SUSTAINABLE GEOSPATIAL DEVELOPMENT OF NATURAL AND ECONOMIC SYSTEMS IN UKRAINE

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Monograph is devoted to the issues of managing the process of sustainable development of natural and economic systems.

Monograph will be useful to scholars, entrepreneurs, experts in the field of economics, management and administration, educators, graduate students, students and all those who wish to improve their command in English.

CONTENTS

The more I studied economic science, the smaller appeared the knowledge which I had of it, in proportion to the knowledge that I needed; and now, at the end of nearly half a century of almost exclusive study of it, I am conscious of more ignorance of it than I was at the beginning of the study.

Alfred Marshall *(1842–1924)*

INTRODUCTION

The modern reality of the theory and practice of sustainable development is based on the problem of productive forces` territorial organization. In fact, this has not lost its relevance, but, on the contrary, due to the systematic and consistent involvement of random «experts» in public administration, the issues of regional and local policy are not only appropriate but already «pre-given» (using the conceptual apparatus of Alain Badiou). What is going on today? Regional policy has derived from community policy, and the last, in turn, is based on the up-to-date practice and challenges, but in the strict sense.

Sustainable development for the objectively created and newly formed natural and economic systems is a policy, tactics, planning and design, as well as the strategic basis for forward-looking goals and combination of ambitious programmes with green innovations. The proposed monograph deals with it. Today we must find out for ourselves a socially agreed solution of three hot-button issues: our concept of the future from the perspective of the real present; resources and their features for the sustainable harmonious growth; our vision of social compromise and civic harmony amid global climate change, destruction of the XXth c. political structure, pandemics and information dependence, which go along with the worst consequences of virtually safe second half of the last century.

The answer is sad.

No.

Thus, there are spaces for discussion. It is an attempt to understand what the 21st century is preparing for us and how it has demonstrated itself. And this

manifestation is in: scarce, but, at the same time, sufficient resources, shifting from production goods to services, from higher and post-higher education to the relevant professional one, from fundamentality to expediency, from family to individuality, from tradition to postmodernity, from «I» to «they», and to the rejection of «we», because behind it there is emptiness. The answer to the rhetorical question is possible. That's why we took the courage, on the brink of insanity, to show the way it is done. For instance, how traditional economic models and laws lose their meaning and relevance, the way they could and should be interpreted so as not to lose touch with the reality, and how we comprehend reality and see the sustainable development facing current challenges. Therefore, the monograph contains mathematical models, analytical generalizations, philosophical and economic assumptions and environmental challenges. We do it to answer the following difficult questions of the beginning of the third decade of our century, such as How do we see the future and What are we ready to do for it? What resources do we have and What are our chances to use them?

Therefore, I invite you, dear reader, to a fruitful, conflicting, complex, but constructive discussion about the vision of sustainable territorial development in Ukraine.

All the authors thank you for your attention!

1 SUSTAINABLE DEVELOPMENT AND LANDSCAPES: ENVIRONMENTAL QUALITY AMID CLIMATE CHANGE

1.1 History of sustainable development strategies creation and their classification

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The concept of sustainable development is considered one of the most relevant concepts of XXI century and has become a logical result of the process of scientific knowledge greening that rapidly developed in 1970s. For the first time the term «sustainable development» was used in 1972 in Stockholm at the United Nations Conference on the Human Environment. During the conference a Stockholm Declaration was adopted which established 26 principles of environmental conservation [12].

The concept of sustainable development was formulated in 1987 in the Report of the United Nations World Commission on Environment and Development, «Our Common Future», where sustainable development was defined as «development that meets the needs of the present without compromising the ability of future generations to meet their own needs» [16].

Despite the fact that a large number of works of domestic and foreign scholars are devoted to the issues of sustainable development, at present there is no generally accepted periodization of the history of the sustainable development strategies of the world. Defining steps of the process will organize key events that took place in the field of sustainable development from 1972 to 2015, and will look at the problem on a global scale which is especially important for Ukraine, where a national strategy for sustainable development has not been adopted at the state level yet.

Development of the category «sustainable development» is rightly associated with the Club of Rome, namely, with the reports developed by Donnella and Dannis Mead- ows, J. Randers, E. Pestel, A. King and its founder – Aurelio Peccei.

A significant contribution to the development of a sustainable development concept have made foreign researchers – L. Brown, K. Hamilton, G. Gardner, N. Carter, Lyle S., M.S. Swaminathan, H. Schellnhuber, J. Meadowcroft [13], Fred B. Schnei- der, S. Schmidheiny and others.

L. Rudenko, I.A. Aleksandrov [1], B. Burkyn- s'kyi [4], S. Lisowski [5], D.A. Hrytsyshena [3], M. Orlov [7], L. Miller [8], S.K. Harichkova [10] and others should be named among the scientists who developed this subject in the post–Soviet time.

The aim of the paper is to identify and characterize the stages in creation of strategies for sustainable development of countries and define the classi- fication strategy on several criteria.

In the history of sustainable development strategies are the following milestones:

1) Designing the **s**tage of sustainable development (1972–1992).

As noted above, history of the concept of sustainable development is thought to have begun in 1972, when I International Conference on the Human Environment in Stockholm proclaimed inclusion of measures to solve the environmental degradation in the program of action at the government level and a plan of action which included 109 recommendations was adopted. Before the Stockholm conference there were only 10 Ministries of Environment in the world, from 1972 to 1982 such ministries or departments were established in 110 countries [11]. One of the most important results of the Conference was the establishment of the United Nations Environment Programme (UNEP).

In 1980 UNEP urged the international community to address the «development without destruction» in the World conservation strategy, developed jointly with the International Union for Conservation of Nature (IUCN) and World Wildlife Fund. On the initiative of the United Nations in 1983, the World Commission on Environment and Development, led by Gro Harlem Brundtland was established [18].

Finally, in June 1992 Rio de Janeiro hosted the UN Conference on Environment and Development (the Earth Summit), which adopted a number of documents. Among them, «Agenda 21», in which managers of 179 countries,

including Ukraine, voted. The adoption of this document was the result of years of work that allowed to unite and present in a systematic form the results of years of research in the field of sustainable development [19].

Thus, during 1972–1992 a theoretical frame- work for creation of sustainable development strategies, the term «sustainable development» and the corresponding concept were formed, a series of conferences, which attracted international attention to the problems of environmental management were held.

2) The initial phase of sustainable development strategies (1992–1997).

In 1992, at the Conference in Rio de Janeiro the United Nations urged all countries to develop national sustainable development strategies (NSDS) in accordance with their priorities, ecological and economic situation and characteristics of the national economy. Such a strategy was designed to «develop and harmonize various areas of economic, social and environmental spheres» [15]. Some countries (Australia, Sweden, UK and China) worked out the first sustainable development strategy for the period from 1992 to 1997.

It should be noted that these strategies were not complete in contents, covering components of sustainable development (economic, social and environmental) to varying degrees, were not provided with high–level illustrative and cartographic soft-ware. However, their development contributed to the creation of new approaches to environmental policy: nature–directed management of companies and enterprises, complex control of environmental pollution, joint environmental protection measures by countries with different levels of development [20].

During the UN General Assembly in 1997 (Rio+5) a call for working out sustainable development strategies acquired a more concrete form, the countries were asked to develop their own sustainable strategies by 2002 [20]. This was the impetus to revitalize the process of mass creation and imple- mentation of strategies in the world.

As you can see, at this stage the first sustainable development strategies were created in the countries of the world and new approaches to environmental policy as well.

3) Stage of mass development of sustainable development strategies (1997–2005).

Two most common definitions of «sustainable development strategy» were formulated at this stage. In 2001 Organisation for Economic Cooperation and Development (OECD) defined the strategy for sustainable development as «a co-ordinated set of participatory and continuously improving processes of analysis, debate, capacity-strengthening, planning and investment, which integrates the economic, social and environmental objectives of society, seeking trade offs where this is not possible» and issued a set of recommendations on strategies development [14].

The document, prepared by the UN Commission on Sustainable Development for the World Summit 2002, states: «A national sustainable development strategy is a coordinated, participatory and iterative process of thoughts and actions to achieve economic, environmental and social objectives in a balanced and integrated manner. The process encompasses situation analysis, formulation of policies and action plans, implementation, monitoring and regular review. It is a cyclical and interactive process of planning, participation and action in which the emphasis is on managing progress towards sustainability goals rather than producing a plan as an end product» [20].

1997–2005 period is characterized by mass de- velopment of national strategies in the countries that had not joined the process (for example, in Poland, the Czech Republic, Slovakia, Austria, Estonia, Greece, Slovenia first strategies were presented between 2000 and 2005).

The feature of this stage is creation of not only national but supranational strategies for sustainable development. In particular, the first sustainable development strategy was approved by the European Union in 2001 at the Gothenburg Summit. In 2005 a Nordic Strategy for Sustainable Development (Denmark, Finland, Iceland, Norway and Sweden) was presented, which complemented the national policies of the countries concerned [17].

In 2002 Johannesburg World Summit on Sus- tainable Development (Rio+10), became an important event in which all countries were called «to make progress in the development and preparation of national strategies for sustainable development and begin their implementation by 2005» [6].

However, not all countries managed to develop and adopt NSDS. According to the UN Division for Sustainable Development, as of 2005 only 23 of 191 countries had implemented the strategies; another 46 had strategies that were approved by state govern- ments or were in the process of development [17].

Summing up, it is possible to say that in 1997–2005 the definition of «sustainable development strategy was formulated, recommendations for the strategies development were issued, the first supranational sustainable development strategies were created. It is at that time when the countries of the world contributed massively to the strategies for sustainable development.

4) Stage of updating sustainable development strategies in the developed countries and development of strategies by developing countries (2005 – 2015).

At this stage, many developed countries have gained valuable experience in developing strategies. As of 2007, all European Union member countries presented their strategies for sustainable development, and by 2015 most of them have already updated versions. In 2006 and 2009 a sustainable development strategy of the European Union was revised. Currently, of all regions of the world Europe is characterized by the highest percentage of the security strategies of sustainable development. This can be explained by several reasons: the existence of supranational initiatives on sustainable development, a high level of elaboration of environmental policies in Europe.

According to a report prepared by the United Nations Division for Sustainable Development in 2009 106 UN member states took part in the implementation of NSDS, another 13 countries reported that they were in the process of formulating their national strategy.

Many developing countries have not joined the formulation of national development strategies process yet, although there is some positive trend. Thus, from

2005 to 2015 national sustainable development strategies were presented by Nauru, Ghana, Togo, Sri Lanka, Samoa.

Post–Soviet countries also participate in the strategies for sustainable development but there is excessive politicization of decision–making in these countries, so strategies that are offered often remain at the level of legislation only [9]. Ukraine, having signed Rio–92 and Johannesburg 2002 documents, has no approved strategy for sustainable develop- ment yet, though the concept was worked out in 2006 and updated in 2012 by the National Academy of Sciences of Ukraine [6].

In 2012, the participants in the seminar Rio+20 reaffirmed the course of human development in the XXI century stated in the decisions of the Rio Conference 92, and expressed concern over the fact that most of the global challenges are linked to the crisis in the relationship between man and nature [17]. We can assume that in the future interest of the world to strategies for sustainable development will only in- crease.

Having specified the stages in the history of sustainable development strategies for the period from 1972 to 2015, we can say that the process has been complicated, beginning from formulation of the concept of sustainable development as such and creation of the first strategies in the developed countries to attraction of developing countries to the development strategies and updating existing strategies. As to the prospects for the future formulation and implementation of strategies for sustainable development in all countries can be specified as well as the creation of a significant number of supranational policies, constant updating and improvement of existing NSDS.

The contents analysis of strategies shows that despite the existence of OEBR and the UN Commission on Sustainable Development recommendations, each country or region has some differences caused by economic and legal characteristics of administrative structures, horizontal and vertical distribution of responsibilities between the government, national traditions.

According to the level of territorial coverage sustainable development strategies can be divided into supranational (e.g. sustainable development strategy of the European Union), national (German Sustainable Development Strategy) and regional (sustainable development strategy of Kharkiv region).

According to the structure frame strategies, action plans and «mixed» type strategies can be identified. Framework strategies set out the general policies and guidelines for achieving sustainable development. They are often complemented by separate, more detailed plans of action or current work programs on sustainable development. Strategy plans clearly define short–term and medium–term goals, with rigid schedules and detailed evaluation criteria. Most strategies include the «mixed type», that is, essentially they are framework documents but contain a detailed description of measures to achieve sustainable development [18].

According to the approach to the planning process strategies can be divided into comprehensive, multi-dimensional SD strategies; cross-sectoral SD strategies relating to specific dimensions of SD; sectoral SD strategies; SD integration into existing national development strategies.

Comprehensive, multidimensional strategies constitute a single document, a process that includes economic, social and environmental dimension of sustainable development. Strategies created by this approach meet the definition of a sustainable development strategy proposed by the Commission on Sustainable Development best of all. Examples of these strategies are national strategies of China, South Korea, Switzerland, Denmark, Germany and Sweden. Such strategies are characteristic mainly for the developed countries.

Strategies between the branches of the economy are associated with a particular area of sustainable development, covering several sectors, one or two areas of sustainable development are presented in them (e.g national environmental management plans). According to this approach strategies of Morocco, Madagascar, Cameroon, South Africa have been created.

It should be noted that first EU sustainable development strategies were also mostly of one theme character, as they focused their attention on the environmental

component. Economic and social components were often «left out» and did not consider all the attributes of sustainable development as a unity.

Sectoral strategies cover economic, environmental and social areas of sustainable development, but are focused on a specific sector of the economy (e.g. SD strategy for a ministry of transportation). Canada is an example of the country that applies this approach. Some countries, such as the United Kingdom and Mexico, are also developing sectoral strategies for specific departments, but as integral parts of national development strategies.

Sustainable Development Strategies integrated into existing national development strategies are presented, for example, in Mexico and India. These countries joined the process of creating sustainable development strategies relatively late, but it is possible that in the future they will be able to create them as separate complete programs [18].

In accordance with the goal we proposed periodization of the history of sustainable development strategies in the countries of the world and identified four key stages: the stage of the sustainable development concept formation (1972– 1992), the initial stage of sustainable strategies development (1992–1997), the stage of strategies mass development (1997–2005), and an updating stage in sustainable development strategies in the developed countries and development strategies by developing countries (2005–2015).

Sustainable Development Strategies can be classified in many ways. In terms of territorial coverage they can be identified as supranational, national and regional strategies, in terms of the structure – a framework strategy, action plans and strate- gy of «mixed» type, in terms of the approach to the planning process – as complex, intersectoral, sectoral strategies and sustainable development strategies that are part of national development strategies. Creation and implementation of strategies for sustainable development is a dynamic process, its periodization can not end in 2015. In the future, the emergence of new types of strategies can be expected, expanding the number of countries and supranational entities that have their own sustainable

development strategies. This determines the prospect of further research in this direction.

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1.2 Social determinants of sustainable development of the country (security aspect)

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1. Theoretical foundations of the social component of security development

The strengthening of globalization processes in the economic sphere is manifested by the increasing influence of social determinants on Ukrainian population level of life, the competitiveness of the national economy and the state of its economic security. At the same time, the system of requirements to ensure the proper economic security of the national economy (ESNE) and the economy of its regions are increasing. Regional economy acts as a guarantor of sustainable economic development in interconnection with social and political stability. The level of the economic security system formation at the macro-, meso-, micro-level influences the dynamics of socio-economic development, strengthening of state economic system and prevention of negative manifestations of social determinants related to the level of material population well-being, individual social security, society and the preservation of national economic interests.

Ensuring the national security of the state is a major factor in preserving the integrity of society and forming strong social relations. The peculiarity of the state existence in the modern world and the provision of its main function - national security is the presence of rapid and sudden changes, which are characterized by the

multi-vector life of society and the emergence of new challenges. The study of the complex architecture of the state national security reveals the main factors influencing its status in the light of European integration processes and tendencies.

The multifaceted and comprehensive mechanism of the national security implementation is ensured through its basic components, taking into account the national interests and values of society, such as: economic, power, environmental, information, military, political and state security [1, p. 121]. At the legislative level, the main objects of national security are the person and the citizen (their constitutional rights and freedoms); society (spiritual, moral, ethical, cultural, historical, intellectual and material values, environment and natural resources); the state (its constitutional system, sovereignty, territorial integrity and inviolability) [2].

In the national security system, its economic component is the basis and foundation of organic, balanced development and is able to provide effective mechanisms aimed at eliminating threats to society in the realities of today.

The work of many well-known researchers and scientists is about the problems of economic security. In particular, scientists S.V. Onishchenko, O.V. Komelina, A.V. Matkovsky, O. A. Pugach in their researches [3, p. 16; 4] emphasize that the ESNE plays a decisive role in the national security system as a defining element of it, since all structural elements of national security have economic basis and dimensions of consequences, and also emphasize that the economic security of the national economy in modern conditions is a fundamental basis for national security of the state.

It should be borne in mind that the ESNE is the result of the key factors that form the basis of public policy in the field of economic security: first, the integrity of the territory, systems of government and governance, while taking into account the historical, social, natural and climatic features of the country development; secondly, national sovereignty, where the population acts as the sole source of power, subject to the supremacy of the national constitution and legislation throughout the state, the presence of recognized state borders at the international level [5, p. 42].

An analysis of the scientific literature and the achievements of foreign and Ukrainian scientists-economists testifies to the ambiguous definition of «economic security of the national economy». The systematization of scientific development allowed us to identify the following approaches to the interpretation of ESNE:

− condition of the state (or national economy), in which the following are ensured: the possibility of creating conditions for the productive life of its population, prospective development in the future and increasing the welfare of its inhabitants [6]; preserving economic stability to internal and external threats and meeting the needs of the individual, society, state [7]; meeting the vital needs of the country for material benefits, regardless of the emergence in the world economic system or within the country of force majeure circumstances of social, political, economic or environmental nature [8, p. 148];

− the state of country economic mechanism, which is characterized by a balance and resistance to the negative impact of internal and external threats, the ability to ensure on the basis of national economic interest realization sustainable and effective development of the domestic economy and social sphere [9, p. 26];

− state of economy and institutions of power which provides guaranteed protection of national interests, social policy orientation, sufficient defense potential even under unfavorable conditions of internal and external processes, as well as ability of power institutions to create mechanisms for realization and protection of national interests of national economy, support social and political stability of society [10, p. 16; 11, p. 72; 12, p. 35];

− a set of conditions and factors that ensure: the independence of the national economy, its stability and permanence, the ability to constantly renew itself and improve itself [13]; ability to satisfy own interests in the long-term mode, to generate innovative shifts in the economy; confront external threats; to realize competitive advantages in the international division of labor [14, p. 57];

− the ability of the national economy to ensure: free, independent development and maintain the stability of civil society and its institutions, as well as

sufficient defense potential of the country under various adverse conditions and variants of events [15];

– expanded self-reproduction in order to meet the needs of its population and the state at a certain level, to counteract the destabilizing effects of factors that threaten the normal development of the country, to ensure the competitiveness of the national economy in the world economic system [16]; effective meeting public needs at national and international levels [17, p. 38].

There are other positions to clarify the content of this category (A.V. Rogovy [18], T.V. Momot [19], A.Yu. Obolensky, S.M. Shkarlet [20], L.O. Ptashchenko [21], I.V. Chernysh [22], O.M. Levchenko [23], I.V. Khovrak [24] and others). It is impossible to overlook the number of works by V.O. Onishchenko on covering such important issues of economic security as international experience in ensuring the economic security of the state [25], problems of public debt management, monetary and fiscal policy [26], security of the banking system [27], shadowing of the economy [28 – 29].

Some foreign scholars regard economic security as a multifaceted category, depending on the diversification and technological level of domestic industrial production, the degree of self-sufficiency in food, raw materials and fuel needed, the size of stocks, and the geographical location considered strategic for imports [30, p. 3]. It should be noted that the existence of different approaches to the interpretation of ESNE indicates a lack of a common understanding of the problem and ways to solve it.

Generalization and systematization of foreign and domestic approaches to the essence and content of national economic security have made it possible to determine that ESNE is a complex, difficultly structured category, determine the causes of social determinants and their specific impact on the status of ESNE. Its properties such as integrity, interaction with outer space, knowledge of the system, hierarchy, are revealed through its characterization as a complex dynamic system. In particular, the integrity of economic security is manifested as the aggregate functioning of heterogeneous interconnected elements whose dynamic development gives rise to

qualitatively new functional properties of economic security as a system [31, p. 246 – 247].

ESNE from the standpoint of a systematic approach is determined by the integrity, systematic, interdependent functioning of the individual, society and state; acts as an indicator of country balanced development (when the state of economic security is the result of internal and external influence and the need to preserve national interests); it allows to identify protection level of economic interests and population vital needs at the level of the country, its regions and other levels, and its status characterizes the effectiveness of the existing mechanisms for their provision. The manifestation of the interaction of economic security as a complex dynamic system with the external space is revealed by reacting to its influence while preserving its properties and related to the influence of development social determinants.

In today's environment, the approach is becoming more and more relevant, with the view that ESNE is a vertically integrated three-tier system (national, regional and local self-government) with developed horizontal links (at each of these levels), characterized by self-sufficiency, ensuring the economical stability from the negative external and internal actions and promotes its progressive development [32, p. 36]. It allows to identify the occurrence of dangerous processes and phenomena, to determine the peculiarities of economic security at different levels, to structure the causes of their occurrence and to justify the ways of solving.

In addition to this approach, it should be noted that in the face of increasing global challenges, economic security is manifested at the following hierarchical levels: global, interstate (within the various associations of countries), national, interregional, regional, local, nanoscale. The structure of this category is manifested at other levels as well: international (global and regional); national (state and non-state); corporate (enterprises, firms, corporations, etc.); personal (natural and legal persons) [32, p. 7].

Thus, the complexity of ESNE concept is manifested by the infinite number of structural and functional variants that reflect the existing characteristic aspects of its

objects and subjects interaction and the system of economic relations and social values in the country. The structure of this category is characterized by the complexity of its internal features of manifestation. It allows to determine the structural components of economic security: energy, financial, social, innovation-technological, food, foreign economic, demographic and environmental one. These components are closely related to one another and to the external environment and have direct and indirect connections [15, p. 14].

In the context of transformational changes, a certain threat to the economic development of a country can be created by the crisis in individual regions. The region as a whole social and economic system has its own peculiar features of economic development strategy and policy formation, security mechanisms. A number of works are about this issue by V. O. Onishchenko, T. M. Zavory, and A. V. Chepurny, where the theoretical approaches and methodological foundations of regional economic security social component ensuring are systematically investigated [29]. Kozachenko G.V., Pogorelov Yu.S. and other scientists under the economic security of the region offer to understand the totality of the current state, conditions, factors that characterize the stability and progressive development of the regional economy, organically integrated into the economy of the country as a relatively independent structure [14, p. 111]. However, it should be borne in mind that the stable development of a regional social and economic system depends on its ability to counter threats [33, p. 104].

Scientists believe that the level of economic security determines the following important characteristics of national and regional economic development: economic independence (management of state and regional resources using competitive natural-geographical, social, economic, environmental benefits); economic stability (reliability of all economic system elements, protection of all forms of ownership, restraining the influence of development destructive factors); self-development and progress (realization and protection of state and regional political interests, modernization of production, effective investment and innovation policy) [3, 15, 7, 34].

It should be noted that nowadays social challenges are becoming more acute in different countries, and the social component of economic security is gaining high priority. Solving social security problems is extremely difficult due to the lack of practical and theoretical problems associated with the uncertainty of their interaction, coordination and implementation [35, p. 31].

Well-known Ukrainian scientist V.M. Geyets defines the social contours of the state economic security as ensuring economic development in order to meet the social and economic needs of citizens with optimal labor costs, environmental use of raw materials and environmental protection [15, p. 15].

In the works of many American and European researchers, ESNE is primarily considered through the social lens of human well-being and the level of its social protection [36 - 40]. This approach is gaining ground. In particular, the American scientist J. Reid defines economic security as one of the main components of well-being and treats it as well-being sense of a person who is able to meet basic needs both in the present and in the future [41, p. 4].

