI*. To do this, it is necessary to assess the potential impact of each community (or region) on national security according to five key criteria (Table 10, Fig. 8).

Thus, the formal mathematical model for estimating *RSI* for a territorial community is represented by the expression

$$RSI = 0.25E + 0.20S + 0.15I + 0.25C + 0.15R. \quad (10)$$

The following scale for interpreting the results of the RSI calculation is proposed:

– > 80 – the region is a pillar of national security;
– 60–80 – stable region;
– 40–60 – potential vulnerability;
– < 40 – security risk, intervention required.

Table 10

Components of the Regional Security Index

Criterion	Indicator content	Weight (%)
Economic capacity (*E*)	GDP per capita, employment rate, investment climate	25%
Social stability (*S*)	Access to education, medicine, poverty level, protest activity	20%
Infrastructure availability (*I*)	Roads, IT networks, energy supply	15%
Civil solidarity (*C*)	Participation in elections, volunteering, patriotism	25%
Security risks (*R*)	Crime rate, separatism, IPSO activity	15%

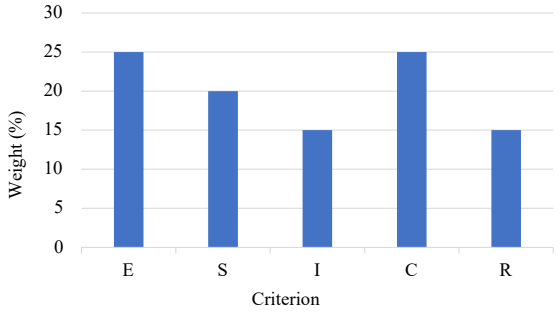

Fig. 8. Distribution of the Regional Security Index components

An example of calculating *RSI* for communities is given in Table 11, Fig. 9.

Table 11

Example of calculating *RSI* for communities

Community	*E*	*S*	*I*	*C*	*R*	*RSI*
Lviv	85	80	70	90	30	65.75
Mariupol (before occupation)	55	60	50	40	70	32.75
Uzhhorod	65	70	60	80	25	55.5

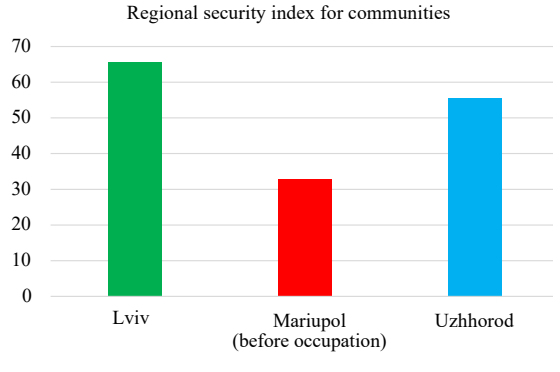

Fig. 9. Regional security index for the example of three communities

Loyalty Index Model.

The next step is to develop an analytical model for determining voter loyalty to the current government, adapted by age group. (18–29, 30–39, 40–49, 50–59, 60+).

5. 4. Development of a mathematical model for evaluating the loyalty index

The model is based on a quantitative assessment of the loyalty index (LI) of voters to the current government based on certain socio-political parameters that vary by age (Table 12).

Table 12

Key criteria for assessing loyalty

Criterion	Description	Justification	Weight (%)
Level of trust in government institutions (*T*)	Belief in the honesty and effectiveness of the government, president, and local authorities	Directly reflects loyalty	30
Assessment of personal well-being (*W*)	Subjective assessment of life now compared to 2–5 years ago	Voters often vote with their wallets	25
Participation in government/social programs (*P*)	Experience in using government support (pensions, subsidies, grants, etc.)	Strengthens ties with authorities	15
Information environment (*I*)	What media and news sources does a person consume (state/opposition/neutral)?	Determines susceptibility to influence	15
Political activity/interest (*A*)	Participation in elections, signing petitions, party membership, etc.	Activity = = higher loyalty/control	15

Formally, the mathematical model for evaluating the loyalty index (LI) is represented by the expression

$$LI = 0.30T + 0.25W + 0.15P + 0.15I + 0.15A. \quad (11)$$

The Loyalty Index interpretation scale is given in Table 13.

Table 13

Interpretation of the Loyalty Index calculation results

LI	Loyalty level
> 75	High
50–75	Moderate
< 50	Low

An example of calculating the loyalty index is given in Table 14.

Table 14

Example of calculating the loyalty index

Age group	*T* (30%)	*W* (25%)	*P* (15%)	*I* (15%)	*A* (15%)	*LI*	Loyalty level
18–29	40	50	20	35	60	43.25	Low
30–39	55	65	40	45	50	54.5	Moderate
40–49	60	60	50	55	55	59.75	Moderate
50–59	70	65	65	60	60	66.75	Moderate
60+	80	55	85	70	65	72.25	Moderate-high

The formation of a generalized matrix model of the integral assessment of national security (economic component) in the region allows to systematically combine *RSI* and *LI* through the age structure of voters. In addition, to obtain an integral assessment of regional political and security stability; it is easy to adapt and scale it to any region or region.

Formally, the mathematical model is described by the expression

$$As_{economic} = RSI \cup LI. \quad (12)$$

Thus, strong communities are the "soft power" of the state, which ensures stability, defense capability, and protection against hybrid threats. Vulnerable communities require targeted state policy: support, investments, social programs, and security reinforcement. Analytical tools like the IRB allow the state to manage risks at the regional level.

