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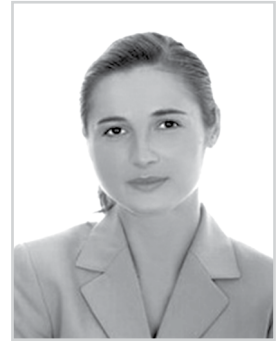
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Assessment of the safety of environment in terms of sustainable development

Abstract
The article reveals the main ecological and natural and technogenic prerequisites for the formation of adverse environmental conditions in today's Ukraine. The authors consider the functional dimension of modern threats to sustainable development and propose a classification depending on their origin, including classic and synergistic threats, transformations of human consciousness as well as social, ecological and economic imbalances. It has been found that the main problems of institutional ensuring of the environmental protection in Ukraine are primarily caused property transformation, economic relations, restructuring of the mechanisms relating to the functioning of industrial enterprises, which is aggravated by the difficult social and economic situation in the regions.

The study is devoted to the development of conceptual bases, principles and scenarios of modelling of environmental safety in the system of sustainable development. It considers artificiality, structural instability, quantifiability and duality of environmental safety. Factor and time components of safety determined according to the modified stochastic approach are also disclosed. They interpret the dependence of the environmental competitiveness of the region with regard to environmental hazard (component by component), innovation and investment activity aimed at improving the state of the environment. The authors of the paper argue that safety modelling, in view of institutional transformations (or responses), characterises the level of response to challenges, taking into account the analysis of environmental safety issues in terms of sustainable development, the state of legal mechanisms, the struggle against threats and risks, etc. In the light of the aforementioned, the authors of the article have developed an econometric model of the period and change in the dependence of the ecological competitiveness of the territory with regard to environmental hazard, innovation and investment activities aimed at improving the state of the environment. The obtained results, based on the modified stochastic approach using real information that quantitatively reflects the features of such processes, have prove a significant impact of genetic factors on the competitiveness of Ukraine.

Keywords: Safety Modelling; Assessment; Sustainable Development; Scenario Approach; Environmental Safety; Institutionalisation

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Оцінювання безпеки навколишнього середовища в системі сталого розвитку
Анотація
У статті представлено основні передумови формування несприятливих екологічних умов в Україні. Автори розглядають функціональний вимір сучасних загроз для сталого розвитку та пропонують їх класифікацію залежно від походження: класичні та синергетичні загрози, перетворення людської свідомості та соціально-еколого-економічний дисбаланс. Запропоновано сценарій моделювання екологічної безпеки в системі сталого розвитку. Доведено, що моделювання безпеки з урахуванням інституційних перетворень характеризує рівень реакції на виклики та ілюструє стан правових механізмів, боротьбу із загрозами тощо. Отримані результати моделювання, що базуються на модифікованому стохастичному підході з використанням реальної інформації, що кількісно відображає особливості таких процесів, доводять значний вплив виділених генетичних факторів на екологічну безпеку України.
Ключові слова: моделювання безпеки; оцінка; сталий розвиток; сценарний підхід; екологічна безпека; інституціоналізація.

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Оценка безопасности окружающей среды в системе устойчивого развития
Аннотация
В статье представлены основные предпосылки формирования неблагоприятных экологических условий в Украине. Авторы рассматривают функциональное измерение угроз для устойчивого развития и предлагают их классификацию в зависимости от происхождения: классические, синергетические, угрозы преобразования человеческого сознания и социально-эколого-экономический дисбаланс. Сформированы концептуальные основы моделирования и оценки экологической безопасности в системе устойчивого развития. Доказано, что оценка и моделирование безопасности с учетом институциональных преобразований характеризует уровень реакции на вызовы, иллюстрирует состояние механизмов борьбы с угрозами и т. д. Полученные результаты оценки, основанные на модифицированном стохастическом подходе с использованием реальной информации, количественно отражают особенности таких процессов, доказывают значительное влияние выделенных генетических факторов на экологическую конкурентоспособность Украины.
Ключевые слова: моделирование безопасности; оценка; устойчивое развитие; сценарный подход; экологическая безопасность; институционализация.