Nesadurey H. views economic security as protecting a person from sudden loss of income sources through the social security system [42, p. 4]. Economic instability in the country and rising risks of unemployment affect the well-being of individuals, their identity, territorial mobility, consumer behavior and require significant public expenditures to stabilize social processes [43, p. 240].

In defining the concept of «social security», most economists emphasize the protection of social interests against threats that are divided into internal and external, but do not single out conceptual approach [6, 44 - 61]. At the same time, most of them relate to the concepts of social security (or social component of economic security) with the concepts of management, regulation, control, and thus the construction of a comprehensive security system in the economic and social spheres, taking into account the influence of social determinants.

We consider it expedient to study social security in a three-pronged approach: as an economic security subsystem, the parameters of which determine the level of economic security; state of the economy and public administration institutions in the

social sphere; the effectiveness of ensuring social policy and the protection of public interests mechanisms, taking into account the influence of social determinants and neutralizing their manifestations. It should be noted that the poor efficiency of the system that provides the social component of the ESNE and the activity of public administration becomes a catalyst for the formation of social determinants that cause negative manifestations in the form of social risks, threats, challenges and dangers, having a deliberate impact on the level of economic security of Ukraine.

2. The impact of social determinants on sustainable development of the country

The main factors of economic development impact on the social sphere include the level of GDP, which depends on the financial support of the population, employment, the level of social infrastructure institutions financing (health care, education, culture, etc.), social guarantees to the population; the level of inflation, which affects the purchasing power of the population and the structure of personal consumption and as a consequence of the population social equilibrium; innovation-investment component of economic development, which is a source of progress and a condition for the viability of the social sphere. The manifestation of a permanent nature in the unresolved majority of social problems in Ukrainian society adversely affects all structural elements of national security and is a major factor in the emergence of many negative effects in all components of social security.

At the same time, the level of ESNE is formed and determined by a number of components, among which its social component is endowed with significant content. Under current conditions, the importance of economic security social determinants, which generate negative manifestations and generate risks and threats due to multicriteria impact on social and economic development is increasing.

In such circumstances, it is an important task to investigate the impact of social determinants on Ukrainian economic security, identify the criteria for their evaluation, and direct and inverse relationships with all spheres of society through the system of economic relations, interests and priorities. This task is actualized in the period of increasing globalization challenges, when it is extremely important to

ensure the social component of Ukrainian economic security and its regions as a basis for sustainable economic development. This requires the task of harmonizing Ukrainian legislation with European norms and social standards within the implementation of the Association Agreement between Ukraine and the EU.

It is theoretically proved that social determinism expresses patterns of social development, relationships, the emergence of the main causes, conditions, factors, sources and drivers of its development and functioning [62, p. 14]. Modern social determinism is characterized by the interchangeability of the subject and the object place in the chain of their relations, since both are acting agents with their intentions and interests; manifested differently in one or another sphere of human activity, in different social structures, depends on the historical context [63, p.16]. The emergence of specific social processes under the influence of external and internal factors and the emergence of new social determinants that exist simultaneously in two states (the object and subject of social and economic dynamics), require the study of their manifestation features and the relationship with social security as component of ESNE.

The expediency of the study of ESNE from the standpoint of determinism allows to study the interconnections and mutually consistent phenomena and processes through the conditions, causes and patterns of changes in social processes and their impact on the security of human existence. From this point of view, social determinants in the ESNE category system reveal the nature of the specific relationships that determine the strategic directions and dynamics of social development processes [64, 65]. Deeva N.M. [66] defines social determinants as the cause or causes of social changes related to the life and relationships of people in the community or generated by social conditions or conditioned by a particular environment. Balanda A.L. [67] The basic social determinants include property, the level of social differentiation, competition and conflict in the form of the individual struggle for such a situation in society that would satisfy their needs. The scientist determines the main informative indicator of the social impact as the level of social tension in individual regions and in the country as a whole. Goroshkova L.A. [68] in

the economic security model of the national economy distinguishes the determinants that directly or indirectly influence the social component of the ESNE (parameters of production factors, infrastructure, market demand, etc.).

The nature of the emergence of the social determinants of ESNE is related to changes in the society caused by the system of economic relations, the environment and social values in the country. The objective existence of the interdependence of economic and social security makes it possible to investigate the nature and content of social determinants that reveal the existence of a causal link between economic processes, have a dominant influence on the development of ESNE, generate integrative risks and threats that cause the emergence of trends in social development and, at the same time, the interaction result of social objects, public institutions, existing models and mechanisms for ensuring social security as a component of ESNE.

At the state level, the impact on the emergence and ESNE social determinants manifestation occurs through the system of regulation and management of social and economic processes, the creation of appropriate institutions, which are endowed with the necessary powers that: create the legal, financial and organizational foundations of social protection; regulate social differentiation; create consistent forms of interaction between social security - the system of social protection and social position [67].

Scientists believe that «the social direction in economic security should ensure the proper status of legal norms and relevant security institutions, which allow to organize the protection of human rights and freedoms, spiritual and material values of society [69, p. 30]. In this aspect, the Constitution of Ukraine (Article 3) states that «a person, his/her life and health, honor and dignity, integrity and security are recognized in Ukraine as the highest social value» [70].

In Ukraine, during shaping the model of socially oriented state, the social component of economic security is receiving considerable priority. This is stated in the Law of Ukraine «On the basics of national security» [2]: a proper degree of security must be ensured at the national, regional, enterprise and citizen levels. The

National Security Strategy of Ukraine (2015) [71] defined the main direction of the national security policy of Ukraine in the field of ensuring ESNE conditions for overcoming poverty and excessive property stratification in society, bringing social standards closer to the level of Central and Eastern Europe countries − EU member states, achieving the economic criteria necessary for Ukraine to become a member of the EU.

3. Domestic and foreign experience of the institutional structure of ensuring the social component of security development

The reform of Ukrainian public administration system takes place in the conditions of new social and economic relationship formation and the search for acceptable mechanisms to ensure social standards of life under the influence of the processes of European integration. The experience of developing a mechanism for ensuring the development of the national economy and its economic security in the EU countries is assessed through the social lens by the introduction of social standards. The managerial influence on the social sphere must first and foremost be carried out in the interests of improving life and saturating the system of ensuring the social interests of people, social groups, their values (adherence to the principle of social justice), structure of society and social relations through effective management measures.

In general, the institutional structure of Ukrainian economic security social component ensuring is shown in Fig. 1. It includes a set of institutions and entities: line ministries, the National Security and Defense Council, regional state administrations, local governments, including executive and administrative bodies, etc.).

Within the limits of their competences and certain tasks aimed at regulating social processes, they influence the economic and social complex of the country, which is tasked with meeting the needs of the population in education, health care, cultural development and housing, expanding conditions. employment and efficient use of labor potential, reproduction of the population and labor, information adequacy and security of existence [73, p. 165].

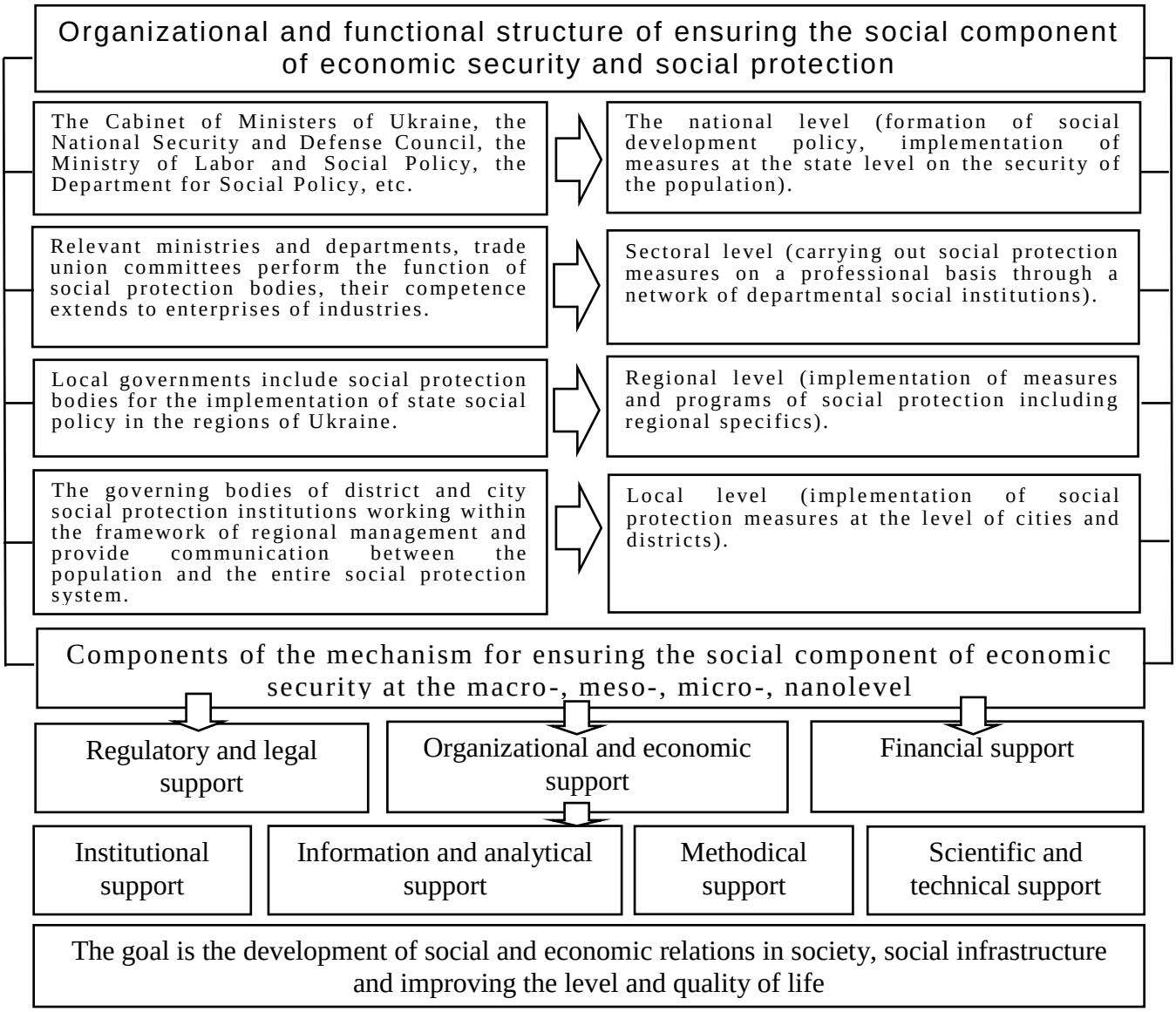

Fig. 1. Subjects of ensuring economic security social component at the state level

The content of institution activities ensuring social component of the EBNE should be determined by the level of social development, the nature of social and economic relations, the strategy of country economical development. However, there is a functional complexity and inconsistency in the system of executive bodies of state power and local self-government. The absence of a single concept of social development complicates the development and implementation of social processes management [73, p. 165].

The imperfection of modern institutional actions ensuring the social component of EBNE diminishes the organizational, economical, financial, human resources, innovation, technological, digital potential of social development.

The mechanism of state and regional ensuring the social component of economic security is defined as a coherent system of successive stages, interrelated and interacting structural elements, which determines the order, features, methods and instruments of purposeful influence of state authorities and local self-government (entities) on social, economic processes at the state and regional level (objects of management) with the purpose of preventing the emergence, mitigation or overcoming of threats to social security [74, p. 88]. This mechanism should take into account the relationship between social and economic processes. The general scheme of ensuring the social component of economic security in Ukraine is presented in Fig. 2.

Structural and functional feature studies of social security institutional activities in individual EU countries shows their differences. According to MISSOC information sources [75] in Bulgaria, the activities of social security institutions are carried out under the compulsory supervision of the Parliament, the Cabinet of Ministers and the judiciary in cooperation with representative organizations of workers and employers and other civil society organizations (e.g. patients' organizations).

The social security management system in Bulgaria is represented by a number of institutions, namely: National Revenue Agency, National Social Insurance Institute, National Health Insurance Fund, Employment Agency, Social Assistance Agency, Agency for People with Disabilities and more. In Bulgaria, the system of social services recently expanded significantly thanks to reforms aimed at improving social development planning. Social child care services is one of the most successful tools for supporting children and families.

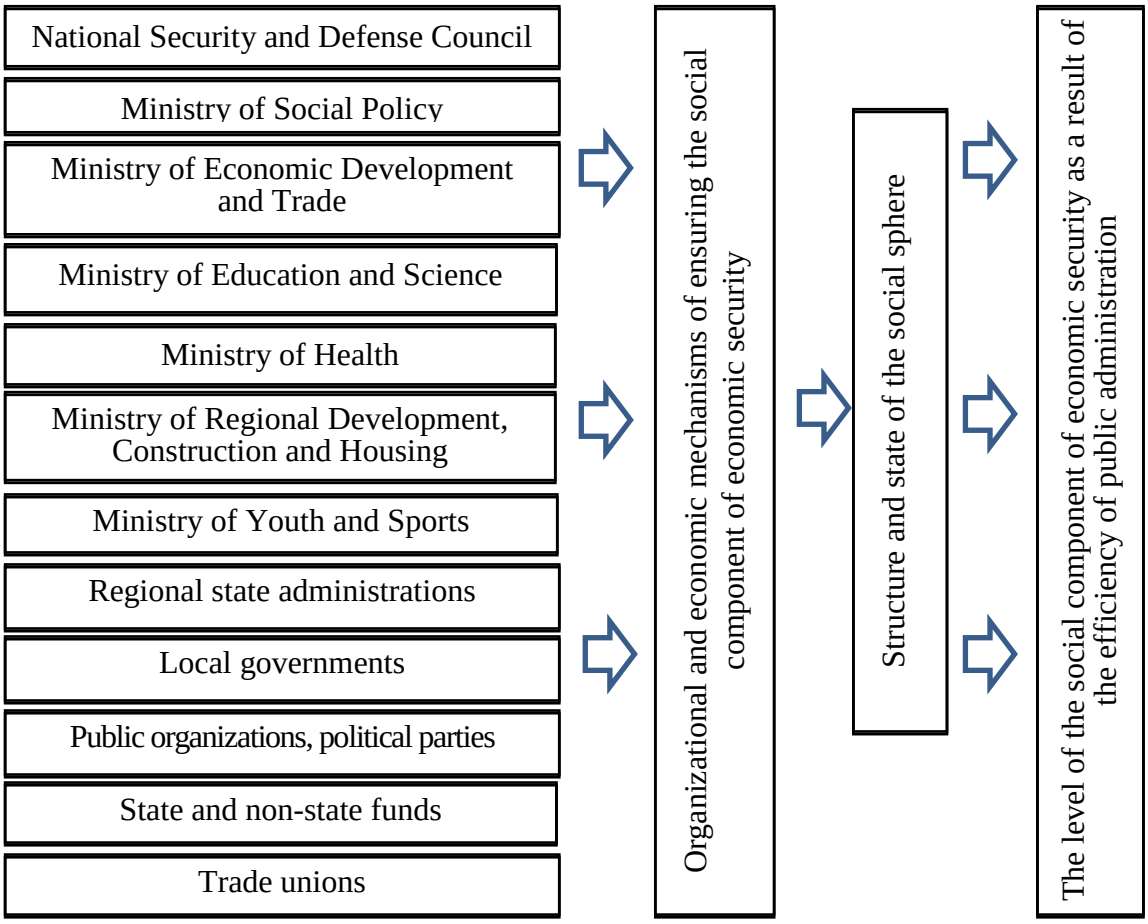

Fig. 2. Generalized scheme of the mechanism of Ukrainian economic security social component ensuring

In Germany, there are five statutory social security sectors, namely: pension insurance; compulsory health insurance; long-term care insurance; accident insurance; unemployment insurance. Pension insurance in Germany is provided through the Federal Institute, regional pension insurance institutions and regulated by the relevant laws. Unemployment insurance is provided by the Federal Employment Agency, which is distributed to the head office, regional governing bodies and local executive bodies. All employees are subject to unemployment insurance.

Functional activity of the Federal Ministry of Health is related to sickness and long-term care insurance, with the exception of health insurance in the agricultural sector, which is under the control of the Federal Ministry of Food, Agriculture and Consumer Protection. The Federal Ministry of Labor and Social Affairs is responsible for the provision of pensions in connection with the loss of a

breadwinner, disability benefits, accident insurance, and unemployment insurance. Regarding the competence of the supervisory authorities, there is a federal land insurance fund (federal agency).

The Federal Insurance Bureau is a competent supervisory authority. While German pension insurance is the responsibility of the Federal Institute, its competence includes basic issues and horizontal functions, the control is exercised by the Federal Ministry of Labor and Social Affairs, including the federal insurance agencies. The Federal Employment Agency is an independent federal public law corporation. Legal oversight is vested in the Federal Ministry of Labor and Social Affairs.

The social security system in Poland, which is a joint competence of the Ministry of Labor and Social Policy and the Ministry of Health, is somewhat different, but the legal, administrative and financial organization of the social security system is not dependent on these ministries. Employees and self-employed persons are subject to the general social insurance scheme. The main organizations that administer social security in Poland are the Social Security Institute, the National Health Fund, public social policy centers, local and regional labor organizations, the State Disability Rehabilitation Fund.

The Social Insurance Institute is divided into regional services responsible for sickness and maternity disability payments, payment of old-age and disability pensions, survivors' pensions, and insurance industrial accidents and occupational diseases. The Social Insurance Institute is entrusted with the function of collecting social security contributions and transferring them to the appropriate organizations. The general mandatory pension system in Poland has open-ended pension funds managed by state-owned private financial institutions. The Social Insurance Institute is responsible for the transfer of the pension insurance contribution part to the pension fund.

In Poland, the National Health Fund is divided into regional health funds, which are responsible for social security in relation to illness and pregnancy and

childbirth. Community social centers provide assistance to large families. Local and regional labor organizations assist the unemployed [75].

In France, the general social insurance scheme is organized in four directions, covering the risks associated with illness, pregnancy and childbirth, disability and death; industrial injuries and occupational diseases; old age; family needs. The National Employment Insurance Fund is responsible for the first two areas. There are also two types of benefits at the local level that have no hierarchical link and are controlled by the National Health Insurance Fund for employees. These are retirement and workplace funds and primary disease insurance funds. Family assistance under the French social security system is under the jurisdiction of the National Family Benefits Fund, which acts as the controlling authority for the family assistance program [75].

The implementation of the Association Agreement between Ukraine and the EU requires harmonization of legislative support in the social sphere and adjustment of both the National Security Strategy of Ukraine and economical development priorities, as well as the mechanisms for their provision [72;74;76].

Research of the legal and organizational and economic foundations of the national economical development ensuring mechanism, study of the structural and functional features of relevant institution creation and operation in Ukraine and the EU, the identification of the main functions and tasks assigned to the subjects of EBNE, allowed to define the criteria ensuring their effectiveness: 1) compliance with the general civilizational norms and existing world practices of creating a «welfare state»; 2) adequacy of the social protection system to the existing external and internal challenges and requirements of European integration; 3) the level of social and territorial integration of society (overcoming social differentiation); 4) balance between social protection system and social status.

The complexity of implementing these criteria is exacerbated by the instability of Ukrainian economical development and the need for financing from the state budget for joint operations in the east of Ukraine.

In the conditions of reforming the management system and its decentralization, achieving the solution of social problems depends on the purposefulness of the state and regional policy and the organizational and economic mechanism of its provision, a comprehensive analysis of task set effectiveness and the coherence of the relations in achieving the strategic goals of social development between the executive bodies [78, p. 61].

The solution of social problems should be embedded in the social policy of the state and ensure the security of the individual and society as a whole. Scientists [72, p. 11] define social policy as a system of managerial, regulatory, self-regulatory ways and forms of subject activity, a set of principles, decisions, actions that find incarnation in social programs and practice in order to meet social needs, balance the interests of man, social groups, achievement of social goals, solving of social problems, formation of social values.

The effectiveness of social policy is determined by achieving the unity of goals and means at all levels, the consistent structuring of the powers and responsibilities of each governmental level, the consistency of the system and the complexity of social policy itself [66, p. 43; 25]. Scientists point out that the implementation of social policy in Ukraine should be systematic and should be based on modern concepts: social security, social state, human development, human capital, knowledge economy, innovative development, sustainable development [77, p. 86]. The objects of social policy are interconnected with social relations, contain a wide range of society existence processes and influence the level of individual social security, social needs and interests.

It is believed that the adoption of the Constitution of Ukraine (1996), which defines the social vector of the state existence with the fixing of basic social rights and guarantees to its citizens, is the historical beginning of the state social policy formation, the formation of the national social protection and social security system. At the same time, the question remains about the forms of exercising the constitutionally protected rights of the state, society and human liability for their

guarantee and realization in market conditions. At the same time, it raises the need to explore other models of social security in different countries of the world.

It should be noted that in spite of discussions in the scientific and political circles, a number of these articles became the starting point for the basis of state social policy formation, the smoothing of social differentiation in society and the guarantor of Ukrainian population life safety. Fundamentals of state social policy are stated in the laws of Ukraine «On pension» [78], «On the subsistence minimum» [79], «On state social standards and state social guarantees» [80], «On social services» [81], «On employment of the population» [82] and others. They underpin social policy and social protection systems in Ukraine and make it possible to identify their key elements.

It should be noted that the modern social policy of the state as a component of ensuring EBNE system in Ukraine is influenced by external factors, which to a certain extent determine the content and legal norms of population social protection; the objective dynamics of changes in the development of the international community and the formation of new criteria for evaluating its effectiveness; implementation of the Association Agreement between Ukraine and the European Union.

Ukraine's accession to key international treaties within the United Nations (UN), the International Labor Organization (ILO), the Council of Europe and the EU, the conclusion of bilateral acts within the framework of the Ukraine-EU partnership, bilateral treaties with other countries in the field of social security (Spain , Estonia, Latvia, Lithuania, Slovakia, Bulgaria, the Czech Republic), Ukrainian membership in a number of international treaties is an important tool for adapting social policy. From the standpoint of EBNE, social protection of the population is, firstly, a multifaceted system of interrelated with all legislative and executive decisions of different levels of economic, legal and social guarantees of realization of the most important social rights of every member regardless of residence, working capacity, gender, age [46, p. 37]; secondly, a set of legal, economic and organizational measures to identify the causes of social risks, evaluate their possible impact at different stages of manifestation, as well as provide social guarantees in accordance

with the economic conditions of social system development [55, p. 15]; third, a qualitative feature of the national model of economic development.

According to the Concept of Ukrainian Population Social Security [83], the foundations of the legal and regulatory framework of social security for the citizens and mechanisms were developed which, based on the real possibilities of the economy, ensure compliance with the statutory state guarantees.

The Concept also defines forms of social security for the population, which include: 1) financial support through social insurance in case of unemployment, temporary or permanent disability; 2) social assistance to disabled and low-income citizens; 3) maintaining living standards in the context of rising consumer prices; 4) compensation and benefits to citizens who have suffered from man-made environmental and natural disasters. At the moment, special attention is needed on the issue of social security for displaced persons and citizens who participated in the operation of the Joint Forces in eastern Ukraine.

It is worth noting that the social protection institute is characterized by the presence and use of interrelated organizational and economic forms [65, p. 21]: social insurance; social assistance; state social security; compulsory accumulations; private forms.

Social security as a component of economic security in its interdependence and interaction ensures the development of a socially oriented economy, realizing the system of socio-economic interests and priorities in the prosperous existence, reproduction, development of man, society and the state mechanisms to international standards [73].

At the same time, priority is given to the creation of adequate economic opportunities in the implementation of social policy, without breaking the balance between social expenditures of society and the economic capacity of the state, stimulating the growth of production and accumulation of funds spent on measures to improve social status.

Thus, the ESNE security system is formed taking into account the existing conditions of state and regional development, external and internal factors of

influence on their social and economic development, existing mechanisms and instruments, peculiarities of potential and natural resources production utilization. The essence of the ESNE security system is revealed through the interaction of state regulation and market self-regulation, coherence of national and regional interests in the protection of the economy from possible external and internal threats [72].