5. 5. Development of a mathematical model for an integrated assessment of the level of a regional society national security

The developed partial models of the national security components in the regional society have a comparable representation due to the age stratification of the population according to their belonging to the category of voters. Therefore, the complex of partial indicators allows to form a general integral assessment of the regional society national security (*RSNS*) level. The formal mathematical model of RSNS is represented by the following formula

$$RSNS = As_{political} \cup As_{social} \cup As_{economic}. \quad (13)$$

For practical application, it is proposed to use the additive integral estimate of *RSNS*

$$IRSNS_{add} = \alpha_1 As_{political} + \alpha_2 As_{social} + \alpha_3 As_{economic}, \quad (14)$$

where α_{1-3} – weighting factors of *RSN*S components ($\sum \alpha_i = 1$), and multiplicative integral estimation of *RSNS*

$$IRSNS_{mult} = As_{political} \times As_{social} \times As_{economic}. \quad (15).$$

The calculation of RSNS in the additive form allows to determine the overall assessment of national security in the regional society. The application of the multiplicative form of RSNS takes into account the synergistic effect of the interaction of the components of the integral assessment and allows to determine the potential opportunities for increasing the level of national security in the regional society.

6. Discussion of the results of developing a method for assessing the national security of society

The proposed mathematical models (4), (7), (10), (11) provide the formation of a method for assessing the level of national security of a regional society based on the Triple Helix Concept. This approach is guaranteed to increase the level of national security in the regional community, substantiated decisions to improve the socio-political and economic components of the national security of the community. The features of this use of the Triple Helix Concept are that the integration of partial integral indicators by components of national security allows the formation of a general integral indicator of the level of national security of a regional society. Scientific confirmation of "preventive measures" to stabilize and/or increase the level of national security, and also ensures timely intervention in case of its destabilization. It is necessary to take into account that national security is not only the army and external threats, but also the ability of the state to ensure stability, well-being and development at all levels. This differs from the approaches proposed in [10–12], and also complements the work of [22]. This provides not only the prediction of voter loyalty (political aspect of national security), but also the economic and social aspect for each age category of regional society. Thus, the proposed solutions form the scientific and practical components of the method for assessing the level of national security of a regional community, which ensures its use in the field of national security. This ensures timely intervention of state bodies/law enforcement agencies in the socio-political and economic aspects of a specific regional community.

The analysis of Tables 1–5 showed that aspects of assessing the level of national security need to be given timely attention, especially in critical situations (military conflicts, full-scale war, natural disasters, etc.). The analysis of Table 6 confirms that the highest shares of the population of all categories of regional society receive incomes below average and low. This trend indicates significant socio-economic vulnerability of the population, and significantly affects the level of regional society national security.

Analysis of Table 7 showed that the largest proportion of the population is concentrated in a group of large places, which may lead to migration of the first two age groups to cities or abroad in order to obtain higher incomes.

Analysis of Table 8 determines that high income is observed in large cities, but in order to maintain this correspondence, it is necessary to review opportunities and promote income growth, which also affects the level of national security.

The model for determining the Regional Security Index (10) and the model for evaluating the loyalty index (11) provide an objective assessment of the regional security index and loyalty to state authorities of the relevant age groups of the population. This makes it possible to determine the scale of interpretation of these indicators. The results of the research, which are given in Table 9, confirm that the proposed models can also be used during the election campaign.

Thus, the proposed mathematical models provide the formation of an integral indicator of the level of national security of the regional society. This approach provides a determination of the level of stability of national security. Thus, strong communities ("soft power" of the state) provide stability, defense capability, protection from hybrid threats. Vulnerable communities – require targeted state policy: support, investments, social programs, security reinforcement. Analytical tools, such as the RSI, allow the state to manage risks at the regional level, as well as to resist external and internal threats. The main limitation of the proposed approach is the unreliability and/or lack of objective data for all models.

A promising direction for further research is the construction of an intelligent system based on artificial intelligence and machine learning mechanisms. This approach will provide the ability not only to process large amounts of data offline, but also to provide objective proposals for stabilizing and/or increasing the level of the regional society national security.

7. Conclusions

1. The analysis of national security aspects provides their division into three components: political, social and economic, which ensures the use of the Triple Helix Concept and takes into account its features. The analysis showed that to increase the level of assessment it is necessary to use the integration of the relevant indicators of each of the national security components. This approach not only ensures objectivity and a scientific evidence base for "preventive measures" to stabilize and/or increase the level of national security of a territorial community.

2. The proposed model for assessing the social stability of society provides a comprehensive analysis of the main indicators of social stability of age groups of regional society, as well as the possibility of timely forecasting their "behavior" during the electoral process. The model provides the possibility of qualitative assessment not only of the level of national security, but also of the actions of the authorities to maintain it.

3. The mathematical model for determining the regional security index is based on the main indicators of the economic component: economic capacity, social stability, infrastructure and accessibility, social cohesion and security risks. The proposed model provides an integrated assessment of the stability of the region.

4. The proposed model of voter loyalty provides for the definition of an integrated indicator by integrating the activity criteria of age groups. Thus, the level of trust in government institutions, assessment of personal well-being, participation in state/social programs, information environment, and political activity/interest provide an objective assessment of the loyalty level.

5. The proposed mathematical model of the integral indicator of the regional society national security level is based on the integration of integral indicators of each of the components of national security. The proposed method takes into account the basic indicators of each component, which provides an objective assessment and the possibility of timely formation of preventive measures to stabilize and/or increase the level of national security.

Conflict of interest

The authors declare that they have no conflict of interest regarding this study, including financial, personal, authorship, or other, that could influence the study and its results presented in this article.

Financing

The study was conducted without financial support.

Data availability

The manuscript has no associated data.

Using artificial intelligence tools

The authors confirm that they did not use artificial intelligence technologies when creating the presented work.

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