1. Introduction

Environmental, natural and technogenic safety determines the level of protection of individuals, society and the state from the adverse impact of the environment that is caused by natural, technogenic and anthropogenic factors. On the whole, the current ecological situation in Ukraine can be characterised as extremely tense.

Both society and the state are considered to be safe when implementing a model of balanced development is implemented, and dangerous when such a model is ignored. The survival of both humanity as a whole and each state in particular requires a safe transition to a model of balanced development and harmonious life. The model of harmonious coexistence between humans and nature, as well as achievement of balanced development of social, economic and ecological components, implies the observance of the following principles relating to the creation of the model of environmental safety (Danilishin, Stepanenko, Obikhod, 2008) [1]. They are as follows:

1. Information sufficiency. If complete information on the system unavailable, it is impossible to construct a model; and in the case when information is redundant, the construction of the model is viewed to be irrelevant.
2. Expediency. The model assumes the achievement of goals that are defined at the initial stage of the formulation of the modelling problem.
3. Feasibility. The model promotes the realization of the research goal with allowance for marginal resources with a probability which is essentially different from zero within given time.

4. Multiplicity of models. The emerging model should reflect, first of all, those properties of the real system (or phenomena) that affect the chosen efficiency indicator.
5. Aggregation. A complex system preferably contains units (subsystems), the adequate formal consideration of which is promoted by standard mathematical schemes.
6. Parametrisation. In a number of cases, the modelled system includes some relatively isolated components that are characterised by appropriate parameters, including vectors. They can be replaced by numerical values, rather than describe the process of their functioning. If necessary, the dependence of the values of such indicators on the situation can be presented in the form of tables, graphs or analytical expressions (formulas), for example, by using regression analysis.

The detailed analysis of the results of the research is given below. The need for modelling arises both at the stage of the systems design, when analysing the effectiveness of the taken decisions, and exploitation to evaluate the consequences of introducing changes into the system. In this case, the degree of the detailed elaboration of the process increases with specification of the initial data and discovery of new significant factors at different stages of design (technical or work project), which should be reflected in the model. Consequently, the latter can simultaneously include blocks of detailed elaboration with varying degrees, which model the same components. That is, it is necessary to apply the methodology of the integration multilevel modelling.

At the same time, due to the lack of the established theoretical and methodological basis, modelling of environmental safety does not meet modern needs. In particular, the impact of the institutions that guarantee safety, the role of investment activities on improving the environmental situation are smoothed over. Time and space factors are ignored.

Safety is the basic requirement for the person who cares that any destructive factors do not threaten his/her life, property and welfare. The need for safety is objective and is realised at both the individual and collective (group) levels. It should be emphasised that the need for safety cannot be fully met, for threats are continuously generated. That is why, in the context of the research topic, institutionalisation of environmental safety is considered as a dynamic and purposeful process of identifying and systematising the norms, rules, statuses and roles. This system is based on the principles of balanced nature management and is able to work towards satisfaction of certain social needs, in particular the sufficient level of environmental safety.

2. Brief Literature Review

Theoretical studies and practical developments of the institutional principles of balanced nature management in the context of environmental and natural-technogenic safety were conducted within the scientific-applied subject matter of the Institute for Environmental Management and Sustainable Development of the National Academy of Sciences of Ukraine in the research works:

- «Theoretical-methodological and practical basis for technological and ecological safety in the dimensions of sustainable development» (SR No. 0111U000330, 2011-2012), where the authors developed institutional and organisational mechanisms of ensuring safety policy;
- «Institutionalisation of relations of subjects of using natural resources of Ukraine» (SR No. 0111U000328, 2011-2012), where the authors identified the priority directions of institutionalisation of natural resource relations;
- «Environmental and natural-technogenic safety of Ukraine in the regional dimension»(SR No. 0112U004967, 2013-2014), where the authors developed strategic directions of the regional environmental and natural-technogenic safety of Ukraine in the context of sustainable development.