The provision of ESNE is carried out by the state in the formulation and implementation of social and economic policy. The close interrelation of economic security, together with its social component, creates conditions for economic independence of the state, which at the same time requires guaranteeing the proper conditions for the reproduction of the population and the well-being of its life in order to maintain the level of economic stability of the country. The effectiveness of ESNE mechanism and its regions is assessed by achieving a certain level of social development and raising the level of population welfare.

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1.3 Natural and economic system: Sustainable Development management in conditions of climate changes

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A comprehensive vision of the reforms required by the Ukrainian society is presented in the «Strategy for Sustainable Development of Ukraine-2020» approved by the Decree of the President of Ukraine [Ukaz Prezydenta Ukrainy, 2015]. Among the priorities of the Strategy are decentralization and reformation of national social and economic system, restructuring of business entities` territorial organization

giving maximum geographical considerations. In accordance with the goals of Sustainable Development, adapted for Ukraine (during 2015 – 2030s) [Tsili Staloho Rozvytku: Ukraina. Natsionalna dopovid, 2017], the goal 11 concerning sustainable development of cities and communities is directly related to the process of decentralization. Goal 1 – End poverty in all its forms everywhere, Goal 2 – End hunger, achieve food security and improved nutrition and promote sustainable agriculture, Goal 4 – Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all, Goal 6 – Ensure availability and sustainable management of water and sanitation for all, Goal 7 – Ensure access to affordable, reliable, sustainable and modern energy for all, Goal 9 – Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation, Goal 14 – Conserve and sustainably use the oceans, seas and marine resources for sustainable development, Goal 15 – Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss and Goal 17 - Partnership for Sustainable Development are related to it.

Nowadays the problem of strong united territorial communities (UTCs) formation in the context of administrative and territorial reform implementation based on the principles of decentralization becomes especially acute. Resources are the paramount factor for the development of capable and sustainable communities.

Analysis of recent studies or publications initiated solution to the problem and used by the author. Pavliuk Y. P., Oliinyk D. I., Batanov O.A., Dashko O.I., Murkovych L. L., Molodozhen Y.B. and other scholars studied current aspects of territorial communities` and local self-government`s development problems solution [Batanov, 2008; Murkovych, 2010; Molodozhen, 2006]. Own findings concerning the problem are presented in [Volkov, Horoshkova, Karbivnychyi R., 2018; Volkov, Horoshkova, Karbivnychyi I., 2018; Volkov, Karbivnychyi I., Karbivnychyi R, Horbova, 2018; Horoshkova, Volkov, Kapranova, Komelina, 2018; Horoshkova, Volkov, 2018; Khlobystov, 2016; Khlobystov, 2016; . Huseva, Segeda, Khlobystov, 2015].

The article is dedicated to the identified unsolved problems. The new administrative and territorial system should become the basis for constructing a new model of territorial administration, based on the principles of decentralization, subsidiarity, balance of national interests with regional and territorial communities` interests representation, local self-governance widespread, territorial communities` power and autonomy, coherence with natural geographical capacity. That is why the problem of UTCs resource management and their sustainable development conditions deserves special attention.

Setting objectives of the article. Development of conceptual foundations of the management system for sustainable development of natural and economic systems, illustrated by the example of united territorial communities.

The main material of the research with justified scientific results. According to the Law of Ukraine «On Local Self-Government in Ukraine» (statutory wording of 02.08.2017), «the territorial community is presented by residents permanently residing within a village, settlement, city, which is an autonomous administrative and territorial devision, or a voluntary association of residents of several villages having a single administrative center» [Zakon Ukrainy,1997].

Hence, UTC is a complex natural and economic nonlinear, dynamic system able for self-governance [Dudnyk, 2009]:

1) Infinity of the system learning. It is impossible to fully understand the system, it is possible to offer some of its structural and functional options, reflecting its various aspects.

2) Interaction with the external environment. External environment affects system development, but retains its special, inherent properties.

3) Integrity (emergence). System components function together, they are interconnected, create new properties. Properties of the system as a whole cannot be reduced to the sum of properties of its elements.

4) The hierarchy of the system. Each element of a complex system is an independent system, but it is also an integral part of the overall system.

5) Structure. Each system has elements that form a certain dynamic structure. Dynamism provides the ability to system changes and development.

6) Components. The primary component of the system is also a system, but its structure is not considered at this level of analysis.

Additional properties (characteristics) of a complex system are:

1) System status. It is formed due to the states of its elements, it can be changed both continuously or in discrete steps.

2) System behaviour. The system is able to move from one state to another. Each has certain properties and structure.

3) Continuity of functioning. The property is inherent in dynamic systems. All inner processes are interrelated. A complex system functions as a whole, and vice versa. It is accompanied by continuous changes, the accumulation of which provides the development.

4) System development. It is caused by subsystems` and elements` pass through different stages of functioning and development. Both components and the system as a whole are renovated.

5) Dynamism. Economic systems function and evolve over time, have certain stages of their development, and a life cycle.

6) Compilation. Systems are formed by heterogeneous elements and subsystems, there are connections between them. This provides their multivariate properties and development.

7) Homeostasis. The systems ability to self-preservation, the ability to counteract the destroying external environment.

8) Purposefulness. Setting the objective of its existence. Change of goals acts as the source of development.

9) Guidance. Realized, targeted functioning of a system and its elements. Gives the possibility of solving contradictions that arise in the system. It is targeted self-organization, which provides the possibility of self-development while maintaining system's quality determinacy.

10) Adaptability. Ability to self-regulation (passive adaptation) and

management for effective functioning (active).

11) The response rate. The system complexity leads to slow respond to the impact issues, time (lag).

12) Stability (sustainability). The system behavior and status do not change significantly with little influence within certain limits. They consider system`s structure sustainability and the trajectory of its behavior. Sustainability is supported by self-organization, namely its properties - differentiation and lability (sensitivity). Differentiation is system ability to solve contradictions, adapt to changes in the environment due to structural diversity. Lability is functions mobility of system elements with its total sustainability.

13) The state of equilibrium. System sustainability is connected with its aptitude to equilibrium. Equilibrium is the state of maximum system efficiency, that is, the main purpose of its functioning. A complex system cannot achieve full equilibrium as its constituent elements function in different conditions and dynamically interact with one another. Having achieved a certain equilibrium, the system avoids it. In some special cases, bifurcations can emerge that remove the system from the equilibrium. Thus, the stable (sustainable) economic system fluctuates near the equilibrium, moving from one equilibrium state to another, that is, it is in a dynamic equilibrium that ensures its development.

Hence, UTC is an open, dynamic system that is not in equilibrium. Relevant management processes are mutually consistent with its components (subsystems). J. Schumpeter proved that outbalanced economic system does not return to it [Shumpeter, 1982]. It moves to another stationary state of equilibrium at a qualitatively new level of development. The transition mechanism is a combination of new methods for more efficient use of available resources to create capital and non-capital goods.

Dynamic equilibrium is optimal for a complex system. It is formed based on interactions of two opposite trends in production and consumption growth. Equilibrium is characterized by a certain organizational structure of the economic system. Quantitatively it is characterized by the effectiveness of economic relations.

The instability of complex systems is one of the managerial tasks for creating prerequisites for stable dynamic development. The systems are capable for self-governance. Management of systems self-organization is a source of their accelerated development, as a result the selection of qualities, features and properties that increase the level of system organization in the process of adaptation to external environments occur. To ensure system development there is a need to maintain its sustainability applying management instruments. The state of maximum stability of the dynamic equilibrium is the state of system equilibrium with the maximum possible efficiency (Pareto-efficiency) [Klebanov et all, 2004]. Pareto-efficiency is the maximum possible efficiency of resources and products distribution, i.e. the indicator of marginal stability of economic system`s equilibrium. The minimum possible efficiency is an indicator of the marginal minimum stability of economic system`s equilibrium.

A quantitative measure of equilibrium is economic efficiency - Pareto-efficiency [Klebanov et all, 2004], which requires an optimal resources distribution among market players for production, taking into account their scarcity and limited products with their unlimited consumption. In non-equilibrium (crisis) conditions, the Pareto-efficiency principle is violated. The problem of resource allocation is important for UTCs, since resource support is the basis of UTCs dynamic development.

In the process of its development there is a quantitative accumulation of system efficiency. After reaching the maximum for a certain period of development (Pareto-efficiency), the redistribution causes new state of disorganization. At the same time, there is a change in the values of efficiency or the ratio of production and consumption indices from maximum to minimum.

Management of interconnections between internal capabilities and external impact creates conditions for UTCs sustainable development. The main infrastructural components of UTCs sustainable development are economic, environmental and social.

Economic component of sustainable development is provided by current mechanism for the formation of UTCs financial resources, which ensures stability and self-sufficiency of territorial communities.

From the ecological component standpoint, sustainable development must ensure the integrity of biological and physical natural systems, their viability, which depends on the global stability of the entire biosphere.

The social component is focused on human development, maintenance of social and cultural systems stability, reduction of conflicts number.

System harmonization and the balance of these three components form enormously complex challenge. Its result is reflected in the «Methodology for the formation of communities capacity» [Postanova Kabinetu Ministriv Ukrainy, 2015]: a powerful territorial community is a territorial community of villages (settlements, cities), which, as a result of a voluntary association, can independently or through appropriate local self-government bodies provide an adequate level of service provision, in particular in the sphere of education, culture, health care, social protection, housing and utilities infrastructure, taking into account human resources, financial support and infrastructure development of the corresponding administrative division.

But the ecological component itself needs, in our opinion, additional attention.

Current climate change is a key factor of external environment that significantly influences the parameters of UTCs natural and economic system functioning. These changes have already led to the manifestation of a number of negative consequences in the geophysical, geochemical and biological systems of the Earth (sea level rise, desertification, degradation of the polar and mountain glaciers, increasing volatility and abnormality of weather conditions, etc.), which affected the human socio-economic sphere (agriculture, energy production, urban environment, etc.). According to the UN Intergovernmental Panel on Climate Change, the average annual air temperature rose by ~ 0.85 ° C / 100 years during 1880-2012s [IPCC:Climate change, 2013]. According to a more optimal scenario, taking into account levels of greenhouse gases concentration in the atmosphere and in case of

their concentration doubling by the end of the XXI century, it is expected that the temperature will increase within ~ 1.5-2.5 ° C [IPCC:Climate change,2013].

At the United Nations Climate Change Conference in Paris (December 12, 2015), the agreement concerning intentions to achieve a significant reduction in greenhouse gas emissions and thus to keep the global average annual temperature in the range from 1.5-2 ° C was approved. Signatories from Ukraine undertook a commitment to reduce CO_2 emissions by at least 30% by 2030 and adopt the integrated approach to mitigation and adaptation to climate change [Dosvid Yevropeiskoho Soiuzu v adaptatsii do zminy klimatu ta zastosuvannia yoho v Ukraini, 2012].

The climate of Ukraine has definitely been affected by the global climate change. In the XX^{th} century and in the beginning of the XXI^{st} century the average annual temperature has increased by 1.0 ± 0.2°C / 100 years, annual atmospheric precipitation in the territory of Ukraine has not changed significantly, but their significant territorial and seasonal redistribution has taken place [Boychenko, 2018]. Besides there is a typical decrease in the amplitude of seasonal temperature fluctuations: serious warming in the cold season of the year to 0.4 ± 0.1 ° C / 100 years. Recent decades have been marked by the increase in frequency and duration of summer heat (abnormally high temperatures above 30 ° C) followed by an important decrease in precipitation) [Boychenko, 2016].

Let us conduct general analysis of weakness of Ukraine's natural and economic systems (NES) for climate change.

Climate change undoubtedly affects different fields of national economy, but it is worth noting the ambiguity of these impacts in various areas.

Agriculture. On the one hand, there is an improvement in climatic conditions (temperature increase in the cold season, decrease in the number of frosty days, increase in the duration of the growing season, etc.), which leads to higher yields. On the other hand, deterioration (decrease in the amount of precipitation and abnormally high summer temperatures, alternation of long dry periods with heavy rainfall, significant climate variability) requires an alternative transition from nonirrigated

agriculture to irrigation one, introduction of new adapted plants, pest and disease control of crops and livestock, implementation of ecological agriculture, using optimal amount of pesticides and mineral fertilizers and ecologization of the processing industry [Demianenko, Butko, 2012]. Therefore, forecasts indicate that average annual temperature rise to 1°C causes reduction in agricultural production by 5-10% [Kucher, 2017; Stratehiia nyzkovuhletsevoho rozvytku Ukrainy do 2050 roku, 2015].

Moreover, agriculture is a source of greenhouse gas emissions from economic activities in this area, and therefore low-carbon agricultural land use is a strategic development priority. Estimated reduction of CO_2 emissions in agriculture by 17% in Ukraine by 2020 (from total CO_2 emissions in 2013) [Kucher, 2017]. At the same time, high CO_2 concentration in the atmosphere leads to the development of class C_3 yield of crops. Scenario scores for the 21st century of the major agricultural crop yields in the context of global warming at 2-3 °C and doubling CO_2 emissions in the atmosphere give positive assessments for the agrosphere of Ukraine (for C_3 plants (wheat, soybean, rice, etc.) yields rise by 15-20%, but C_4 plants (sorghum, corn, sugarcane) yields do not change)[IPCC:Climate change, 2013].

Water resources. Climate aridization (rise of surface temperature and low amount of atmospheric precipitation, especially in summer), intensive water use and pollution can lead to negative impacts on water resources. A critical shortage of water resources will increase the vulnerability of agriculture, water power engineering, shipping and affect the population health. Although the reduction of river runoff can lead to contraction in flooding frequency and scale, during long arid periods, sudden heavy rainstorms can provoke strong flooding and underflooding (because of higher share of impervious surface (pavement), decline of imperviousness and water absorption into the ground, loss of green area that holds water in the ground) [Dosvid Yevropeiskoho Soiuzu v adaptatsii do zminy klimatu ta zastosuvannia yoho v Ukraini, 2012].

Implementation of some policies to prevent water crisis (accumulation of water in multifunctional reservoirs, boost of territory`s water storage capacity, optimization of geosystems structure in river basins).

Energy production. The total energy and industrial CO_2 emissions rose to 37 Gt by 2016, and reached a 41 Gt level in 2017 [https://phys.org/news/2017-11-global-carbon-dioxide-emissions-stable.html]. The main strategic objective is the transition of Ukraine's economy to low carbon growth based on sustainable development.

Problems faced by the power industry in the context of climate change provoked by changes in the thermal regime and the regime of humidification, reduction of river runoff (natural-biased and caused by the increased water intakes) would have a direct impact on hydraulic power industry and nuclear and thermal power plants cooling [Dosvid Yevropeiskoho Soiuzu v adaptatsii do zminy klimatu ta zastosuvannia yoho v Ukraini, 2012].

Warming in the cold season reduces the need for heating, but at the same time, there is a growing need for cooling air in the summer.

Transport. One of the main climate change factors is greenhouse gas emissions from transport sector (up to 25% of total emissions). Moreover, transport is a source of air and noise pollution.

The main areas of climate change impact are: abnormal atmospheric rainfall and rainstorm (precipitation exceeds standard level by 2-3 times) give rise to underflooding (transport collapse) over outdated drain systems and drainage; abnormal temperature rise above 28-35 degrees leads to intensive use of air conditioning systems, which creates additional network loading, road surface begins to melt and fail, traffic is significantly limited over rails deformation (for example, in hot summer days some road sections of the railways were heated to 53-55 °C, and in some places up to 57 °C); sagging, breaking and short circuit of power lines, deteriorating working conditions pose risks in traffic and driver's health risk [Transport i zminy klimatu. Stalyi rozvytok transportnoi systemy., 2016; Kucher, 2017; Karpenko, Beznisko, Chernavtsev, 2011].

Coastal territories. Climate change led to the Black and Azov seas level rise (in the XXth century the level rose by 0.15-0.20 m, and with further warming by the end of the XXth century, one can expect seas level rise by 0.5-1.0 m) will cause intensive coastal erosion and marine ecosystems degradation, changes in the species composition, algal bloom. This is a problem for the population, infrastructure and recreation [IPCC:Climate change, 2013; Dosvid Yevropeiskoho Soiuzu v adaptatsii do zminy klimatu ta zastosuvannia yoho v Ukraini, 2012; Demianenko, Butko, 2012]. Wearing away of the Black and Azov Seas coastline is vulnerable to the processes of abrasion (when raising its level by 1 cm the shore is flooded by 1-2 m, which in future may lead to part of coastal areas losses, including the unique Black Sea and Azov's sand bars [Boychenko, 2016].

Biodiversity. The biodiversity around Ukraine (especially of steppes, forests, delta rivers and coastal zones) is greatly affected by current climate and human impact, which may induce changes in species composition and even loss of some species, increase in the number of pests, fire development. [Tkachenko, Boichenko, 2014]. Forest expansion will increase the absorption by 3.5×10^6 t $CO_{2eq.}$ Besides, absorption level will rise more as a result of greater phytomass of newly formed forests [IPCC:Climate change,2013].

Health of the population. Warm winters affected by global climate change do not create preconditions for increasing mortality and morbidity due to cold, but abnormal summer heat and serious changes in weather conditions during the cold season increase risks to human health and lead to cardiovascular disease (makes up about 60% of deaths in the country) [Ofitsiinyi vebsait proektu Climate Forum East. Chervonyi khrest,2013–2014; WHO. Highlights on health in Ukraine, 2005.]. The population of Ukraine is not adapted to survive intense heat, which goes with heat discomfort. Activation of climate-sensitive pathogenic microorganisms and endemic situations are likely to rise.

Urban environment. Climate changes produce larger and more powerful abnormal phenomena that cause direct (physical) influences (flooding, abnormal heat, etc.) and indirect processes and phenomena that complicate functioning of individual

urban business divisions and reduce the quality basic services supply for the population (water supply, energy supply, etc.). The peculiarities of climate change manifestations in large cities are more threatening than in other types of settlements (towns and villages). Thus, the manifestation of certain natural hydrometeorological phenomena (snowfall, ice, rainstorms and snowstorms) may become a complete collapse for various business entities and large city dwellers, whereas village and towns residents may be less affected, and sometimes face no impact at all. Furthermore, specific microclimatic effects are being formed in the cities (thermal effect «island» of heat, photochemical smog, local zones with high air turbulence, etc.) [Dosvid Yevropeiskoho Soiuzu v adaptatsii do zminy klimatu ta zastosuvannia yoho v Ukraini, 2012].

For example, abnormal atmospheric precipitation (rainstorms) affects urban infrastructure functioning (buildings, roads, sewage and power systems) and the comfort, prosperity and life security of city dwellers.

The Covenant of Mayors for Climate and Energy states that the main potential negative climate impact that may occur in Ukrainian cities include: abnormal weather conditions, including thermal stress, underflooding, natural hydrometeorological phenomena, growing scarcity and deterioration quality of drinking water, increased number of infectious and cardiovascular diseases, exacerbation of allergy, deforestation and plant species disorder, traffic and energy systems breach [https://phys.org/news/2017-11-global-carbon-dioxide-emissions-stable.html].

A comprehensive understanding of the impacts` consequences, risks and weaknesses as well as activities coordination at national, regional and local levels is needed to develop appropriate climate change adaptation measures and policy programs [Dosvid Yevropeiskoho Soiuzu v adaptatsii do zminy klimatu ta zastosuvannia yoho v Ukraini, 2012; Karpatskyi instytut rozvytku (Koshytse, Slovachchyna), 2015 Ahentstvo spryiannia stalomu rozvytku Karpatskoho rehionu «FORZA» (Uzhhorod, Ukraina), 2015].

The assessment of UTCs vulnerability to certain negative climate impacts is based on vulnerability indicators, which are divided into specific groups according to

different principles (territory vulnerability to thermal stress and underflooding, settlements` green spaces vulnerability, vulnerability to natural hydrometeorological phenomena, vulnerability of quality and growing scarcity of potable water, vulnerability to the increased number of infectious diseases and allergy, the vulnerability of urban energy systems). After identifying the level of vulnerability to a specific climate impact, UTCs develop adaptation activity included to natural and economic system development.

Taking into account the specifics of natural and economic systems at mesolevel (UTCs), it is expedient to search for new innovative technologies of management and business. Let us consider some of them.

Startup is one of these innovative business forms. It is a newly created company (perhaps not yet officially registered but plans to obtain formal registration), which does its business on the basis of innovation or innovative technologies, has not entered the market or has begun to enter it and which has scarce resources. An important incentive to attract start-upers (innovators) to the ecosystem is the creation of an integral «green» complex and constant advancement of its advantages such as: access to resources, communications and ideas exchange, common data and contacts base, etc. Considering that the principles of voluntary association of territorial communities are, in particular, economic efficiency, state support, transparency, openness, and responsibility, then the formation of friendly environment naturally complements fundamental principles of UTCs founding. The basis for the environment`s success is the maximum consideration and application of the existing infrastructure features, as well as analysis and challenges stating for the new business models.

Thus, carrying-out of start-ups within and in the interests of UTCs has several positive characteristics in social, economic and environmental context. The main ones are: opportunity of effective and rapid ways to solve local problems (to put in practice one of the fundamental principles of sustainable development - think globally – do locally), investment attraction, development of innovative ecological environment: organization of cooperation of all interested parties and infrastructure

development, positive information dissemination about UTCs success, which may contribute to their economic development in the future, in particular due to the increased investment attractiveness of a community, raising communities awareness concerning problems (including environmental), and the ways of their solution in a profitable and effective way, active participation of a community in implementation of sustainable development goals and in international organizations` activities.

Study results. It is proved in the study that UTC can be considered as a complex natural and economic nonlinear, dynamic system capable for self-governance. Its main properties are: infinity of the system learning; interaction with the external environment; integrity (emergence); hierarchy of the system; structure; available components; has a certain status and behaviour; continuity of functioning; system developmental; dynamism; compilation; homeostasis; purposefulness; guidance; adaptability; the response rate; stability (sustainability); equilibrium. It is shown that the state of dynamic equilibrium and volatility, as the prerequisites for dynamic development are optimal for UTCs.

It is proved that quantitative measurement of equilibrium is economic efficiency - Pareto efficiency, which requires optimal resources allocation among market players for production, taking into account their scarcity and limited products with their unlimited consumption.

It is found out that management of internal opportunities and external impact interconnections creates the background for UTCs sustainable development. The main infrastructural components of UTCs sustainable development are economic, environmental and social ones.

It is shown that the economic component of sustainable development is supported by the current mechanism of UTCs financial resources formation, which ensures stability and self-sufficiency of territorial communities. From the ecological component standpoint, sustainable development should ensure the integrity of biological and physical natural systems, their viability, which affects global stability of the entire biosphere. The social component is focused on human development, preserving social and cultural systems stability, reducing the number of conflicts.

It is proved that current climate change is a paramount factor of the external environment, which seriously affects the parameters of UTCs` natural and economic system functioning. General analysis of the vulnerability of Ukraine's natural and economic systems (NES) to climate change has been conducted. It is confirmed that climate change affects different sectors of national economy, but this it is not unequivocal.

The expediency of finding new innovative management and business technologies is substantiated. It is shown that startups carrying-out within and in the interests of UTCs has several positive characteristics in social, economic and environmental context. Among the main ones are: opportunity of effective and rapid ways to solve local problems (to put in practice one of the fundamental principles of sustainable development - think globally – do locally), investment attraction, development of innovative ecological environment: organization of cooperation of all interested parties and infrastructure development, positive information dissemination about UTCs success, which may contribute to their economic development in the future, in particular due to the increased investment attractiveness of the community, raising communities awareness concerning problems (including environmental), and the ways of their solution in a profitable and effective way, active participation of a community in implementation of sustainable development goals and in international organizations` activities.

The future prospects for research are to identify and assess current and potential impacts, to determine value characteristics of potential damage to the regional economy and life support systems. This will allow to determine current and potential impacts on environment, health of the population and the economy as well, provide guidance to authorities and local communities to prevent adverse changes caused by human-induced impacts and climate change, propose adaptation activity.

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1.4 The use of GIS to study accessibility of the urban environment (case study of secondary cities project)

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Vulnerable populations are usually defined as people who experience difficulties in self-moving, obtaining services, necessary information or orienting in space. In particular, they include people with disabilities or temporary disability, pregnant women, the elderly, people with strollers.

In today's increasingly tolerant world, more and more attention is paid to ensuring equal rights for every member of the society. In this context, the concept of «accessible urban environment» has emerged, which broadly involves the equal participation of disabled people in all spheres of society's life [9]. The formation of a barrier-free environment is a complex task that requires interdisciplinary cooperation, since all types of transport, places of residence and rest, workplaces and information resources should become available.

Most countries of Europe and North America, after the Second World War, developed transport services for people with special needs, formed an accessible urban environment as well as a tolerant attitude towards this problem. On the contrary, in the urban planning policy of the Soviet Union, the idea of servicing enterprises, economy and defense was cultivated while the practice of environment «humanizing» was not popular [9].

Only after Ukraine gained its independence, adaptation of urban infrastructure for people with disabilities began. Currently, the goal of architects is to create harmonious, healthy, comfortable living spaces. In this regard, in our country, the study of the accessibility of urban environment for vulnerable populations, especially by means of geographic information systems, is becoming increasingly relevant.

Issues of social protection of people with disabilities, the state of integration of such people into society as well as the availability of the environment are considered by both domestic and foreign researchers. Currently, a new scientific trend is emerging - the economy of a barrier-free environment, which considers accessibility as a public good and examines its impact on economic development and investment efficiency [4]. Research which describes the methodology for assessing the availability of objects for vulnerable populations has been developed [1, 3].

The results of the study [2] demonstrate the importance of projects for the «disabled maps» creation and emphasize their constructive role in urban design rebuilding and social discrimination overcoming.

The recommendations for creating availability maps for vulnerable populations has been formed: usage of different color icons to indicate the degree of objects

accessibility; integrated interaction of maps of settlements with maps of other settlements and regions of individual countries; indication of all possible routes for the disabled people from public transport stops to the objects of their interest [1].

The researchers [6] developed the simulation model of the geographic information system for vulnerable populations, identified its elements, functional and interaction principles, set the parameters of input and output variables. Structure-functional and logical schemas of the system model have been created. The GeoWheel system, which contains data on the availability of social infrastructure objects in the city of Khanty-Mansiysk of the Russian Federation, has been implemented.

Thus, the use of GIS to study the urban environment is a modern trend and requires further theoretical and practical research.

The purpose of this material is to to reveal the possibilities of using GIS in the study of urban environment accessibility on the case study of Secondary Cities project, which is implemented in the city of Kharkiv.

One of the main problems that impede movement of people with special needs is the inaccessibility of information on characteristics of social infrastructure objects. The most popular way of solving this problem is to develop separate maps of accessibility and geographic information systems for vulnerable populations based on web technologies.

More recently, maps of cities or certain areas, reflecting the results of the survey of sidewalks, pedestrian crossings, buildings entrances, means of visual and audio information as to their availability have emerged on the Internet.

In many countries of the world there are interactive, socially-oriented geographic information resources intended for obtaining information on the availability of social infrastructure objects for vulnerable populations. Examples include: Wheelmap (this German system displays about 250,000 objects broken down into 12 categories, one of the largest resources of this category in the world); Accessible.net (the French resource allows searching available places by category on the map); AXSmap (the American project that allows searching for social

infrastructure objects, evaluate the level of accessibility, and exchange information between users of this system and other resources); Affordable Environment (the system is implemented in the Russian Federation as well as the state program with the same name) [5]. Most of these systems also work on Android and Apple iOS mobile devices.

Unfortunately, in Ukraine such social-oriented resources are not widely presented, although the problem of vulnerable populations in the country is urgent. According to the State Statistics Service of Ukraine [7], as at 2016, more than 2.6 million people with disabilities lived in the country, that is 61 per 1, 000 people. A certain percentage of these people have difficulty with movement on the ground. For other categories of vulnerable populations calculation is difficult to implement since some of the indicators are dynamically changing (people with temporary injuries that complicate movement, pregnant women, etc.). At the same time, experience has shown that even the largest cities of the country are not comfortable for people with disabilities.

Kharkiv, the second largest city of Ukraine, the weakness of which is the socio-cultural sphere, which is insufficient to meet the needs of vulnerable social groups, is not an exception. During the creation of the Kharkiv City Development Strategy to 2020, there were conducted a survey, which revealed that one of the main problems of the city development is the state of the engineering infrastructure (11,1%), unsafe and uncomfortable living conditions (4%), and imperfect architectural building (1,9%). According to the same paper, one of the strategic goals of the city development is «modern space and provision of the city with engineering infrastructure», and the vision of Kharkiv city is «a large European green city with a unique architecture, comfortable and safe living conditions of educated people that work in innovation-creative branches of the economy» [8]. The goals set cannot be implemented without creating the barrier-free environment that would allow all social groups to take an active part in the life of the city.

Secondary Cities project [10], which is supported by the American Association of Geographers and the US Department of State, deals with the detailed study of the

city infrastructure, in particular in terms of its accessibility to vulnerable populations. Esri company is the partner so all the project participants have access to ArcGIS software.

In addition to Kharkiv, Secondary Cities project include the following cities of the world: Cusco (Peru), Medellin (Colombia), Esmeraldas (Ecuador), Santiago de los Caballeros (Dominican Republic), Mekelle (Ethiopia), Port Harcourt (Nigeria), Douala (Cameroon), Denpasar (Indonesia), Pokhara (Nepal).

This project seeks to build partnerships to create relevant geospatial data, to enhance the understanding and management of the Kharkiv city through better data and mapping, to build resiliency and develop local capacity in geospatial science-based decision making.

The project executors in the city of Kharkiv are: faculty and students of higher educational institutions (V. N. Karazin Kharkiv National University, O. M. Beketov National University of Urban Economy in Kharkiv, National University of Civil Defence of Ukraine, National Aerospace University «Kharkiv Aviation Institute», Kharkiv National University of Radio Electronics), representatives of commercial and public organizations, volunteers from the local community. Teachers and student of the Department of Physical Geography and Cartography of V. N. Karazin Kharkiv National University have taken active part in the project (7 teachers and 5 students participated in the workshops, and more than 60 students of the Department have been directly involved in the data collection).

At the preparatory stage of the project, 2 series of workshops were conducted on the basis of V. N. Karazin Kharkiv National University and O. M. Beketov National University of Urban Economy in Kharkiv. During the training, the participants got acquainted with: the general purpose and features of project implementation in other countries; field data collection tools (Field Papers, Survey 123, Mapillary, OSMAnd, GeoForms); ArcGIS Online capabilities for visualization and analysis of data; QGIS analytical tool; the importance of creating metadata and its uploading rules; general rules for maps design and layout. Through the presentations of the representatives of the City Information Center and the non-

governmental organization of disabled people Creavita, the participants deepened their knowledge on the problem of vulnerable populations in the city of Kharkiv. During the workshops, the area surrounding the higher educational institutions was divided among the teams of participants in order to practice data collection tools and to work out the skills acquired in the field.

For the project, the following layers of spatial data were provided: borders, hydrography (rivers, water bodies), transport network (bridges, railway stations, tramway lines, metro stations and lines, forest roads, traffic lights, power lines, pedestrian barriers, footpaths), elevation contours, oil and gas, building use, monuments, street lights, medical facilities, hydrants.

Implementation of Secondary Cities project in Kharkiv can be divided into several stages: the collection of geospatial data and its initial analysis; the development of cartographic products, mobile applications and recommendations for improving accessibility and safety of the urban environment.

Data collection is currently ongoing, which is mainly performed using Survey 123 mobile application. This application is used for surveys development, field data collection and its uploading to ArcGIS Online or ArcGIS Desktop for further processing and analysis operations. The project curators created 3 surveys («Mobility», «Community Resources and Services», «Public Safety») according to the categories of the objects of interest. All data collected by volunteers through the mobile application is added to the layers with similar names on the Secondary Cities ArcGIS Online account. Accordingly, it is possible to view and edit online data or download layers to work with them offline.

In addition to the fieldwork, street panoramas from cartographic services on the Internet as well as OpenStreetMap platform have been actively used as a data source to optimize the work.

To make data collection for the project participants easier, the study area of the city of Kharkiv was divided into several zones, assigned to different teams of educational institutions and organizations (Fig. 1).

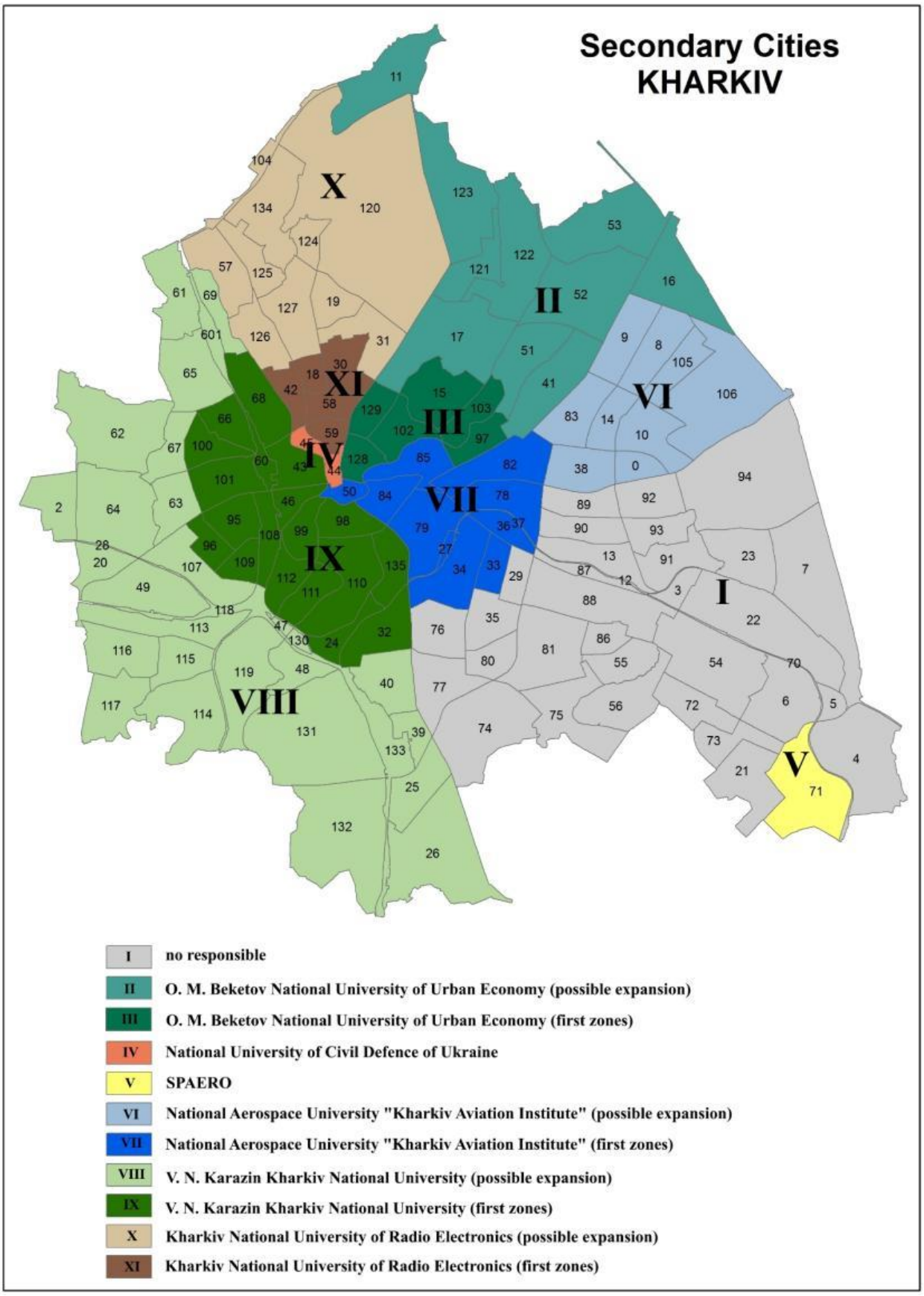

Fig. 1 Responsibility Areas of the Secondary Cities Project Participants

Data has been collected for three general feature categories: «Mobility» (infrastructure features that contribute to the mobility of vulnerable populations in the urban environment), «Community Resources and Services» (resources and services that align with integral needs of identified vulnerable populations), «Public Safety» (infrastructure features and community services that contribute to the safety of vulnerable populations in the urban environment). All the objects, by the level of accessibility, were divided into 3 classes: *accessible* (there are no steps at entrance and venue is accessible for wheelchairs and strollers), *limited access* (there is one or two small steps on entry, not accessible for wheelchairs users without assistance but accessible for people with strollers), *not accessible* (not wheelchair or stroller friendly, there is more than one or two small steps on entry). Collected features and attributes are presented in Table 1. Fig. 2 shows classes of accessibility of the features of the category «Community Resources and Services».

During the data collection, project participants encountered the following main problems:

– study period is summer – season of holidays and vacations;

– problems of field data collection from scratch, although a lot of data is already available on the open resources;

– some disadvantages of software tools for data collection;

– insufficient provision of all volunteers by devices for data collection (mobile devices, tablets);

– problems of mobile Internet coverage on the study area (Internet is required for Survey 123 application).

At present, data is collected on: 2417 features from the category «Mobility» (34% of data was collected by students of the Department of Physical Geography and Cartography), 1496 features from the category «Community Resources and Services» (28% – by the students of the Department), 18039 features from the category «Public safety» (46% – by the students of the Department).

Table 1 Data collection features and attributes

Categories	Features	Attributes
1. Mobility	Street Intersections	Curb cut or ramp: present or absent; name of road the ramp connects access to
	Stairs	Surface material; number of stairs; handrail: present or absent
	Subway Station Entrances	Name of the underground station
2. Community Resources and Services	Healthcare Facilities	Type of healthcare facility; type of healthcare specialists; name and street address
	Housing Resources	Type of housing resource; name and street address
	Childcare Resources	Type of childcare resource; name and street address
	Employment Resources	Type of employment resource; name and street address
	Social Service Organizations and General Community Services	Type of social service or general community service; name and street address
3. Public Safety	Streetlights	The location; if the light currently works; type of urban infrastructure feature this light provides coverage for
	Lamp posts	The location; if the light currently works; type of urban infrastructure feature this lamp post provides coverage for
	Evacuation gathering place	Type of evacuation gathering place

This data allowed us to pre-evaluate which percentage of social institutions can be considered accessible for all population groups.

In particular, among 419 public establishments of the city center, information on which has been collected by the team of V. N. Karazin Kharkiv National University, 42% are accessible, 31% have limited accessibility and 27% are not accessible. 3. It is clear that even in the center of the city of Kharkiv, a person with disabilities can independently get to only one third of all public institutions, that is, the urban space is not comfortable at all. It can be assumed that the availability of facilities in remote areas of the city is even lower.

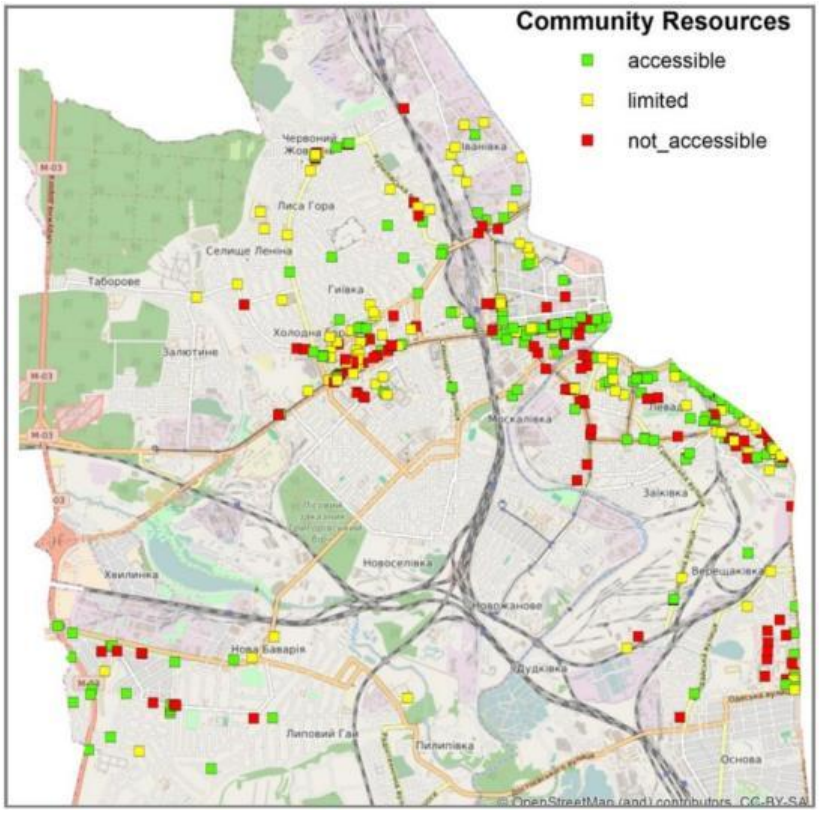

Fig. 2 Classes of accessibility of the features from the category «Community Resources and Services»

Prospects for the development of Secondary Cities project in Kharkiv are: continuing collecting data with the help of more volunteers; further involvement of students of higher educational institutions through the introduction of new tasks in the GIS courses, training practices and individual study; presentation of project results in the media and in the scientific circles; development of other relevant thematic projects using the same data collecting methods:

- creation of mobile applications for people with hearing and/or vision impairment;
- detection of unsafe areas of the city in the dark time;
- assessment of routes quality;
- detection of infrastructure features for vulnerable populations in the winter period.

After completing the data collection on the whole area of the city, it is expedient to put it in public. The exchange of data and information, interaction

between scientists, NGO representatives and community members are the principles on which the Secondary Cities project is based. So, all the findings will be made available to the general public. In part, it has been started as the data collected in the central part of the city is available on GeoNode – a web-based platform for developing geospatial information systems and spatial data infrastructures.

The collected data and the results of its analysis can be visualized with the help of an interactive map of the availability of the Kharkiv city urban space for vulnerable populations. Creating an intelligent, user-friendly and at the same time informative map will attract the attention of the authorities, businesses and residents of the city to the level of social infrastructure comfort. The interactive map will allow scientists to visually assess the condition of the living environment for people with special needs, and, based on the analysis, develop measures to improve the situation. Such recommendations will be useful for creating a new development strategy for Kharkiv city and for developing emergency response plans. The idea of developing a free mobile application that will allow planning travel routes for disabled people looks promising.

An extremely important aspect is the dissemination of information about the availability of an interactive map or a mobile application among the target audience - people with disabilities. This issue requires the assistance of non-governmental organizations and the media. Advertising on the Internet is also promising.

The field data collection methodology described in the study can also be used to determine the urban space accessibility level of other cities and towns of Ukraine. In future, it is reasonable to create the all-Ukrainian GIS intended for obtaining information on the availability of social institutions for vulnerable populations. Among the functional requirements for it there are: targeting different categories of citizens with special needs; a detailed description of the accessibility degree of an object; an advanced search functionality; an ability to add new features and their attributes; an ability to add objects descriptions, photos and other necessary information.

As a result of the conducted research the following conclusions can be made:

- the method of data collecting, processing and visualization used by Secondary Cities project and the Department of Physical Geography and Cartography of the V. N. Karazin Kharkiv National University should be introduced in other cities and towns of Ukraine, especially those where geoinformational and cartographic training of students in higher education institutions is available;
- the most accessible way to receive operative information on the statics and dynamics of social infrastructure for vulnerable populations is the use of geoinformation systems and results visualization in mobile applications;
- the subject of cartographic web applications for vulnerable populations in different settlements should be unified and developed for all groups of people with special needs;
- projects similar to Secondary Cities should be implemented not only in cities but also in other settlements of Ukraine.

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1.5 Visual aspects of urban environment

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Due to the rapid development of urban areas, the environment is undergoing significant changes. This also applies to the visual environment. Man deforms the appearance of the natural environment, adjusts to himself, constantly bringing new and new architectural structures and elements. However, solving the problems of urban infrastructure has exacerbated the problems of visual comfort. Therefore, there is a need for a clear assessment of the visual environment.

In modern conditions, the problem of assessing the ecological state of the environment has acquired economic and social significance for Ukraine. Raising the issue of environmental safety, usually means air quality, water pollution, increased noise, vibration, and radiation, but leaves aside no less important socio-environmental factor – the quality of the visible environment. Everything visible environment that surrounds a person is divided into two components: natural and artificial. The natural visible environment fully complies with the norms of the psychophysiological state of man and the physiological norms of vision. The artificial environment is a completely different matter. It differs from the natural and in many cases contradict the laws of human visual perception. The processes of urbanization and industrialization have distanced us from the visual ideal: the artificial environment has ceased to bring aesthetic pleasure and has created a large number of socio-environmental problems.

The interaction of architecture and ecology is often limited, at best, to the use of environmentally friendly materials and energy-saving technologies in construction. In Ukraine, the most pressing problem of the quality of the visual environment has become in the former Soviet times in connection with the increasing pace of general urbanization. The color scheme and structure of urbogeosystems in this period differ sharply from the natural one. The architecture of cities is dominated by uniformity, urban buildings are mostly static and have a large number of planes. Thus, the artificial environment has given rise to another problem of human ecology - the

problem of the quality of the visual environment, which is studied by the science of videoecology. This scientific field studies aspects of the visual perception of the environment by man. The author of this scientific field, as well as the term «video ecology» is prof. Filin V. A [1]. His research shows that a constant visual environment, its saturation with visual elements, can in some way affect the psycho-emotional and physiological state of man. In general, the artificial visual environment can be divided into comfortable and uncomfortable [2]. In turn, uncomfortable visual fields are represented by two types: aggressive and homogeneous. It is determined that aggressive visual fields consist of many identical elements, evenly distributed on a surface, and homogeneous are those visible fields in the surrounding space, where either there are no visual details at all, or their number is sharply reduced [1,2,3].

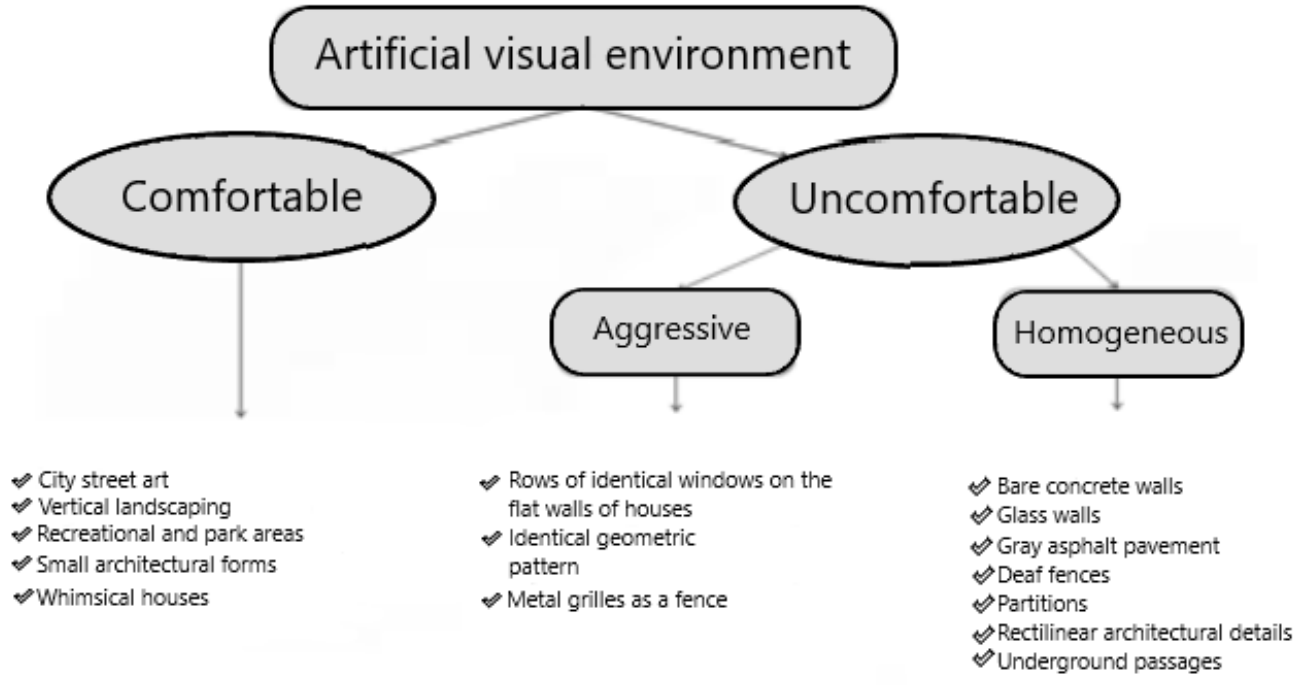

Fig. 1 Classification of types of the artificial visual environment

The figure presents the classification of types of the visual environment of the city. Thus, a comfortable visual environment includes objects that bring visual aesthetic pleasure to a person, such as planar surfaces with the use of vertical landscaping, colorful graffiti, and architectural details using smooth lines. An uncomfortable visual environment can include objects such as monotonous walls of

houses, gray asphalt, and defenses because such objects contain straight lines, monochromatic shades, and gray planes. Metal grilles and rows of identical windows in houses can also hurt the psycho-emotional and psycho-physiological state of a person. Such objects can be classified as aggressive.