Scientific results, conclusions and recommendations based on the authors' developments were sent to regional economic agents, state bodies of executive power and local government bodies of Ukraine in the form of scientific and analytical reports. J. Campbell (2004) [2], M. Heller (2009) [3], G. Hodgson (2004) [4], D. North (1990) [5], D. Burkaltseva (2012) [6] study the problems of forming institutional principles of balanced nature management in the context of the genesis of environmental and natural-technogenic safety.

Joe Aldy and Alan Krupnick (2008) [7] examine the interaction between environmental and resource economics. In a short time, this area of economics has come a long way to establish a secure theoretical paradigm and a set of policyrelevant research results.

Finn R. Førsund (2008) [8] analyses good examples of modelling to avoid poor outcomes. He claims that pollution modelling must be of a multipronged. The most flexible transformation function in outputs and inputs, which is used in textbooks, is too general to make sense in pollution modelling.

S. Nakagawa and H. Schielzeth (2013) [9] criticise the traditionally used coefficient of determination R^2 (ranging from 0 to 1) as summary statistics to quantify the goodness of fixed effects models such as multiple linear regressions, ANOVA, ANCOVA and generalised linear models (GLMs). According to researchers, the concept of R^2 as variance is intuitive. Since R^2 is varies, it is extremely useful as a summary index for statistical models because one can objectively evaluate the fit of models and compare R^2 values across studies in a similar manner as standardised effect size statistics under some circumstances.

I. Esponda and E. Vespa (2018) [10] indicate that sample selection is a challenge not only for empirical researchers, but also for the agents that fill in models. Yet, most models abstract from these issues and assume that agents successfully tackle selection problems. They design an experiment where a person who understands selection observes all the data required to account for it.

B. Kelsey Jack (2017) [11] points out an environmental crisis observed in the developing world. High levels of air pollution imply immediate and direct health consequences for the exposed population, which may also limit the accumulation of human capital for millions of children exposed to poor air quality. Productivity may also be affected: recent evidence suggests impacts both on labour supply and workers' output. The situation is unlikely to get better. Most of the pollution in the developing world is a by-product of economic activity. Yet the relationship between the pollution and health or productivity remains poorly understood, particularly at the level of the pollution recorded recently in cities of the developing world.

The specified problems, including the individual aspects of the manifestations of safety, the principles of the modelling processes are described in the works by I. Bystriakov (2016) [12], Małgorzata Sej-Kolasa (2009) [13] and others. An important aspect in the development of conceptual bases, principles and scenarios of the modelling in sustainable development is the study of perspective schemes of the corresponding design, the theory and methodology of institutional changes, the fundamental theoretical foundations considered in the works by T. Veblen (1992) [14], J. Campbell (2004) [15], D. North (1990) [16], A. Płachciak (2009) [17]. In the light of the abovementioned problems and the established principles of the modern institutional model, we single out nine basic aspects of environmental safety: *artificiality, complexity, durability, structural stability, quantifiability, targeting, manageability, thoroughness* and *duality,* which in different combinations and with the corresponding priority predetermine its genesis and management actions (Danilishin, Stepanenko, Obikhod, (2008) [18]; Burkov, Novykov, Scepkyn, (2009) [19]; Yerina, (2001), [20]).

Symmetrical characteristics of danger complement the concept of safety. Generally, danger corresponds to what we call insecurity due to different circumstances and conditions including the existence of society in the desired state and a certain system or its subsystem (natural, technogenic, fire-explosive danger, dangerous geological and hydrological phenomena, etc.). The peculiarity is that safety and danger, in contrast to risk, operate in the same functional plane, the first relates to the desired, the second corresponds to the real state of things.

3. The purpose of the study is to model environmental safety of sustainable development on the basis of the existing conceptual bases and principles of overcoming threats and risks.

4. Scenario of the modelling of environmental safety in terms of sustainable development

4.1. Research methodology

The transition to balanced development of nature management is a new political goal for most countries, including Ukraine. Good management and effective state governing bodies are the prerequisites for the implementation of this policy. However, in order to be able to implement a new policy of balanced development in compliance with safety requirements of, it is necessary to establish institutions focused on this policy.

The ambivalence in social, ecological and economic system is a direct threat to the stability of any system at the national, regional and local levels. Manifestations of this threat can take various forms (from explicit to implicit, or latent), but threats intensify and acquire the character of direct actions during the financial, economic-financial and economic crises different by the scale and intensity. The functional dimension of the danger contains a range of dangers that differ within the system (object) in which they operate, its environment, stimulus, scope and nature of the hazard (latent condition, accident, crisis, catastrophe), prevention opportunities and so on. In addition, transformation

processes started by humans give rise, firstly, to unpredictable by nature dangers and, secondly, «synergicity» of dangers, which is a combination of different types of components of «output» dangers, including the impact of the environment on the neutral phenomena and processes, thus turning them into dangers. Hence, a clear initial classification of dangers is impossible and, moreover, the very identification of the type and content of danger becomes an element of safety management and blocking of corresponding threats. Classic threats are related to the unregulated work of technical systems of the economy and its infrastructure and characterised by spontaneous action not combined with the negative purpose. Synergistic threats are defined by synergistic laws of interaction between social and natural universes, the violation of which is accompanied by implicit but real pathologies of organic (natural, social) systems. Threats regarding transformation of human consciousness arise when the human psyche acquires more and more instrumental and pragmatic properties and loses organic, creative and critical properties at a growing human «diving» into functionally inorganic information and communication networks. Threats of the so-called techno-humanitarian imbalances arise as a result of the prevalence of new technical possibilities of humans that are rapidly growing over the moral responsibility for their use.

Taking into account institutional transformations (or responses), we can assume that safety modelling characterises the level of response to challenges with regard to the analysis of environmental safety issues in terms of sustainable development, the state of legal mechanisms, the fight against threats and risks, etc. However, institutional indicators are difficult to quantify. Thus, D. Burkaltseva (2012) [21] suggests that this category should consider the level of corruption and the shadow economy, emphasising their significance in the process of qualitative assessment of economic security. According to other definitions (Ivashina (2009) [22]; Ostrom (2005) [23]), institutional indicators reflect the nature of changes in ownership forms in the economic context, as well as the role of small enterprises in economic development and social change. Considering the institutional transformations in terms of environmental safety and taking into account the peculiarities of the study of ecological, natural and anthropogenic safety, it is worth emphasising their decisive influence on the ecological competitiveness of the territory. As already mentioned, this indicator is vulnerable to any organisational and economic transformation that reflects the level of competition in the environment.

In the process of modelling, two aspects of the econometric model should be taken into account: theoretical, qualitative analysis of interconnections and empirical information. Theoretical information is reflected in the specification of the model, which is an analytical form of the econometric model. It has one or more functions used to construct models and probability characteristics. We have chosen an econometric model in order to parametrise the effects of external and internal factors on the environmental safety of the territory.

The choice of the analytical form of the econometric model should take into consideration the list of specific factors, the selection of which is essential for econometric modelling. In the course of such research, repeated return to the stage of the specification of the model, specification of the list of factors used, and the type of dependence when the function and its components do not correspond to the actual processes, which indicates the false specification, may become possible. Their types are as follows:
- ignoring individual factors while developing an econometric model;
- the possibility of using a factor that is not important for measurable connection;
- inappropriate forms of dependence.

The choice of an acceptable form of dependence is based on the degree of consistency between the type of function and the input data of observance. The adequacy of the model can be determined by analysing the residues.

Based on the results of the calculations of the ecological safety in Ukraine and its regions in 2005, 2008-2010 and 2017 (Khvesyk, Stepanenko, Obikhod, 2014 [24]), econometric modelling of environmental safety is proposed, which is based on two separate approaches.

The model of the period determines the impact on environmental safety:

$$ES = f (IFA_t, SC_t, IN\&E_t, FIA_t),\qquad(1)$$

where:
ES is ecological safety;
IFA is index of level of investment and financial activity;
SC is social security index and fixed capital investment;
$IN\&E$ is index of innovation in the national economy;
FIA is index of foreign economic investment activity.

4.2. Research results

The modelling results are based on a modified stochastic approach, which in addition to the actual one, includes additional (conditional) information that quantitatively reflects the peculiarities typical of such processes (Table 1).