Professor Filin V. A. notes that in recent years there has been a significant deterioration of the visual environment in human habitats [3]. Particularly great changes have taken place in cities, where there are many homogeneous and aggressive visual fields. For example, in the environment of homogeneous fields, the human eye can not fully perceive the surrounding information because in such an environment it has nothing to cling to, that is, the eyes do not work in «economy mode», and this inevitably leads to feelings of discomfort. Also prof. V. A Filin [2] states: «Adverse environment is one of the factors that lead to changes in eye function, so the number of myopia in cities is usually greater than in villages». In an aggressive visible environment, a person is often in a state of unreasonable resentment. Experts call this disease «Big city syndrome», which is often about is the aggressiveness of society. As a rule, where the visual environment is not more comfortable, there is a tense atmosphere, more cases of criminogenic and immoral behavior. Psychologists who studied the behavior and level of development of children in areas of new development found that children in the neighborhood lag in development from their peers who live in the historic part of the city. According to scientists, the very architecture of new buildings with their right angles has a depressing effect on the psyche. These facts are another evidence of the urgency of the problem of video ecology of the city [1, 2, 3, 4].

The urban environment cannot be successfully studied and modeled without taking into account the attitude to it that exists in the minds of ordinary inhabitants of this environment. According to Kaganov G. Z. [5], their subjective opinions, sympathies, and assessments are no less important environmental factors than purely objective factors – sanitary, geographical, socioeconomic, and others. Explains it interesting socio-ecological phenomenon hypothesis psychologist HeydmetsaM.

under which a resident of the city pays special attention to the environment mainly when there is something wrong [6, 7, 8].

Therefore, for videoecological assessment, it is possible to use sociological methods [9]. They are based on questions about total assessments of the quality of life in different areas of the city, their aesthetics, and the quality of the visual environment. However, the methods of sociological surveys are not devoid of subjectivity, which is explained by sharply individual aesthetic assessments of people's acceptance. In this regard, they can be used only in combination with other research methods.

Ukrainian scientist prof. Fesyuk V. O. [10], considering aspects of the formation and development of large urban systems of north-western Ukraine, proposed an algorithmic model of constructive-geographical and geo-ecological analysis of the environment of large cities and an algorithm for implementing the process of optimizing the ecological state of cities. A technique has been developed that allows us to practically assess the level of video-ecological favorableness of the urban environment. Its essence is to calculate the coefficient of videoecological favorability [7, 8].

Petruk V. G. and Kvaternyuk S. M. also considers the urgency of the problem of comfort and ecological safety of the visual environment of the city in their works [5–8 , 11–13]. They believe that the problem of the visually uncomfortable environment is caused primarily by the following factors: reduction of green areas; lack of purposeful work on the restoration of the facades of existing buildings on the central streets and squares of the city, as a result of which there is an « anti-aesthetic effect «; spontaneous location of small architectural forms on sidewalks, unsystematic installation and sometimes aggressive advertising posters and billboards, low lighting of facades of architectural monuments and new compositional and architectural structures [7, 8]. Accordingly, it is important and relevant to determine the video-ecological situation of urban areas.

The Kholodnogirsk administrative district of the city of Kharkiv was chosen for research. The choice of this territory is due to social demand because the

Kholodnogirsk district is one of the largest industrial districts of the city, where 9334 households are located, in which about 84 thousand people live. More than 90 large, medium, and small industrial enterprises of various industries operate in the district: production of machinery and equipment, chemical, food and processing, light, metallurgical, machine-building industry, and metal and wood processing. Industrial sites of enterprises are evenly distributed throughout the district. It should also be noted that the Kholodnogirsk district has a developed transport infrastructure, including its territory is crossed by city highways, here are the two largest railway stations and four bus stations, two metro stations. With such a saturation of man-made objects in a relatively small area, the need to construct an urban visual space, which would take into account not only economic indicators but would create conditions for the rest of the population living in the area for their comfortable living. Such conditions can be created primarily due to recreational areas within the city. Therefore, it is important to determine the quality of the visual environment of the recreational areas and adjacent areas [14].

The study was conducted in three stages. As already mentioned, there are two types of visual fields: aggressive and homogeneous. That is why at the first stage of research by the method of objective assessment with the help of photo and video fixation the assessment of the homogeneity of the visual environment was carried out. By themselves, recreational areas are comfortable for the psychophysiological state of man, homogeneity is created by the visible fields around, it is mainly planes created by residential buildings. Therefore, it was advisable to choose a space within a radius of 500 meters around the areas set aside for recreation. The following areas were selected for research: areas around the park on the Volonteer Street, Yunost Park, O. I. Meshchaninov Square, Pryvokzal′na ploshcha, Tivoli Garden, and the park around the monument to the firemen.

With the help of visual research and the method of photo fixation, the total number of buildings in the study areas and the number of buildings that create planes of homogeneous visual fields were determined. So, in the area around the park on the Volonteer Street, it was found that about 55% of the surrounding visual space is

characterized by monotony, monochromaticity, lack of objects to distinguish the human eye, and so on. These are, as a rule, end vertical walls of high-rise buildings, walls of some objects of social infrastructure (schools, kindergartens, etc.). Around most other recreational areas within a radius of 500 m, there is 17–50 % of visual space, which can be described as homogeneous, because it is mainly multi-story residential complexes of the 60–70s of the last century. The lowest level of visual field homogeneity was observed around the Yunost Park area and accounted for about 3% of the total number of visual areas created by certain objects. This rather low figure can be explained by the location of the park because it is located on the outskirts of the city, so the surrounding streets are built up mostly one-story houses of the private sector or not built at all.

The results of the first stage of the study showed that the homogeneity of the visual environment of the Kholodnogirsk district of Kharkiv has high rates in residential areas, where people spend most of their lives. Such areas should be arranged with the help of greenery, small architectural forms, and graffiti. After all, only in this way it is possible to create a comfortable visual environment [13].

In the second stage of the study, an aggressive visual environment was identified because, in contrast to homogeneous visual fields, aggressive ones can be more clearly characterized and quantified. For this purpose, the method of a quantitative assessment of the aggressiveness of the visual environment, proposed by Golubnichy A. A. [11], was used. The main principle of the technique is based on the differentiation of the plane of the visible field into cells. It is further possible to calculate the coefficient of aggression (K_{agr}) as the ratio of the number of aggressive cells (with the presence of identical objects) to their total number. Initially, objects for assessing the aggressiveness of the visual environment and viewpoints (ie, stationary points in space from which the researcher observes a specific object) were selected for photo-fixation in the study area. The research was conducted at the following objects: Plastychnyi lane, 198, Illinska str., 65, Volonteer str. 1a, the new building on the Sloviansk str., Pryvokzal′na ploshcha, 2. The viewpoints are chosen

according to the places of mass presence of people. Photo fixation was performed for each object at the same height - the average height of the human eye.

Subsequently, the number of grid cells was determined horizontally N h = α / φ, and vertically N v = β / φ, where α is the angle of view of the investigated plane horizontally – for vertical or inclined surfaces or width – for horizontal surfaces, in degrees; β - the angle of view of the studied plane vertically – for vertical and inclined surfaces or along the length – for horizontal surfaces, in degrees; φ is the angular size of the area of clear vision, in degrees. This approach was chosen following the research results of prof. Filin V. A. [1, 2].

The obtained photographic materials provided an opportunity to determine the coefficient of aggression. In this case, it depends on the number of cells with more than two visually similar objects and the total number of cells in the grid. This is determined by the formula [11]:

$$K_{agr} = N_{agr} / \Sigma N \text{ , where} \qquad (1)$$

N_{agr} - the number of cells in which more than two visually similar objects;

ΣN ($N_h + N_v$) – the total number of cells in the grid.

As a result of the study, the coefficient of aggressiveness of the visual environment for each of the objects was determined. The approximation of indicators to 1 indicates an increase in aggression. For the plane created by the house on the lane. Plastychnyi, 198, this ratio is 0.68. Given the almost complete absence of landscaping around, this is a small indicator, which was positively affected mainly by the alternation of architectural details. As a result of visual assessment of the next visual field – a plane created by a multi-story building on the street. Illinska, 65, the coefficient is set at 0.86. Regarding the visual fields created by the house on the Volonteer Street 1a, the coefficient of aggression is 0.8. These houses and the visual fields they create are located directly around the recreational area, the landscaping of which can be considered satisfactory. However, due to the significant number of identical small elements and their close relationship in the visible field, the rate of aggression increases significantly. The maximum coefficient - 1, characteristic of a plane set buildings on the street Slovyansk. Such a high value is due to the uniform

placement of the same architectural details over the entire plane of the visible field. The lowest coefficient - 0.66 has a visible field created by the facade of the post office building (Pryvokzal′naploshcha, 2). The large size of architectural details and sufficient landscaping, which «hides» the same details, reduce aggression.

The results of the study showed that most of the visual environment of the recreational areas of the Kholodnogirsk district of Kharkiv meet high levels of aggression, and therefore do not provide positive visual needs of the population. The fact that the highest coefficient of aggression is inherent in the areas with new buildings, indicates the emergence of problems at the design stage of architectural structures. Given this, it should be noted that now it is necessary to focus considerable attention on specialists responsible for urban development on the video-environmental aspects to optimize them [9].

But there is another factor that affects the quality of the visual environment - is landscaping. Greenery can hide aggressive and homogeneous fields, changing the environment to a more visually comfortable for the psychophysiological state of man. Therefore, at the *third stage of the* research, an assessment of landscaping of the Kholodnogirsk administrative district of Kharkiv was performed. The research was conducted by measuring the area occupied by greenery and the total area of the park or recreational area. Thus, the degree of the landscaping of the park on the Volonteer Street is 37% of the total area, and the area that is classified as recreational - Pryvokzal′na ploshcha - is landscaped by only 6%. Other recreational areas are landscaped by 30-36%. It is determined that landscaping of recreational areas does not reach even 50%, which should meet the standards [15] and is not sufficient. Thus, even recreational areas are not able to provide the Kholodnogirskdistrict with sufficient indicators of landscaping, not to mention landscaping of residential buildings.

Based on the results led the study should be noted that the planting area Kholodnogirsk area is not sufficient and needs much the optimization updates green space in the park areas, new planting areas, and, consequently substantial investment [15]. Such measures will include not only the creation of new facilities that will be

able to solve the visual video-ecological problems of the city, the improvement of microclimatic conditions, partially solve the problems of exposure to polluted air and others. Also, thanks to the solution of the problem of landscaping, it is possible to talk about the greening of all elements of the infrastructure of the district and the city as a whole. For example, it is more appropriate to use vertical landscaping. Unfortunately, currently, the use of this type of landscaping is not typical for recreational areas and adjacent areas of the Kholodnogirsk district of Kharkiv, and this, above all, hurts the video-ecological situation. Another means of greening the urban space with the help of greenery is the creation of plant corridors. These objects create a favorable microclimate due to greenery and have a positive effect on the psychophysiological state of the population. However, it should be noted that solving the problem of landscaping requires a comprehensive approach. Not only landscape designers but also ecologists, scientists, economists, local governments, and local authorities should be involved.

In modern urban areas, a significant part of the wood species used in urban landscaping is negatively affected by various factors. Atmospheric pollution, surface runoff pollution, pests, and parasitic plants – all this leads to the mass death of urban flora. It was found that for the Kholodnogirsk district of Kharkiv the main problem of landscaping is the defeat of tree species by mistletoe (Viscum album L.). Mistletoe (Viscum album L.) is a dioecious semi-parasitic shrub with yellowish-evergreen leathery leaves that grows in the crowns of many species [16]. Mistletoe is called semi-parasitic because its leaves are capable of photosynthesis, from the host plants take only water and minerals. As a rule, mistletoe spreads in its natural environment with the help of winter herbivorous birds – thrushes and waxwing, which feed on its fruits. Another way of spreading it is that spores are transferred with the help of contaminated tree pruning equipment and this promotes vegetative propagation of mistletoe. Studies have shown that maple trees (Acer Platanoides) and linden trees (Tiliacordata) are most susceptible to infection by this semi-parasitic plant.

It is known that mistletoe (Viscum album L.) belongs to the category of active invasive plants. This is due to particularly favorable conditions for the development

of populations of this plant semi-parasite in areas where plantations are usually the weakest compared to natural due to increased anthropogenic pressure. Such areas are recreational areas of the city. The greenery here is not only the «lungs» of the city but also a means to create a comfortable visual environment. Therefore, maintaining these plants in good condition is an extremely important and urgent task. The research was conducted in the above-mentioned recreational zones of the Kholodnogirskdistrict of the city of Kharkiv: Yunost Park, O. I. Meshchaninov Square, the park on Volonteer Street, the park around the monument to the firemen and the Tivoli Garden.

The results of field studies of park areas made it possible to perform calculations of the severity index (SI) and the degree of damage to trees by the semi-parasite plant Mistletoe white (Viscum album L.).

Thus, first the severity index (SI) of tree species was calculated according to the formula [16]:

$$SI = [\{ (P \times Q) \} / (M \times N)] \times 100 \% , \qquad (2)$$

where P = severity score, Q = number of infected plants having the same grade; M = total number of observed plants, N = maximum number on the rating scale [21].

A visual inspection of woody plants within recreational areas was conducted. The basis of the above formula is to assess the severity of damage to trees (P). To find it, we used the appropriate scale (Table 1), where the number of points depends on the number of bushes of White Mistletoe (Viscum album L.), parasitizing on a tree plant.

According to the scale, an assessment of the severity of the lesion was provided for each active plant in the recreational areas.

Based on the determination of the severity assessment, the lesion severity index (SI) was calculated. Therefore, for the territory of Yunost Park, this index is 3.4%. For the O. I. Meshchaninov Square – 4.1%. The area of the park around the monument to the firemen has a severity index of 7.2%, the highest figure is 10.5% in the Tivoli Garden.

Table 1 The scale of the severity of plant damage by Viscum album L.[21].

Score	Description
0	No incidence (no mistletoe)
1	1-5 per plant
2	6-10 per plant
3	11-15 per plant
4	16-20 per plant
5	>20 per plant

In subsequent studies, the degree by white mistletoe infestation was calculated, which is determined by the ratio of the total number of trees in the study area to the number of woody plants affected by white mistletoe (Viscum album L.) The highest value is typical for the Tivoli Garden – 27.3%. The trees of the park on Volonteer Street were also significantly affected – 24%, in the park around the monument to the firemen- 14.4% and in the Yunost Park – 12.5%. The lowest figure – 8% was recorded in the O. I. Meshchaninov Square.

Thus, as a result of the study, it was found that the greatest damage from White Mistletoe (Viscum album L.) affected the tree vegetation of the Tivoli Garden and the park of the park on Volonteer Street. These recreation areas are located directly next to residential buildings, where there are virtually no measures to ensure plant health. The least damage by this semi-parasitic plant is characteristic of O. I. Meshchaninov Square and Yunost Park. This is explained by the fact that in these areas there is an alternation of species composition of vegetation and the presence of tree species resistant to damage (so 12% of the trees in the O. I. Meshchaninov Square are birches). Another factor in reducing the infestation of plants with White Mistletoe is the sanitary pruning of trees, in particular in the O. I. Meshchaninov Square and Yunost Park. The conducted research allowed to develop recommendations for creating a comfortable visual environment for recreational areas and adjacent areas [17] To prevent the appearance of aggressive and homogeneous visual fields, you can use the following:

- It is important to improve landscaping work in the city: increase the number of greenery, maintain plant health. For example, several methods can be used to control white mistletoe. This is primarily the treatment of mistletoe-infected tree species (Viscum album L.). Also, following paragraph 11.5 of the «Rules for the maintenance of greenery in the settlements of Ukraine», approved by the order of the Ministry of Construction, Architecture, and Housing of Ukraine №105 from 10.04.2006, to control mistletoe mechanical method is used - pruning mistletoe bushes that do not bear fruit, 5–7 cm, and with fruiting – at least 15–20 cm below the place of its attachment to the branches. In the case of damage to the crown of trees by white mistletoe by more than 60%, they must be removed [18, 19, 20]. It is also important to constantly replace remotely affected trees with invulnerable species such as conifers, nuts, or birches.

- Use vertical landscaping on the walls of buildings where there are no architectural accents;

Fig. 2 The building of NUPh, Kharkiv

- Use advertising posters to optimize an aggressive visual environment;

- Increase the number of small architectural forms as objects of a comfortable visual environment.

- Create modern wall paintings. Mural painting has drawings on large planes. These include wall paintings, murals, ancient cave paintings. Such works were

created in the city of Kharkiv: portrait of actress Natalya Fateeva on the street. Primerskii 22A, the portrait of Lyudmila Gurchenko, lane Gurchenko, 7, the mural at «Strelka» on the street Kontorskiy, etc [12].

Fig.3 Portrait of actress Natalia Fateeva [22]

Fig. 4 Portrait of Lyudmila Gurchenko [21]

- Apply whimsical architectural elements of various shapes;
- Use the modern urban landscape element and Street Art.

Fig. 5 Graffiti Salvador Dali, Kharkiv

Finally, it should be noted that videoecological issues should be addressed by involving municipal authorities and utilities, such as Kharkivblagoustriy, administrative (Kharkiv Regional Department of Forestry and Hunting) and production resources, involving modern scientific developments and using design fantasies to improve the urban environment. After all, it is very important to take into account a comprehensive approach to create a comfortable visual environment in the city of Kharkiv.

Thus, the problem of poor visual environment is related to the spread of the artificial environment, which arose due to the processes of urbanization and industrialization. Particularly great changes have taken place in cities, where there are many homogeneous and aggressive visual fields. It is established that these changes negatively affect the psycho-emotional and psycho-physiological state of a person. It was found that the greatest indicators of homogeneity are inherent in areas with old buildings, and aggression - it is the new building. It is determined that an important indicator of a comfortable video-ecological situation is the landscaping of the city. It is noted that the greenery of the studied area of Kharkiv is less than 50%, which does not meet the normative indicators, and one of the most important factors in reducing the rate of landscaping is the invasion of tree species by White Mistletoe (Viscum album L.). As for recommendations, it is extremely necessary to take some measures that would create a comfortable video environment for the stay and relaxation of the

population. Given the above, considerable attention should be paid to improving the comfort of modern urban geosystems, taking into account all aspects of the video-ecological environment.

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1.6 Ecological quality of natural drinking waters for drinking population

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Actual issue for the population is the accessibility of available sources of water suitable for safe consumption [1]. Drinking water is one of the basic conditions of human existence. Currently, cities are provided with a centralized water supply [6], but citizens also use water from natural sources, which are the outputs of groundwater, interstratal water on the surface.

The state of water in rocks has many forms and depends on the forces of interaction that arise at the boundary of the system «rock-water» and are determined by the composition of rocks, the degree of their fragmentation and physical conditions. Water is contained in the rock in the form of an ultra-thin layer sorbed on the rock (hygroscopic moisture), thin layers that envelop solid particles (layer moisture), a liquid that fills the capillaries in between individual particles of rock, as well as a fairly large amount of moisture - in the drip-jet state, forming underground reservoirs of considerable capacity in the form of aquifers and fractured zones. In the

work of Khilchevsky V.K. and others. [12, p. 182] states that the main features that determine the formation of the chemical composition of groundwater are:

1) Close contact of groundwater with various rocks and minerals of the earth's crust, which facilitates the transition of elements and their compounds into solution.

2) The presence of waterproof hard-to-penetrate layers of rocks that separate certain groundwater horizons, which complicates and often disrupts water exchange between aquifers. This contributes to the formation of the individuality of the composition of groundwater.

3) The complexity of the connection of groundwater with the atmosphere and the earth's surface.

4) Weakening of biological processes, which in groundwater, in contrast to other types of natural waters, are limited by the activity of microorganisms except for karst areas.

5) A sharp change in physical conditions (temperature and pressure) with depth. At great depths, water interacts with rocks at pressures of several hundred and thousands of atmospheres and often at high temperatures (above 100 ° C).

6) Decreasing the oxygen content with depth and establishing from some depth reducing conditions, low redox potential, creating an environment that promotes the development of anaerobic processes.

Such specific features affect certain features of the chemical composition of groundwater. For example, the extraordinary diversity of the chemical composition of water. Groundwater can have a very peculiar composition of gases, which includes all-natural chemical elements. These are significantly increased concentrations of Fe^{2+}, Mn^{2+}, NO^{2-}, $NO^{3-,}$ Ra^{2+}, H^{+}, huge content of CO_2, H_2S, CH_4 and others. The relationships between the major ions are varied. Groundwater mineralization varies from fresh to brine, the number of ions from several tens of mg/dm^3 to 600-650 mg/dm.

Such a wide range of mineralization changes (except for lakes) is not observed among other types of natural waters. Absence in most deep groundwaters of a clearly defined regime of chemical composition by seasons [10].

The diversity of the chemical composition of groundwater and the nature of its distribution in the earth's crust due to the historical development of water in the rock, their dynamics, the transformation of their composition in interaction with rocks and under the influence of organisms [4].

The territory of Kharkiv region is located on the border of the Dnieper-Donetsk basin, which is an integral part of the Dnieper-Donetsk artesian basin. The depth of aquifers is calculated from a few meters to hundreds of meters. Kharkiv region ranks fifth in Ukraine in terms of total groundwater reserves. The intake of fresh groundwater is carried out mainly from cretaceous sediments and is equal to 0.168 km^3/year. The following aquifers are used for groundwater extraction: Novopetrivsky and Mezhyhirsky, Buchatsko-Kanivsky, Cretaceous-marl and Cenomanian-Lower Cretaceous.

Novopetrovsk and Mezhyhirsk aquifers are not used for central water supply in Kharkiv due to man-made pollution [6].

The Cretaceous-marl aquifer associated with the fracture zone in river valleys fades to watersheds. Water-retaining rocks have a thickness of 500 to 150 m, the water content of the horizon is variable from 1-2 l/s to 20-40 l/s. Chemical composition at mineralization of 1-1.5 g/dm^3 – hydrocarbonate-calcium. From this horizon water is supplied to the settlements: Kupyansk, Velykyi Burluk, Dvorichnaya, etc. In Kharkiv, this aquifer is not used due to possible man-made pollution [6].