Tab. 1: **Time model of safety**

Year	Determination coefficient	Constant	Regression coefficient			
			IFA	SC	IN&E	FIA
2005	0.327	0.089	0.906	0.111	1.282	0.631
2008	0.797	0.075	1.233	-0.656	0.669	1.192
2009	0.354	0.166	0.537	-0.015	0.127	0.280
2010	0.488	0.103	0.773	-1.218	0.081	0.348
2016	0.235	0.059	0.819	-1.368	0.157	0.046

Source: Compiled by the authors

The statistical characteristics of the model are within the limits of the relevant probability criteria, the determination coefficient is from 0.235 in 2005 (the worst model by the causative effects) to 0.797 in 2008 (the most effective).

The model of change in content and structure is based on statistical variables over the period under study. The modelling is also based on a modified stochastic approach which is combined with an assessment of the impact on the factor of the safety of the risk factors, taking into account their quantitative effect and the nature of their impact (Table 2).

Tab. 2: **Factor model**

Dependence variants	Regression coefficients				Determination coefficient
ES = f (t)	-0.012				0.426
ES = f (IFA_t)	0.182				0.798
ES = f (SC_t)	-0.939				0.621
ES = f (IN&E_t)	1.739				0.263
ES = f (FIA_t)	0.758				0.476
ES = f (IFA, SC, IN&E, FIA)	IFA	SC	IN&E	FIA	0.835
	0.457	-0.780	0.301	0.289	

Source: Compiled by the authors

This model consists of three components:
- The dependence of $ES = f(t)$, where the safety is related to the factor of time as a numerical index. It is determined by a very low determination coefficient (0.426), which indicates practical absence of a condition of ES time, and its levels is mainly formed by genetic factors (confirmed by the data of the second component).
- The dependencies of $ES = f(IFA_t)$, $ES = f(SC_t)$, $ES = f(IN\&E_t)$, $ES = f(FIA_t)$, where the state of ES is consistently combined with the corresponding variable genetic and temporal factors. This component demonstrates the apparent increase in the condition of ES by its factors, primarily genetic. As for the dependence $ES = f(t)$ with the determination coefficient

0.426, the situation is somewhat different. In the second component of the model, its minimum value is 0.263, and the maximum ones are 0.798. It should be noted that *IFA* is a leading factor.

- Parametric (as direct management dependence) model combining *ES* with its four genetic factors. It most accurately reflects the dependence of *ES* on the latter, quantifying the positive impact on the territory of the index of *IFA* and *IN&E*. We note the negative influence of other factors (due to the specified specificity) and a high level of their causative actions (determination coefficient is 0.835). Such models are open and vulnerable to any external manifestations. The list of relevant factors may be changed, and the expansion of the dynamic range will enable the determination coefficient to be specified.

5. Conclusion

Thus, the scenario proposed by the authors allowed carrying out modelling of environmental safety in terms of sustainable development. This has become possible due to the methodology developed in previous works on the formation of ecological competitiveness as part of the transformational processes introduced to improve regions' ability to compete with others in the context of sustainable development safety and to further assimilate the anthropogenic impact of production. It is important to emphasise that the conceptual scheme of the formation of a system of indicators, taking into account the safety factors proposed by the authors, included ecological, natural, technological indicators and indicators of the development of social (in the interaction of the social environment and the economic environment) and economic (capital investments, expenditures on environmental protection measures, GRP, etc.) subsystems. Therefore, it can be argued that time and factor safety models take into account all factors of influence as much as possible.

The proposed model of environmental safety, based on the principles of information adequacy, feasibility, expediency, aggregation and parametrisation allowed us to analyse the non-standard properties of existing models due to its nonlinear behaviour. The econometric model of the period and change in the dependence of the ecological safety of the territory on the level of indicators (component by component: *IFA, SC, IN&E, FIA*), innovation and investment activity is aimed at improving the state of the environment. Further theoretical, methodological and applied studies in this area will be carried out within the framework of scientific research works on the theme «Natural-technogenic and environmental safety in the conditions of economic transformations in Ukraine» (SR No. 0116U007938, 2017-2018).

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