The aquifer of Buchach-Kaniv deposits is widely developed within the region. It is absent or has a local distribution in the north-eastern and eastern districts of the region, as well as on the north-western outskirts of the Donetsk folded structure. The aquifer complex is covered with water-resistant clays and clay marls of the Kyiv world. Only in the southern and south-eastern part of the Kharkiv region, where clays and clay marls are replaced by siltstones or blurred, the complex loses its independent significance and forms a single hydraulic system with the aquifers lying above. The lower waterproof layer is the clay of Kaniv and Luzaniv. On the right bank of the Orel River, water-bearing rocks are represented by quartz-glauconite sands,

sandstones, and siltstones. The waters of this horizon are usually pressureless or low pressure. The thickness of water-bearing rocks varies from 5-10 to 20-40 m. The filtration coefficient of sands is 1-5 m/day. The Buchach-Kaniv aquifer is fed by infiltration of atmospheric precipitation and by overflow of pressure waters from Upper Cretaceous sediments. Unloading is carried out in the valleys of the Severskiy Donets and its tributaries.

The aquifer is complex in high-pressure places. Pressure height in Valkiv, Krasnograd and Krasnokutsk districts reaches 130-190 m, in other areas – 30-80 m. Specific flow rates of wells vary widely – from almost waterless in Zmiiv and Izyum districts to 0.9 dm^3/s – in Balakliiv area. The type of water is quite diverse and varies from hydrocarbonate-sulfate calcium-sodium in Kharkiv, Vovchansk, Balakliiv and Chuguiv districts to hydrocarbonate-chloride and chloride-hydrocarbonate sodium in the central and southern regions of the region. Water mineralization ranges from 0.3 to 3.2 g/dm^3, total hardness – 0.5-26 $mg\text{-}eq/dm^3$. The aquifer has a local hydraulic connection with groundwater in the valleys of the rivers Severskiy Donets, Udy, Lopan, Kharkiv, Orelka. It has significant operational reserves, which amounted to 645.3 thousand m^3/day according to the regional estimate. It is used throughout the region, except for Velykoburlutsky, Dvorichansky and Kupyansky districts.

According to the information provided in the study Prybylova V.M. [10] The aquifer is widespread, with water quality, conditions and significant operational reserves. For most of its distribution, the aquifer is protected from surface pollution, but is subject to man-made impacts in large settlements and industrial enterprises.

In the central and southern part of the Kharkiv region, the aquifer of the Buchach-Kaniv sediments is fed to a greater extent due to the flow of water from the underlying aquifers containing salt water in the areas of domed structures and in the areas of aquifers in the zones of DDAB joining formation with Ukrainian and Donetsk folded region. The chemical composition of water changes to sodium chloride type with salinity up to 3 g/dm^3 and above and with a total hardness of up to 10 $mmol/dm^3$ and above [10].

The Cenomanian-Lower Cretaceous aquifer complex is referred to the glauconite sands and sandstones of the Cenomanian tier of the Lower Cretaceous and to the same deposits of the Albapian tier of the Lower Cretaceous. The aquifer complex is lined with Jurassic clays. The thickness of water-retaining rocks is 20 – 100 m. The depth of this aquifer complex is as follows: 300 – 350 m in the northern part of the region; 800 – 950 m in the central part; 25 – 27 m in the south. In the valley of the Orel River, the flow rate of wells is 10 – 14 l / s, in Kharkiv – 1 – 2 l / s. Water mineralization – 1 g / dm3, chemical composition – hydrocarbonate-calcium. This aquifer is widely used for centralized water supply in Kharkiv and Kharkiv region [10].

In the study of providing the residents of Kharkiv with quality environmentally friendly water resources, several works on similar topics were analyzed, covering current problems of water supply in cities. In the study of Kravchenko N.B. et al. (2015) [7], it was determined that the population actively uses sources of natural drinking water for economic needs. The paper presents the results of sociological surveys: «The calculation of the rating of closed sources of drinking water in Kharkiv by socio-economic indicators (excluding environmental indicators) showed that the best from the consumer's point of view is the source «Sarzhin Yar», the worst – the source in the park «Yunist» «[7, p. 84-88].

Thus, this problem is more than relevant for the citizens of Kharkiv and therefore requires constant monitoring studies to determine compliance with the requirements for drinking water and to determine their environmental safety.

The purpose is to assess the ecological quality of spring waters in Kharkiv.

To assess the ecological quality of spring water in Kharkiv, water samples were taken from sources in four administrative districts of the city: Kyiv district (Zhukovsky spring), Moscow district (Hlyboky Yar), Shevchenkivsky district (Sarzhyn Yar) and Kholodnohirsky district (spring in Yunost Park).

Objects and methods of research. The object of research is water from natural springs of the city of Kharkiv. A feature of the sources selected for the study is their

territorial location in different areas of Kharkiv, as well as their importance as the largest and most popular natural water sources among the city's residents [9].

The studied spring waters are used by Kharkiv residents as drinking water, so the determination of standard parameters of drinking water samples was performed on the basis of a certified laboratory of analytical ecological research of the Karazin ESI of Ecology using certified methods [8].

Analyzes of drinking water samples from city sources were performed according to the following indicators: pH value, electric potential; nitrate content; chlorides; ammonia; nitrites; transparency; turbidity; water hardness.

Also, with the help of atomic absorption spectrophotometer C-115IIK in spring water samples the concentration of heavy metals was determined: Fe, Zn, Cu, Mn, Cd, Cr [2].

The results of spring water studies indicate the following characteristics: the highest pH level was found in water from the Zhukovsky source – 6.85, which is higher than the level of hydrogen in water from other sources. The normative value of pH is 6.5 – 8.5, which indicates the acidity or alkalinity of water. All spring water samples are characterized by pH level as neutral.

The electric potential indicates the level of water mineralization. The indicator has no normative value. The research results are shown in Figure 1.

The highest level of mineralization was found in water from the source of the Hlybokyy Yar – 6.96, and the lowest – in the water from the source in Sarzhin Yar – 5.78. It can be stated that the waters from the source of the Hlybokyy Yar have the highest content of dissolved inorganic salts and dissolved other substances among the studied water samples.

The standards of chlorides in spring waters according to the standards should not exceed 350 mg/dm^3. The studied water samples in terms of chloride content meet the standards (Fig. 2).

The highest value is in the water of Zhukovsky spring 64 mg/dm^3, and the lowest in the water of Kholodnohirsky spring – 40 mg/dm^3. In this case, the chloride content in all water samples can be considered insignificant in comparison with the

maximum allowable concentrations. Chlorides (Cl-) give water a salty taste and can adversely affect gastric secretion [11]. That is why the content of Cl- in drinking water should not exceed 350 mg/dm^3.

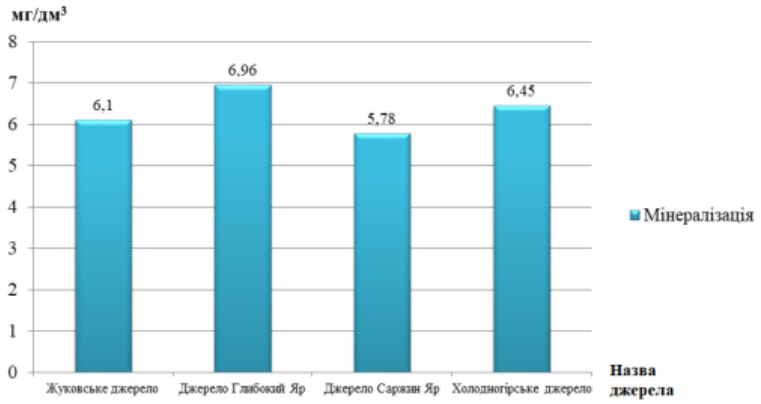

Fig.1 The level of mineralization of spring waters

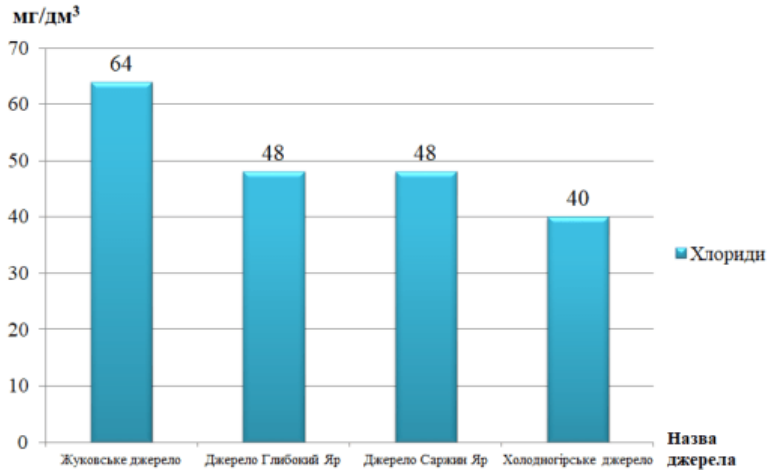

Fig. 2 Chloride content in spring waters

The level of nitrates should not exceed 50 mg/dm^3. No exceedances were detected in any of the samples. The lowest content of nitrates in the samples of water from the Zhukovsky spring and in the water from the spring in Sarzhyn Yar is 3.4 mg/dm^3, and the highest – in the samples from the Kholodnohirsky spring – 4.1 mg/dm^3.

According to the level of transparency, all samples of spring water were evaluated on a 30-point scale and received 24 – 25 points, which is a sign of pure transparent water without impurities with a low level of turbidity.

The content of ammonia and nitrites in the waters meets the standards and is almost the same in all samples. Ammonia: in all spring waters – 0.04 mg/dm^3 (normal – up to 2.0 mg/dm^3). Nitrites – 0.001 mg/dm^3 in all samples of test waters (normal – 3.3 mg/dm^3).

The value of water hardness deviates from the norm (1.5-10 mmol/dm^3) (Fig. 3). For drinking spring water, the indicator is not exceeded only in the sample of water from Zhukovsky spring – 10 mg/dm^3.

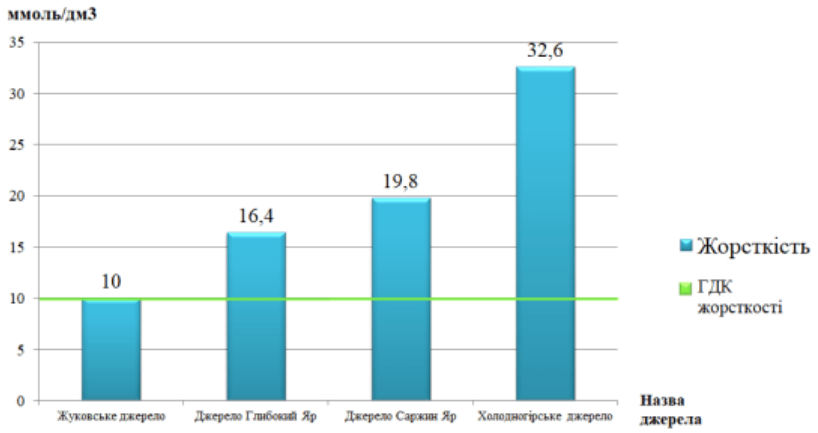

Fig. 3 The level of hardness of spring waters

The spring waters selected for the study are characterized by inflated hardness: in the water from the Hlybokyi Yar spring the standard is exceeded 1.5 times, in Sarzhyn Yar – 2 times, in the water from the Kholodnohirsky spring – 3 times and is 32.6 mmol / dm3.

Drinking water with increased hardness can lead to cardiovascular disease, skin diseases and can negatively affect the strength of hair [4].

Exceedances of the content of heavy metals in accordance with the maximum allowable concentrations were not detected. The content of Cd and Cr in all water samples was determined in very small concentrations, which can be neglected. Deficiency in the human body Cd can adversely affect hydrocarbon metabolism, activation of a number of enzymes, synthesis in the liver of hippuric acid, as well as the metabolism of Zn, Cu, Fe, Ca. Cr also regulates hydrocarbon metabolism and controls blood glucose levels.

Also held in 2019 studies have shown that the highest values of nitrates, nitrites, alkalinity, and hardness were found in a sample of water from a spring in the park «Yunist», located in the Kholodnohirsky district. There is no reliable explanation of the reasons for such indicators, but attention should be paid to the sanitary condition of this source. During the research, a sociological survey of the local population on their personal impressions was conducted after visiting this source. It was found that only one of the three taps brought for use by the source is suitable for water abstraction and is used by the population. And the water taken only from it on organoleptic indicators can be used as drinking. Other taps supply low quality water and are considered by users to be environmentally unsafe.

The results of the study of water hardness parameters from the source Sarzhin Yar and the source in the park «Yunist» were compared with the results of previous studies in 2015 [7] (Fig. 4).

Finally, it should be noted that during the field research, inspection and visual assessment of the location and arrangement of urban sources of drinking water, a survey of citizens who visited the sources and took water for drinking.

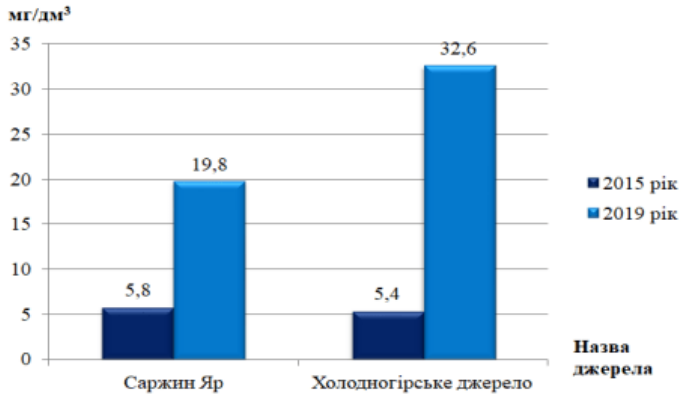

Fig. 4 Change in water hardness of springs in the period from 2015 to 2019

The survey revealed a conflict of interest between the population and local authorities. The problem is the unsatisfactory arrangement of all the sources studied, except for the source in Sarzhyn Yar. First of all, there is no unimpeded access to urban spring water sampling sites, as well as many other problems. In the end, the question arises: who should be responsible for the environmental safety of drinking

spring water in different areas of Kharkiv, which the population has been using for years, and who is responsible for financing and arranging these sources, which are in great demand among Kharkiv residents.

The obtained results of analyzes of urban spring waters showed that the values of pH, electric potential, content of nitrates, chlorides, ammonia, nitrites, transparency, turbidity exceeded the normative indicators.

The content of heavy metals in spring water samples does not exceed the maximum allowable concentrations. Water from an urban spring in the Kyiv district (Zhukovsky spring) is characterized by a hardness of 10 mmol/dm^3, which is the upper limit of the normative value (1.5-10 mmol/dm^3). All other water samples are characterized by inflated hardness. When comparing the parameters of spring water hardness with a similar study in 2015 [7] of water from Sarzhin Yar springs and springs in the park «Yunist», it was determined that the hardness in both samples increased in the period 2015 – 2019 by 3.4 –6 times. Drinking water hardness in excess of drinking water standards can adversely affect human health. Therefore, the only ecologically safe, among the studied, can be considered water from the Zhukovsky spring (Kyiv district of Kharkiv). For other sources, it is recommended to modernize water abstraction sites. Reconstruct the water supply system for water supply from these sources, as well as introduce additional stages of their purification on the way to the consumer.

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1.7 Formation of a model of social and environmental responsibility of industrial enterprises

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The problems of social and environmental responsibility are among the topics that are actively covered in domestic and foreign literature. In the literature, along with a broader interpretation of social responsibility of businesses, wherein environmental initiatives are included as a mandatory part, this question is studied with a focus on proper environmental initiatives [1; p. 38-39].

Today, the the work of scientists who reveal the essence of various development activities of the environmental component of the enterprise is well represented. These scientists include N. Asambaeva, L.V. Goriacheva, V.A. Zubakina, N.P. Karpenko, D.A. Manukyan, K.A. Olejnik, Yu.V. Savina, B. Sydorchuk, P.V. Sorokoletov, A.I. Subetto, N.P. Tikhomirov, M.G. Furutyan. The general theoretical model of ecologization of business activities is considered in the work of G.T. Shkiperova, G.B. Melentyev, [2] V.F. Zlokazov. [3]. The issue of environmental responsibility of direct users of natural resources is reflected in a

variety of schools and economic doctrines. However, a comprehensive approach to the definition of this concept is yet to be developed.

Although the topics related to environmentally oriented business management are widely covered in scientific literature, there is still lack of a coherent methodology and set of mechanisms that can be used for the purposes of comprehensive definition of what is meant by environmental responsibility and, therefore, for development of a set of tools for its implementation and development. Performance of concrete steps in the course of implementation of environmental initiatives requires that public institutions and private sector understand the concepts and the objectives of environmental responsibility of businesses. Given the instability of the financial and economic situation and the high costs necessary for the transfer of the national economy to the «green track» of development, the choice of priorities that are most conducive to achieving success is especially important. Thus, study and rethinking of basic conceptual approaches to the concept of environmental responsibility and to the methods of its realization both in foreign and in domestic practice is extremely important to date.

Domestic enterprises face the issue of environmental responsibility in a particularly acute manner due to the number of reasons, which include the overall high environmental capacity of the economy, the use of outdated («dirty») technologies, the prevalence of primary industries, the low level of development of cultural traditions of respect for the natural resources, and the low level of development of environmental management institutions. The objective of the research as outlined in the present paper is development of a comprehensive definition of environmental responsibility of businesses and analysis of this concept within the system of social and economic categories.

Results and discussion **.** As articulated in the framework of economic welfare theory by Arthur Pigou regarding environmental externalities, the responsible business imperative acquires a much wider sense today [4, p. 58]. We are talking about a wide set of external, positive and negative, effects of activities of businesses that need to be taken into account in the course of approval of economic decisions.

The composition of these effects must include not only purely environmental externalities but also social ones in the narrow sense of the word. The latter are associated with a variety of external effects of businesses on the human capital of the modern society and the quality of life of the population. Given the basic tenets of the theory of externalities and their internalization, it is advisable to understand social responsibility as the strategy of businesses as regards integration of social and environmental imperatives into the process of decision-making, into the systems of values and culture, as well as implementation of this objectives by means of a method that is transparent to all the interested parties.

Historically, approaches to sustainable development and responsibility have been developed in several areas of economic thought: neoclassical, illiberal, institutional, neoinstitutional, and evolutionary economics. The main approaches are as follows:

- the «traditional» approach to responsibility (M. Friedman): business bears only economic and legal responsibility;

- the neoinstitutional ethical approach (M. Dimmock, P. Drucker etc.) or the approach from the viewpoint of the interested parties: business as a whole has an ethical obligation to specific groups of interested parties (stakeholders);

- the socio-ethical approach (K. Lewin, E. Schein, H. Mintzberg): managers and employees are responsible for the balanced adherence of the business to public interest. The latter was developed in the framework of the approach from the perspective of a social and sustainable business (S. Shaltegger, K. Segerson, R. Barr, J. Peterson, T. Dyullik): responsibility in the broad sense removes the conflict of interests of stakeholders and promotes sustainable development of the society.

First, the issues of social and environmental responsibility in the scientific literature have been analyzed to some extent in parallel within the scope of various approaches [5]. The legitimacy of independent reporting and analysis of environmental and social responsibility of businesses (in the narrow sense of the word) is determined by both the practical existence of various mechanisms for their implementation (environmental taxes (A. Pigou) and the market negotiations (R.

Coase)). As regards environmental responsibility, the case is largely about the need for internalization of negative externalities (their imposition onto the culprit). Given these circumstances, environmental responsibility in the narrow sense, as it has been developed in the corresponding literature, refers to a conscious and motivated participation of businesses, along with internalization of external negative effects of its activities, in a variety of measures that prevent environmental damage and poor environmental management as well as in the provision (production) of public environmental benefits.

Today several approaches that define the environmental responsibility of businesses and its objectives have been formed in the world. Table 1 shows the main ones.

It is necessary to pay attention to two important points. Firstly, according to modern ideas, the social and environmental responsibility involves not only and not so much the payment for the damage to the environment caused by the activities of the enterprise as implementation of activities that prevent such damage. This includes the support for socially significant social and environmental initiatives (healthcare measures, preservation of cultural heritage, support of protected areas, conservation of endangered species etc.). Secondly, the implementation of social and environmental responsibility is closely linked to the approval of an ethics that is adequate to the problems of such businesses and which is intended to supplement the formal legal rules and requirements set forth in the approved laws, standards, regulations etc., moral and ethical standards and principles, thereby reinforcing the effect of formal institutions.

On the other hand, an important role in the formation of the «green» growth model of the enterprises is played by institutional conditions that are represented by certain social institutions that act in the form of regulatory organization and regulation of this process. As noted by [6], «a well-designed control system can determine the rights and create the incentives that stimulate the transition to a ‘green’ economy as well as remove the barriers to green investment». Among the factors that generate favorable institutional environments, one can distinguish the development of

property relations, the tax law, and the degree of human development. Efficient functioning of the institutional structure has a positive impact on the process of greening of the economy since it reduces the amount of transaction costs. One of the important prerequisites for formation and development of the process of greening of the economy is the maturity and the stability of the institutional environment.

Table 1 Modern Conceptual Approaches to the Definition of Environmental Responsibility

Conceptual Approach	Definition	Main Features
1	2	3
The American model	Corporate environmental responsibility: a component of the overall business strategy and corporate development, which takes into account the environment that goes beyond creating profit and statutory social standards. The level of corporate responsibility for the environment and the appropriate corporate actions are determined by the management of the corporation.	- a leadership role of the business community; - a low role of government regulation; - kind support for local communities.
The European model	Ecological responsibility of businesses: a concept of accounting of environmental interests of society by the company with a focus on compliance with regulatory requirements and on compliance of the actions with the relevant environmental issues in the operations area.	- regulatory compliance; - the basis of the implementation: legal responsibility; - a high level of media interest.
The domestic approach	Environmental responsibility of businesses: the standards that are binding from the point of view of moral positions and that concern the relationship of economic subjects to the environment, and thus to the life itself of both the present and the future generations. This responsibility covers the following: environmental protection and optimal use of natural resources and environmental safety of production and consumption processes.	- focus on the state and the shareholders; - a low level of reporting; - a low level of vested interest.

Note: formed by [10-12]

Today a number of conceptual approaches to the definition of the model of social and ecological responsibility of enterprises, as well as a number of mechanisms

and instruments for their implementation are created on their basis have been formed. The list of these approaches, which is presented below, as a whole reflects the evolution of content and instruments for implementation of environmental responsibility.

- transformation of external negative environmental effects that are caused by the activities of the business into its internal costs on the basis of the tax of A. Pigou and the derivative instruments (inclusive of the payments for negative environmental effects, as is the case in the Russian Federation) that are applied to the polluters of the environment and are based on an active participation of the state in the area of neutralization of market failures.

- methods and instruments for environmentally sustainable social and economic development, which allows for extending the timeframe of the responsibility of businesses due to social and environmental obligations to future generations and stakeholders, without removing the issue of an increase of the economic and financial performance.

- internalization of external environmental costs in the internal costs of the business through direct market negotiations between the «victim(s)» of environmental pollution and the culprit in terms of well-defined property rights and minimization of the state's presence - in accordance with the theory of R. Coase.

- the economic and legal method of implementation of environmental responsibility, which includes two application areas: 1) insurance of environmental responsibility of businesses that operate in risky sectors (mandatory and voluntary); 2) implementation of responsibility by imposing civil and criminal penalties in court proceedings.

- participation of the business in the process of purchase and sale of quotas for greenhouse gas emissions under the emerging interstate mechanisms of resolution of global environmental issues.

- voluntary environmental agreements and partnerships (business - government; business - business). This is a flexible instrument of exit for the business beyond the legally fixed standards of environmental safety and environmental

management and of focus on solving cross-sectoral resource and environmental issues (recovery and recycling of old large machinery, railway cars, airplanes etc.). Its use is applicable to address both the high degree of uncertainty and the asymmetric distribution of the information that is necessary for effective decision-making [7, pages 121-123].

Along with the development of conceptual approaches, the basis of the evolution of forms of implementation of environmental responsibility also includes the changes in the nature of environmental issues (which are increasingly globalized and complicated) and the practical approaches to solving them, inclusive of the transition to new instruments of resource and environmental policies. This transition is characterized by a change in the management style by means of replacement of the rigid state environmental regulation with a balanced system of mandatory and voluntary instruments, as well as by openness (transparency) of government and business activities and the establishment of partnerships cooperative relations between them [8:]. Thus, the mandatory requirement for implementation of social and environmental responsibility by the business is the transition from a command state with a rigid administrative control to a state that integrates negotiation mechanisms into its activities [9].

Analysis of development of approaches to the environmental responsibility allows for tracing of some of the other trends as well. First of all, from the standpoint of modern requirements, each of the methods used in practice must, in one way or another, be focused on delivering not just a double (as was recently required) but a triple dividend, with a view to ensuring positive social effects. Along with the substitution of the requirement of «the polluter pays» as described above with the principle of prevention (i.e. not causing) of an environmental damage whereof the implementation involves turning the business toward an active application of environmental innovation (process, product, service, organization innovation), we can note the following points. In modern conditions of activation of investment processes with an increase of the anthropogenic pressure on the environment, the method of direct negotiations between investors (or their representative designers)

and the local population on the issue of compensation of the damage caused to the environment that is complemented by public participation in environmental assessment of projects receives all the wider space for application. Development of the economic and legal approach, inclusive of the environmental insurance part, contributes to the solution of this issue serving as a compensation for damages for not only established but also for emergency environmental pollution. The interstate mechanism of purchase and sales of quotas for greenhouse gases expands the geographical boundaries of social and environmental responsibility and enables promoting solutions to global environmental issues on the basis of market incentives [13, 14].

An important type of voluntary environmental agreements that reduce the administrative burden on the business while achieving of socially acceptable standards of environmental safety and sustainable use of natural resources on an incentive basis are the international standards for environmental management and auditing (ISO 14000 and EMAS (Eco-Management and Audit Scheme)), which are introduced at enterprises on a voluntary basis. The features of these standards include further expansion of ideas about the content of social and environmental responsibility of the businesses. This is due, in particular, to consistent integration of the concept of an ecological product life cycle (EPLC) into the ISO 14000 standard and, above all, into its second version, which was adopted in 2004 [15].

This makes it necessary to monitor the social and environmental effects that not only are caused by the production process but that also occur throughout the product life cycle. Namely, from the manufacture of raw materials and components (independently or by suppliers of the company), their transportation, processing, and manufacturing of the final product, its promotion and sales, and so on to the stage of consumption and safe disposal of time-expired products.

Social and environmental responsibility of the businesses is closely linked to the ethical standards of the business community that complement the system of environmental standards and the requirements set out in applicable legislation, standards etc. Various environmental mechanisms and corresponding instruments for

implementation of environmental responsibility in one way or another also apply to Ukraine today, although in terms of coverage (in particular, environmental insurance), they can be seen with a considerable lag in comparison with the best international practices. Some of these problems are directly related to the formation of an adequate institutional environment for environmentally responsible and competitive businesses.

Perceptions of social and environmental responsibility in business economics are being developed and enriched. The following can be offered as a general definition. Environmental responsibility is an informed and motivated participation of the business in a variety of measures that prevent environmental damage and poor environmental management, provision (production) of public social and environmental benefits, inclusive of healthcare activities, improvement of the quality of environment and sustainable use of natural resources along with the internalization of external negative effects of business activities. It is based on environmentally and socially responsible entrepreneurship, which refers to free economic incentive-based activities related to risk and aimed at achieving market outcomes subject to compliance with the requirements of environmental safety and sustainable use of natural resources enshrined in legal documents as well as in the publicly recognized ethical standards that comply with the ethical norms that are established in the society.

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2 MODELLING OF DECISION-MAKING IN COMPLEX SYSTEMS FOR SUSTAINABLE TERRITORIAL DEVELOPMENT

2.1 Modeling of Decision making Ontology

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1. Introduction

Decision making is the main point in human activity, and the decision making patterns remain the same for all subject areas. Difficulties in making decisions arise because of the uncertainty and/or insufficient knowledge about the problem situation and the resources available, the weak structure of the task, and the multi-criteria choice. The formalization of the applied problem, the choice of the decision procedure, the organization of the work of the decision maker and experts are carried out by the consultant-analyst. Introduction to the decision making process of decision support systems (DSS) reduces the level of subjectivity by solving the problems of insufficiency and uncertainty of the initial information.

This paper proposes a method for modeling ontology of decision making, one of the stages of which is the construction of a multi-criteria assessment of the ontology quality. The discussion is conducted on two examples: models of the ontology of a court decision and the ontology of managing the development of a pharmacies network. In these examples, decision areas are distinguished by the initial degree of formalization and the level of possible automation.

2. Related Works

The paper [1] proposed a methodology for developing an information system for decision making using the Information Data Bank of high-tech technologies, which is based on an object-cognitive analysis of the subject area, integrating the methods of object-oriented analysis, ontological analysis and semantic knowledge

representation network with a goal of describing knowledge used in the management of complex dynamic objects in problem situations.

The main provisions of the automated development of ontology based on the analysis of texts in natural languages are set out in the work of the authors V.V. Litvin, A.B. Demchuk, M.Ya. Gopyak [2], where the criteria optimization of the constructed ontology are formed in accordance with the quality standard ISO 9126. This theme is further developed in [3], which is devoted to the adaptation of the characteristics of the ISO / IEC25012 standard for assessing the quality of knowledge systems ontologies. These characteristics include: functionality in use, reliability, clarity, convenience, portability, recoverability, confidentiality. By functionality is meant the ability of a computer system to satisfy functional user requirements and tasks.

The fuzzy-set approach to assessing the quality of ontology, described in [4, 5], offers an integral criterion for the quality of an ontology fragment, which consists of three components: fuzzy functionality, fuzzy injectivity, and fuzzy everywhere certainty. It is applied to individual fragments of the ontology according to the following formulas.

Defines the prototype of a set of concepts C in compliance $\tilde{\Gamma}_{TC}$:

$$\tilde{\Gamma}^{-1}(C) = \{< \mu_{\tilde{\Gamma}^{-1}(C)}(t), t > | t \in T\}, \quad (1)$$

where $\mu_{\tilde{\Gamma}^{-1}(C)}(t) = \vee_{c \in C}(\mu_{\tilde{R}_{TC}} < t, c >)$, $\mu_{\tilde{R}_{TC}}$– membership function value.

The degree of fuzzy functionality implies that each ontology concept will have textual inputs that have a small number of common terms, and is determined by the formula:

$$\beta(\tilde{\Gamma}_{TC})_{fon} = 1 - \alpha(\tilde{\Gamma}_{TC})_{fon} \quad (2)$$

where $\alpha(\tilde{\Gamma}_{TC})_{fon} = \frac{1}{C^2_{|C|}} \sum_{c_i, c_j \in C} \left(\frac{1}{|T|} \sum_{t \in T} \left(\mu_{\tilde{\Gamma}^{-1}(c_i)}(t) \& \mu_{\tilde{\Gamma}^{-1}(c_j)}(t) \right) \right)$; $|C|$ - the number of concepts in the group of homogeneous ontology concepts; $|T|$ the number of terms associated with concepts; $C^2_{|C|}$- the number of combinations of C in two, corresponding to the number of all possible pairs of concepts.

The greater the value of fuzzy functionality, the higher the quality of the ontology fragment. Estimates of the degree of injectivity and non-injectivity are found according to the following formulas:

$$\beta(\tilde{\Gamma}_{TC})_{inj} = 1 - \alpha(\tilde{\Gamma}_{TC})_{inj} \quad (3)$$

where $\alpha(\tilde{\Gamma}_{TC})_{inj} = \frac{1}{C_{|T|}^2}\sum_{t_i,t_j \in T}\left(\frac{1}{|C|}\sum_{c \in C}\left(\mu_{\tilde{\Gamma}_{(t_i)}}(c) \& \mu_{\tilde{\Gamma}_{(t_j)}}(c)\right)\right)$.

The quality estimates (1-3) presented in [5] are applied to the analysis of ontology fragments; therefore, to take into account the structure of the entire ontology, we suggest using topological characteristics of the graphs. In the work of J. Tevet [6], the measurement of a structure is considered in the attributes of the theory of information, which is based on the internal variety of the structure. The measure of diversity in absolute terms is the amount of information, and the variety of degrees of vertices of the graph (elements of the system) determines the degree of topological entropy. Topological entropy HE is calculated through the degree of elements $\deg \vartheta_i$:

$$HE = -\sum_{i=1}^{|V|}(deg\vartheta_i/2|E|) \times \log(deg\vartheta_i/2|E|) \quad (4)$$

where $\deg \vartheta_i$ - valence of structural element ϑ_i and $2|E| = \sum_{i=1}^{|V|} deg\vartheta_i$.

For the structure analysis of a complex system, it is advisable to take into account such graph characteristics: a hierarchy of the structure; the diameter of the graph; the bandwidth of the structure.

Vitor Basto Fernandes [7] explores the problem of multi-criteria optimization of ontology quality on such characteristics: usability; functional basis; structural metrics; semantic.

Despite a fairly representative presentation of ontology modeling and quality assessment of their construction in the scientific literature, there are still unresolved issues of modeling decision making meta-ontology, problems of automating decision making in the social sphere, multi-criteria assessment of the quality of decision making ontologies. This paper is devoted to the problems of using ontologies in designing decision support systems in areas related to human activity (i.e., in the

social sphere), and to determining the multi-criteria assessment of the quality of such ontologies based on non-multiple and topological approaches. As you can see, the intersection of a set of characteristics proposed by different researchers [2, 3, 5, 7] is traced, according to two estimates - functionality and reliability (injectivity), which are also the main characteristics of the ISO / IEC 25012 standard. Therefore, next, these two criteria include in the construction of multi-criteria evaluation, complementing various options for topological (structural) criteria.

3. New approach for modeling ontology decision making

In the theory of artificial intelligence, «ontology» is understood as the formalization of a certain field of knowledge by a conceptual scheme. We will consider decision making as a process taking place according to the scheme shown in Fig. 1, where the sign «→» shows the corresponding relationship between superclasses (SC). Define the ontology of decision making as

$$O = \langle \{O^{form}\}, \{O^{alternative}\}, O^{choice} \rangle \qquad (5)$$

where $\{O^{form}\}$ - a set of subject ontologies of task formalization; $\{O^{altern}\}$ - subject ontologies of producing a variety of alternatives (possible solutions); O^{choice} - ontology of decision making from a given set of alternatives.

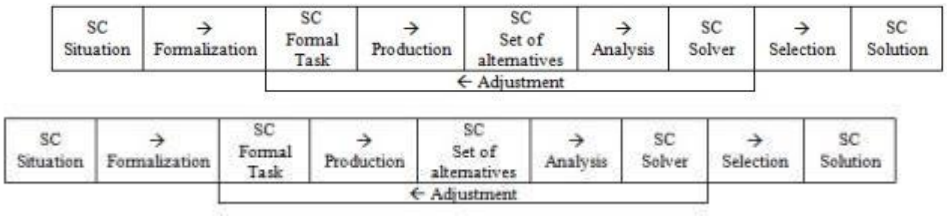

Fig. 1. Decision making scheme

Filling in subject ontologies O^{form} and O^{altern} requires working with a specific subject area, researching specific tasks. Each representative O^{form} of the set $\{O^{form}\}$ of ontologies of formalization of the tasks of the subject areas includes the superclasses «Situation» and «Formal Task», which are in the relation of Formalization. Each representative O^{altern} of a multitude $\{O^{altern}\}$ of ontologies for producing a set of alternatives to subject areas includes the superclasses «Formal Task» and «Set of Alternatives» that are in the relation «Production». The ontology O^{choice} of decision

making from a given set of alternatives includes the superclasses «Set of alternatives», «Solver» and «Decision made», relations «Analysis», «Decision choice». To provide feedback in decision making, lets define an additional relation $\text{Adjustment}: \text{Solver} \to \text{Formal Task}$. The superclass «Situation» includes many classes containing information from a specific subject area and describes the situation in which a decision must be made. The «Formal Problem» superclass consists of a set of classes that carrying information on the construction of formalizations, mathematical models in a particular subject area. At this stage, the decision making task is presented as a tuple $\langle X, opt\_rule \rangle$ where X is a set of alternatives, opt_rule is the criterion of the quality of the alternative. The superclass «A set of alternatives» contains many classes, which include methods for generating multiple alternatives X in a particular subject area. The «Solver» superclass includes a set of classes containing exact and heuristic methods for constructing decision rules $solv\_rule$ on a set of alternatives, as well as the class «Decision making subject» with the subclasses «Decision maker» and «Automatic». The «Decision Making» superclass consists of a set of classes that contain information on the decision made in a particular subject area.

To describe ontologies and work with them, the freely distributed editor Protégé 5.5.0 was used [8]. Fig. 2 shows the decision ontology as an ontograph using the GraphViz graphical module of the Protégé editor.

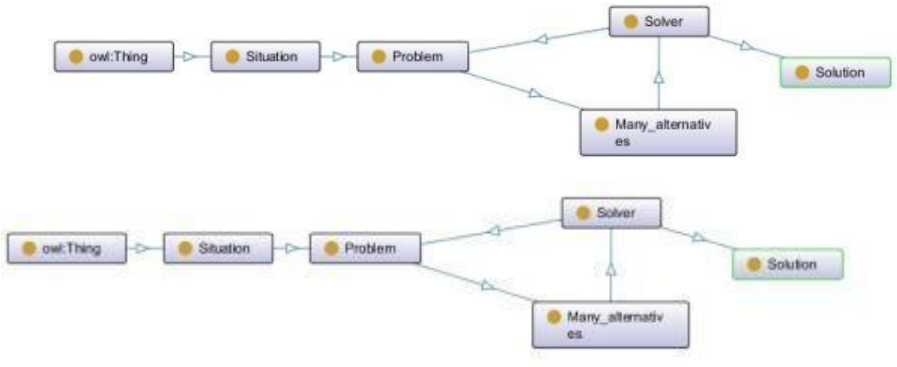

Fig. 2 Ontology of decision making in the form of ontograph

Vector objective function (VOF) includes criteria of functionality and injectivity, defined on the basis of fuzzy sets, as well as topological criteria TG, which characterize the structure and information capacity of the ontograph:

$$Q(O') = (F, I, \{TG\}) \to \max \quad (6)$$

where F - the functionality of the ontology fragment, which is calculated by the formula (2); I - the injectivity of the ontology fragment, calculated by the formula (3); {TG} - topological criteria, from which in this case, those whose values are maximized are selected. For example, in the examples discussed below, bandwidth is used.

The calculation of the ontology fragments estimates is performed on the fuzzy-weighted parts of the ontograph, whose weights are determined by an expert method. VOF (6) establishes a relation of either dominance or partial order on the set of alternative ontologies $O' = \{O'_1, O'_2, ...\}$. If for all criteria F, I, TG with $i \neq j$ inequalities $F(O'_i) \geq F(O'_j)$, $I(O'_i) \geq I(O'_j)$, $TG(O'_i) \geq TG(O'_j)$ and at least one inequality is strict, then they say that the alternative O'_i dominates the alternative O'_j, i.e. $O'_i \succ O'_j$.

Thus, the general algorithm for constructing an ontology of decision making, which is followed in this work, consists of the following steps:

1) building a decision meta-ontology;

2) the construction of a basic ontology manually based on the analysis of the texts of documents;

3) multi-criteria assessment of the quality of the basic ontology;

4) automating the expansion of the base ontology by acquiring new knowledge from various sources with the help of the Protégé editor;

5) integration of ontology with other related ontologies.

4. Experiments

Next, we consider the construction of a basic ontology of decision making on the example of two subject areas.

Example 1. The ontology of a court decision.

Court decisions are made in accordance with Art. 65 of the Criminal Code of Ukraine (CC of Ukraine) [9], the court imposes penalties within the limits established in the sanction of the article of the Special Part, which provides for responsibility for the committed crime, in accordance with the provisions of the General Part, taking into account the degree of gravity of the crime, the person guilty and the circumstances , softening and aggravating punishment. When choosing a sentence the judge must assess all elements of the crime and all the circumstances of its implementation in order to determine the extent of liability of the defendant and the appointment of him a co-sentence. The degree of punishment, depending on the composition of the crime is regulated by the rules of law, which allows formally determine the limits of maximum and minimum penalty. In addition to the objective factors in this process, there is also subjectivity, the so-called judicial oversight.

Walkman, Hala [10] developed the basic ontology for the legal domain, where the formation of a court decision is indicated by a binary relation: *listened_court→court_process*. The proposed ontology of the court decision proposed by the authors of this article allows us to extend the basic ontology for the system of law from the work [10] by introducing the formalization of this binary relation. The ontology of the court decision is a structure that reflects the connection between the classes of input data (the participants in the process, the personality of the defendant, the personality of the judge, the circumstances burdening and mitigating the crime) necessary for the decision, and the measure of punishment, which is represented by many elements: a fine, restriction and imprisonment (real and conditional), public works. When imposing a punishment determine the circumstances that mitigate the punishment specified in Art. 66 of the CC of Ukraine [9]. There are eleven such circumstances. Circumstances that burden a punishment are specified in Art. 67 [9]. These circumstances are determined by 14. The mechanism for making a court decision is determined by the relations schematically shown in Fig. 3.

The court decision ontology allowed to develop a general DSS court model in form [13]:

(Fine,Years,RF,PW,Cond)=F(Severity,Mitigation,Personality,Burden,Lawyer) (7)

where F is the corresponding output algorithm, PW – public work, Cond – condition, Severity- characterizes the severity of the crime; Personality - characterizes the guilty person; Mitigation - mitigating circumstances; Burden - circumstances that burden the punishment; Lawyer - the level of neutrality of a court's decision and takes value with the term -small {loyal, neutral, strict}; Fine - the size of the fine, Years - the number of years of imprisonment, RF - restriction of freedom. PW, Cond - determines the actual or conditional entry into action.

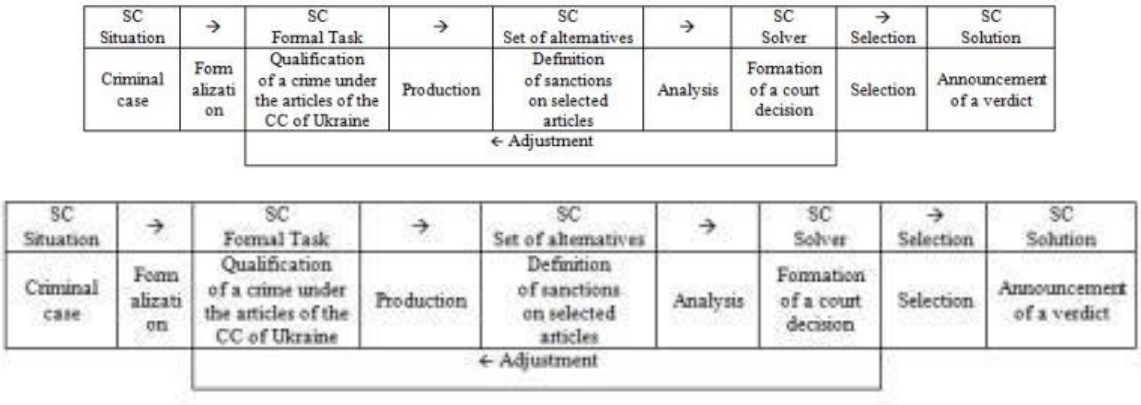

Fig. 3 The scheme of the court decision

Let's evaluate the efficiency of introducing into the ontology class «Judgment Solution», which will have three representatives – neutral (N), strict (H) and loyal (L), within the limits allowed by the rule of law. There are factors shaping the court decision: B - burdening circumstances, M - mitigating circumstances, P+ -positive properties of the defendant's personality, P- - negative qualities of the defendant. Calculate the estimates for the three situations Var_1, Var_2, Var_3. The initial data of the first situation Var_1 are presented in Table 1, which is the matrix of adjacency of the fuzzy graph of the fragment of the ontology.

The second situation Var_2 corresponds to the automated decision making process (Table 2).

Table 1 Initial data of the first situation (Example 1)

Var_1	L	N	H
P+	0,8	1	0,1
P-	0,2	1	0,9
B	0,1	1	0,9
M	0,7	1	0,1

Table 2 The second situation (Example 1)

Var_2	N
P+	1
P-	1
B	1
M	1

Situation three Var_3 describes the initial data presented in Table 3.

Table 3 The third situation (Example 1)

Var_3	L	N	H
P+	1	1	0
P-	0	1	1
B	0	1	1
M	1	1	0

This is an idealized option in which soft solutions take into account all positive and mitigating factors, and rigid ones are all negative and aggravating factors.

For the automatic ontology construction, such topological criteria TG as topological entropy (4) of work [6] and bandwidth are of interest. The results of the calculations of the VOF (6) for the three decision making situations are presented in Table 4. Comparing the results, we get a ranking $Var_3 \approx Var_1 \succ Var_2$.

Table 4 The results of the calculations(Example 1)

Indicator	Var_1	Var_2	Var_3
Functionality	0,64	0	0,67
Injectivity	0,51	0	0,56
Bandwidth	0,25	0,25	0,25
Topological entropy	2,824	2,824	2,824

Example 2. Ontology of decision making on managing the development of a pharmacy network

The choice of the most preferred pharmacy development strategy is the task of making marketing decisions and management. Unlike a court decision based on structured legal documents, this task refers to unstructured, requiring selection of criteria for evaluating the decision, as well as the construction of methods for their initialization. In this case, the source of data for building a basic ontology is mainly the texts of scientific articles and practical publications from scientific journals and the Internet. An example of such a publication is the article by an international group of researchers [11] representing a medical ontology for the care of chronically ill patients, which helps health care providers to detect abnormal circumstances such as irregular diagnoses, unobservable concomitant illnesses, missing information, unobserved associated illnesses or preventive actions. Another example is the work of Thomas Puschmann [12]. An ontological approach is used to harmonize conceptual descriptions of subject areas compiled by various specialists (medicine, pharmacy, commerce).

Ontology for managing the pharmacies network is a mechanism for describing the subject area, including the basic concepts of this area, their properties and the connections between them. Such connections are a type of interaction between the concepts of the subject domain. The ontology of decision making on managing the development of the pharmacy network is a structure that describes the relationship between input classes (the class of target management objects: Buying Capacity - CA, Internet Pharmacy - E, Assortment - As, Traffic - T) needed for decision making, and class A set of control strategies: S_1, S_2, S_3, ..., S_i, by introducing the formalization of the binary relationship: Selection: Manager→Preferred strategy. The mechanism of decision making on managing the development of the pharmacy network is determined by the relationships shown schematically in Fig. 4.

The construction of ontology has allowed us to formulate a general model of DSS management by the development of a pharmacy network, which has the form:

$$S = \mathrm{f}(\mathrm{CA}, \mathrm{As}, \mathrm{E}, \mathrm{T}), \quad (8)$$

where S is the most preferred management strategy.

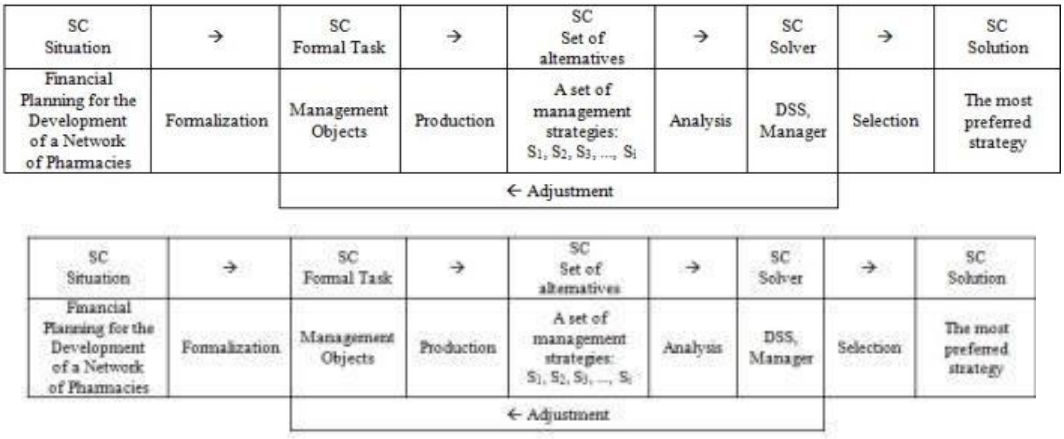

Fig. 4 The scheme for decision making the pharmacy network development

In addition, the elements can be included in the ontology: the quality of the pedestrian flow, the type of district, the competitive environment, the distance to the medical institutions. More detailed DSS for the situation of opening a new pharmacy is considered in article [14].

Let's evaluate the effectiveness of different decision making situations with the help of the VOF (6). The first situation Var_1 corresponds to the decision of the manager (PDM). The second situation Var_2 corresponds to the automatic choice of the decision using DSS. The first situation Var_1 corresponds to the manager's choice of the most preferred of three different strategies: s_1 - oriented to the development of an online pharmacy; s_2 - aimed at increasing the purchasing power (loyalty program) and increasing the range, s_3 - select a place with high traffic for pharmacy placement. The second situation is represented by one strategy, which includes consideration of all criteria for increasing the efficiency of pharmacies, corresponding to the classes of ontology. The results of the calculations of the estimates for the two decision making situations are presented in Table 5. From the calculations we get that the second situation of decision making is not worse than the first, $Var_1 \approx Var_2$.

Table 5 The results of the calculations (Example 2)

Indicator	Var_1 (manager)	Var_2 (DSS)
Functionality	0,958	0,783
Injectivity	0,917	0,822
Bandwidth	0,33	0,33
Topological entropy	0,985	0,985

5. Discussions and Conclusions

The proposed algorithm for constructing a decision making ontology was used to create meta-ontology and two basic decision making ontologies in the social sphere. Conceptualization of decision making (5) defined the need for the construction of objective ontologies for the formalization of problems O^{form} and the production of alternatives O^{altern} in the presence of a common for all areas of human activity ontology of choosing solutions from a given set of alternatives O^{choice}. The introduction of the «Adjustment» relationship raises the question of the possibility and level of decision making automation for various areas. In the presence of a representative of «PDM «class «Solver», the decision is subjective, since a person is involved in the decision.

The introduction of the «Automaton» representative of the class «Solver» makes the decision to be formalized. For example, the court decision making ontology belongs to a strictly structured area. The ontology of decision making on managing the development of the pharmacy network belongs to a weakly structured area. Experiments were conducted to determine the effectiveness of the introduction of automation of decision making. The criterion of effectiveness is the VOF (6), which consists of non-commensurate indicators reflecting the degree of functionality and injectivity, as well as topological criteria characterizing the throughput and topological entropy of the ontographs. The introduction of a full formalization of the sentence resulted in an assessment of the functionality of the system, demonstrating the need for a judge (PDM).

6. Future Works and Acknowledgment

The emphasis in decision making meta-ontology (5) on the ontologies of formalization of tasks O^{form} and on the production of alternatives O^{altern} emphasizes the need for integration between content-related ontologies. Decision making in the social sphere requires the formation of new knowledge from documents available in the semantic web of different nature, which is impossible without the automatic detection of latent knowledge.

The ontological knowledge bases of the consolidated linguistic resources of the syntactic processing of Ukrainian-language texts in the work [15] opens the possibilities for further automated development of ontologies of decision making, in particular, in the social sphere. The work was carried out within the research work «Mathematical modeling of socio-economic processes and systems» at the Department of System Analysis and Computational Mathematics of Zaporizhzhya National Technical University.

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2.2 Production Model for Administration of Judicial Decisions in the Case of Theft

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In addition to the legal aspect, the concept of theft has an economic essence, since it is a crime against property. Theft is defined as a set of actions committed by one or a group of entities that provide for secret seizure or gainful possession of property, which subsequently harms the economic activity of both natural and legal persons. Thefts are the most frequent crimes committed in Ukraine - they account for more than 40% of the total number of reported crimes. The dynamics of the thefts is shown in Table 1. The data are taken from open sources, the website of the Prosecutor General's Office of Ukraine [1].

The main factors of the theft spread in Ukraine are: decrease in the living standards of the population as a result of the socio-economic crisis, changes in legislation on the qualification of such a crime as theft, unemployment. About 65% of

thefts at the time of the crime commission were not taken in work and educational activities, more than a third were previously tried [2].

Table 1. The dynamics of the thefts in 2013-2018 years

Year	Total crimes	Theft	The percentage of theft from the total number of crimes
2013	563560	242769	43,07%
2014	529139	226833	42,86%
2015	565182	273756	48,43%
2016	592604	312172	52,67%
2017	523911	261282	49,87%
2018	487133	238492	48,95%

Punishment appointing is rather complicated and multidimensional process. According to the Art. 65 of the Criminal Code of Ukraine [3], the court imposes punishment within the limits established in the sanction of the Special Part Article of the Criminal Code, which provides for responsibility for the committed crime, in accordance with the provisions of the General Part of the Criminal Code, taking into account the gravity degree of the offense, the person of the offender the circumstances that mitigate and burden the punishment. During choosing a sentence, the judge must evaluate all elements of the crime and all the circumstances of its implementation in order to determine the extent of liability of the defendant and the appointment of him a co-sentence punishment. The degree of punishment, depending on the composition of the crime is regulated by the rules of law, which allows formally determine the limits of maximum and minimum penalty. In addition to the objective factors in this process, there is also subjectivity, the so-called judicial oversight. The choice of the type of punishment where the law provides for alternative sanctions remains for the judge. Consequently, the weakly formalized part of the sentence remains the assessment of the circumstances of committing a crime and the characteristics of the guilty person. While judges do not require a detailed comment on the criteria for evaluation, the need for a very motivated choice of punishment is clearly regulated. To unify the account of mitigating and burdening

circumstances and the guilty person it is natural to formalize their assessments. The development of a general knowledge base for sentencing, with all possible combinations of different circumstances, gives hope for similar sentences in similar composition and circumstances of crimes.

The object of this study is the process of taking court decisions in case of theft. The subject of the study determines the methods of collecting and analyzing the parameters of real court decisions presented in the natural language.

The purpose of the article is to build a general decision support system (DSS) in court as a fuzzy production system, as well as to conduct a cycle of experiments with a developed DSS based on real case data from the Unified State Registry of Judicial Decisions in Ukraine [4].

Problem statement

Punishment appointing is rather complicated and multidimensional process. According to the Art. 65 of the Criminal Code of Ukraine, the court imposes punishment within the limits established in the sanction of the Special Part Article of the Criminal Code, which provides for responsibility for the committed crime, in accordance with the provisions of the General Part of the Criminal Code, taking into account: 1)the gravity degree of the offense, 2) the person of the offender, 3) the circumstances that mitigate and burden the punishment.

The legislative sanction of the article takes into account both quantitative indicators of the relevant circumstances and qualitative ones.

In accordance to this, were chosen the following input variables.

The linguistic variable *Severity*, which characterizes the degree of gravity of the offence, takes on the meaning of the term set {small, medium, large}. This variable allows you to take into account the repetition of a crime, the existence of past punishment, a collective crime, and so on.

The linguistic variable *Personality* characterizes the identity of the offender and takes value with the term set {negative, neutral, positive}. It allows for taking into account, for example, employment, availability of socially useful activities, description from the place of residence, etc.

It should be noted, that according to Part 3 of Art. 66 of the Criminal Code of Ukraine, if in any of the circumstances mitigating the punishment provided for in the Article of the Special Part of the Criminal Code as a sign of a crime that affects his qualification, the court can not once again take it into account when imposing a punishment as such that mitigate the punishment [3]. There are eleven mitigate circumstances. Two linguistic variables were chosen to assess the circumstances, that mitigate the punishment. The linguistic variable *Mitigation* evaluates the possibility of taking into account a judge of a certain number of realized circumstances. The linguistic variable *LM* assesses the level of punishment mitigation by circumstances, that were implemented.

Also, during constructing the algorithm of sentencing, we have taken the specified in Art. 67 of the Criminal Code of Ukraine, burdening circumstances. Such circumstances are determined by fourteen. When imposing a sentence, the court can not recognize that it is burdened by other circumstances. If any of the circumstances that burden a punishment is stipulated in the Article of the Special Part of the Criminal Code as a sign of a crime affecting its qualification, the court can not re-consider it when imposing a sentence as burden it [3]. Input variables to assess the circumstances that impose a punishment on *Burden* and *LB*. The linguistic variable *Burden* gives an assessment of the possibility of taking into account a certain number of realized circumstances. The linguistic variable *LB* assesses the level of punishment burden by the circumstances that were implemented.

The linguistic variable *Lawyer* characterizes the level of neutrality of the judge and takes on the meaning of the term-set {soft, middle, hard}. We will assume that the judge is fair in the level of «middle». Introduction of additional terms will put the problem of the adequacy of the sentence, the impact assessment of judges person.

The court may impose a measure of punishment, the constituent parts of which are fines, restrictions of freedom and imprisonment (real and conditional), public works. Assign the following output variables.

The output linguistic variable *Fine* determines the size of the fine. The output linguistic variable *Years* determines the term of imprisonment. The output linguistic

variable *RF* (Restriction of freedom) determines the level of freedom restrictions. The output linguistic variable *Public Works* determines the public works The output linguistic variable *Condition* determines real and conditional imposition of punishment.

For all output linguistic variables were chosen the term-set, which contain three terms that characterize the implementation level {low, medium, high}.

The membership functions of the terms of input and output linguistic variables are determined by experts. Value ranges are regulated by the relevant legislation separately for each article. Thus, the general DSS model in court has the form:

(Fine, Years, RF, Public Works, Condition) = =F(Severity, Personality, Mitigation, LM, Burden, LB, Lawyer),(1)

where *F* is the corresponding fuzzy output algorithm.

For the experiment, the authors selected art. 185 of the Criminal Code of Ukraine on theft [3].

Different parts of Article Art. 185 of the Criminal Code of Ukraine on theft [3] have different versions of sentences. Difficulty base of fuzzy production rules will be determined by the content of certain articles.

Literature review

The problem of limitation of the court decisions objectivity was raised in 1963 in Clark's work, «The Limits of Judicial Objectivity,» which pointed to the basic rule for passing judgments: «Government of laws, and not of men» [5]. But achieving the perfect implementation of such a rule is impossible for a number of reasons, one of them is the uncertainty of many legal concepts. This is confirmed by the fact that the European Court, in view of the versatility of the notion of «justice» in decisions of national courts, does not define the criteria for a fair judicial discretion, but only sets out its tentative decision taking into account the provisions of Art. 6 «Convention for the Protection of Human Rights and Fundamental Freedoms» [6].

The approach to defining the fuzzy notion of «fair court» was proposed, in particular, in the work of Tobot Yu.A. [7], where the notion of «impartiality» was adopted as the criterion for a fair judicial discretion, indicating the same attitude of

the court to the different sides of the dispute, resolving it without giving preference to one of the parties, that is, «neutrality» of the court. In this case, each judge has his own idea of justice discretion. According to V. Ladychenko [8] , justice is not so much theoretically realized as it is intuitively perceived, sometimes with the subconscious understanding of it: people seem to consider the correctness of one or another act of the judiciary on the «internal scales» of justice.

The formalization of the decision-making process requires such scientific methods that would provide the opportunity, on the input data collected during the investigation and the pre-trial investigation, to propose the judge a version of the sentence, which is formulated in the subject field language and is the same for all courts of the country.

In the monograph Dyadkin D. S. [9] developed an algorithmic approach to the definition of a sentence according to the rules of law. The author advocates developing a more formal approach in determining the extent of punishment and reducing the proportion that is determined by the judge's care. Dyadkin D. demonstrates, on the example of assessing the social danger of crime, the possibility of a formal approach, using fuzzy logical deduction. Another example is the work [10] devoted to the development of a product model in making judgments based on the Mamdani algorithm for the case of moderate causing of serious harm to health.

There is a sufficiently developed theory of fuzzy / linguistic models, which is described in particular in [11]. Such fuzzy / linguistic models that are interpretable and can also be learned from the data. Also, we note that methods of fuzzy mathematics are widely used and are effective in formalizing the knowledge and experience of experts in various fields of human activity, as demonstrated in publications [9-16].

Previously, by the authors of this article in [17], was constructed fuzzy production system based on Sugeno's algorithm. Work was based on the materials of criminal sentences in relation to Part 1 of the Art. 185 of the Criminal Code of Ukraine. But unresolved issues were the choice validity of the fuzzy output algorithm, the study of the impact of different versions of sentences (according to

various articles of the Criminal Code of Ukraine) on the complexity of the production rules base.

Materials and methods

Legal documents are characterized by a certain structuring and precision of the terminology that uses the terminology of the law. The style of legal documents is marked by the language standardization and unification, the wide use of consistent phrases, stencils, standard texts using. It can be argued that the good interpretation of the fuzzy logical conclusion is determined by the well-established theory of the semantics of the specialized language of the legal branch [11]. Despite this, not all legal terms are subject to formalization, which justifies the choice of fuzzy mathematics methods.

To construct the fuzzy production system, it is necessary to form a base of agreed fuzzy production rules that contain formalized domain experts knowledge. The basic formalism is the notion of a linguistic variable, which meaning can be the words and phrases of the experts specialized natural language. The linguistic variable takes on the term-set value, which elements are the terms given by a fuzzy set with a definite membership function, as described in detail in fundamental labor [11].

During constructing the system and conducting experiments, the authors sought to obtain an approximation of the known sentences values from the source [4], which would allow the source data of the system to be used later as a reference, the basis for sentencing a judge, common to all courts all over the country.

Experiments

As can be seen from formula (1), some output variables of common DSS model - Fine, Years - take numerical values, so it is interesting to compare the possibilities of the most common model of fuzzy logic output from Mamdani algorithm with fuzzy logic output from Sugeno algorithm, which has a clear output the value of some function of the input variables.

Consider the stages of the Mamdani algorithm and the Sugeno algorithm implementations in the Fuzzy Logic Toolbox MatLab [18].

Without losing generalization for greater certainty, we will continue to consider the process of making a judicial decision on the example of art. 185 of the Criminal Code of Ukraine [3], consisting of five parts. To conduct an experiment, choose part 3 of this article, whereby theft, which is associated with penetration into the home, other premises or repository, or which has caused significant harm to the victim, is punishable by imprisonment for a term of 3 to 6 years.

Thus, the general DSS model in court by the formula (1) is transformed for part three of Art. 185 of the Criminal Code of Ukraine concerning theft [3] in the formula, which has the form:

$$Years = F(Severity, Personality, Mitigation, LM, Burden, LB, Lawyer), \quad (2)$$

where F is the corresponding fuzzy output algorithm.

Membership functions terms of input and output linguistic variables determined on materials of sentences for criminal case under part 3 of Art. 185 of the Criminal Code of Ukraine. The most successful were the trapezoidal term membership functions for the input variables Severity, Lawyer, Mitigation, Personality, Burden, and triangular for LB, LM.

Membership functions terms of input variables are presented in Fig.1 and Table.2.

Table 2 DSS input linguistic variables and their terms of membership functions.

Linguistic variables	Terms designation and associated membership functions		
Severity	d1 [0 0 0.6 1.2]	d2 [0.5 1 2 2.5]	d3 [1.8 2.4 3 3]
Personality	Disrepute [0 0 0.4]	Norm [0.14 0.46 0.54 0.86]	Good [0.6 1 1.4]
Mitigation	m1 [0 0 3 4]	m2 [3 5 6 8]	m3 [7 8 11 11]
LM	lm1 [0 0 0.4]	lm2 [0.1 0.5 0.9]	lm3 [0.6 1 1.4]
Burden	b1 [0 0 4 6]	b2 [4 6 8 10]	b3 [8 10 14 14]
LB	lb1 [0 0 0.4]	lb2 [0.1 0.5 0.9]	lb3 [0.6 1 1.4]
Lawyer	Soft [0 0 0.15 0.4]	Middle [0.05 0.4 0.6 0.85]	Hard [0.6 0.85 1 1]

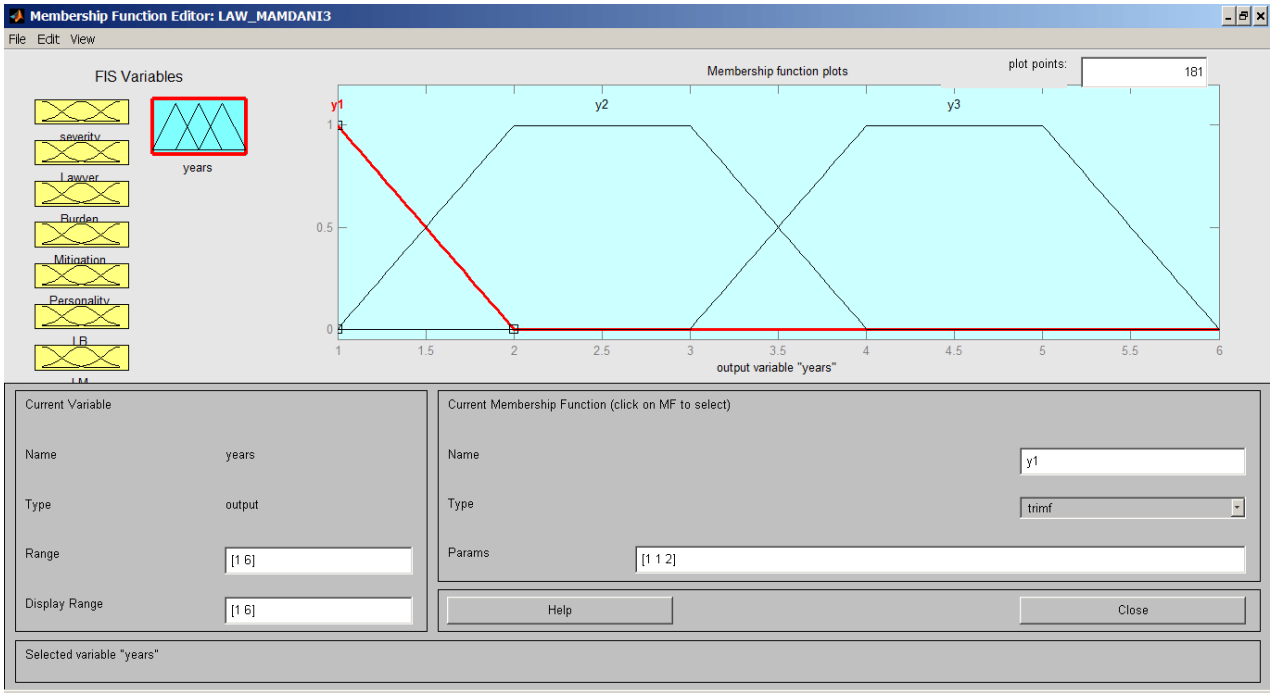

Fig. 1 The membership function of variable outputs on the Mamdani algorithm

The membership functions of the terms of the output variables by the Mamdani algorithm characterizing the years of imprisonment are presented on Fig.2 and in Table 3.

Table 3 The output variables of DSS model.

Algorithm	Variable	y1	y2	y3
Mamdani	Years	[1 1 2]	[1 2 3 4]	[3 4 5 6]
Sugeno	Years (linear)	[0.01 0 0.22 -0.144 -0.01 0.1 -0.09 2.9]	[0.01 0 0.22 -0.144 -0.01 0.1 -0.09 2.9]	[0.01 0 0.22 -0.144 -0.0 0 -0.0 2.9]

The membership functions of the output variable *Years* were built on the basis of judicial practice, according to which it is known that the shortest term, which is appointed according to Part 3 of Art.185 of the Criminal Code of Ukraine, is one year. The longest term - six years - is a very severe punishment that occurs in court sentences very rarely.

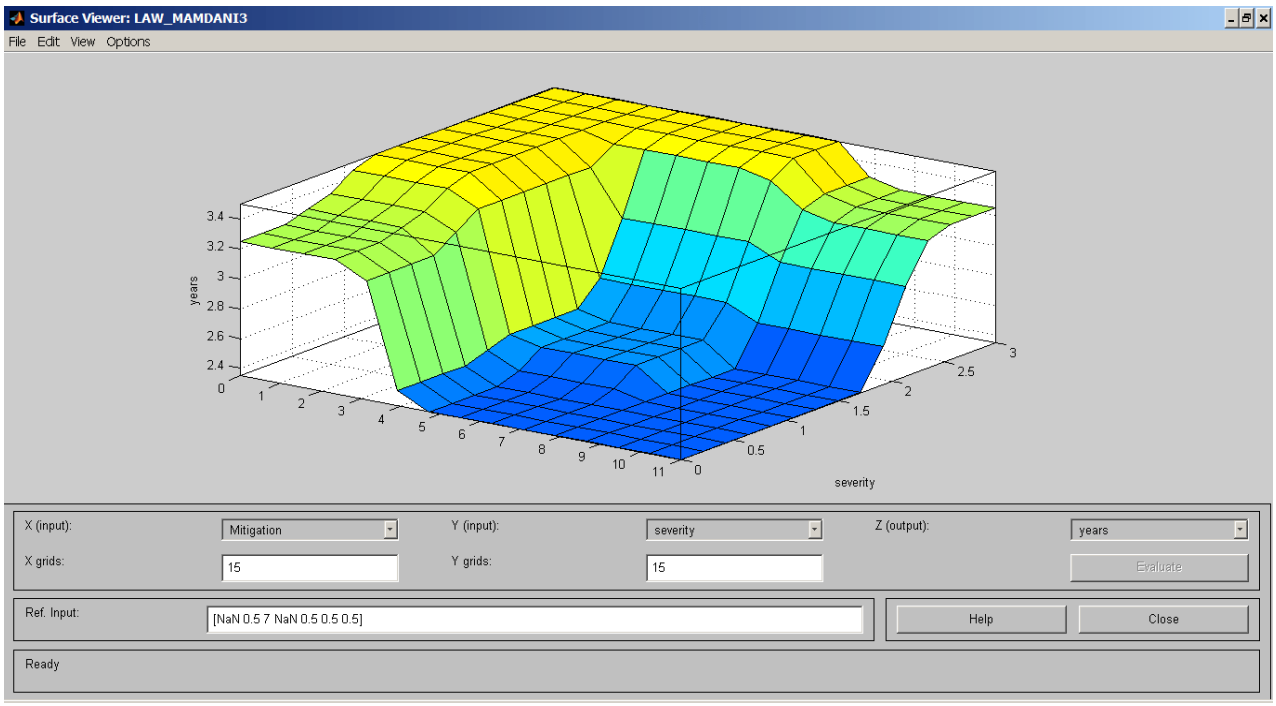

Fig. 2 Surface response to output variable Years of input variables Severity, Mitigation

For an example of the DSS work result in Fig. 2 there is a response surface for the Mamdani model for the output variable *Years* from the input variables *Severity*, *Mitigation.*

For the Mamdani algorithm, such fuzzy production rules have been developed: IF the degree of gravity of the offence = big AND the personality = negative AND the mitigation circumstances = from 7 to 11 AND the burdening circumstances = from 8 to 14 AND the level of neutrality of the judge = middle AND the level of the burdening circumstances = big AND the level of the mitigation circumstances = big THEN punishment will be from 1 to 4.

In the case of the Sugeno algorithm, such fuzzy production rules have been developed: IF the level of neutrality of the judge = «middle» THEN the punishment will be y_1, IF the level of neutrality of the judge = «soft THEN the punishment will be y_2, IF the level of neutrality of the judge = «hard» THEN the punishment will be y_3.

In the case of the Mamdani algorithm, the knowledge base combines 28 production rules (Table 4), three of which coincide with the basic rules of the Sugeno algorithm. Due to such a number of rules, greater compliance with the non-linearity of the court decision-making process is achieved.

Table 4 Fuzzy Production Rules R_s, s = 1-28 for Fuzzy Output System by Mamdani Algorithm.

R_s	Severity	Lawyer	Burden	Mitigation	Personality	LB	LM	Years
1	D1					Lb1	Lm3	Y1
2	D2	middle			norm			Y2
3	D2	soft		M3	norm		Lm3	Y2
4	D3	hard	B3		disrepute	Lb3		Y3
5	D3	middle	B3		good	Lb3		Y2
6		middle	B3	M3	disrepute	Lb1	Lm3	Y2
7		soft		M3			Lm3	Y1
8		hard	B3			Lb3		Y3
9	D3	middle	B3	M3	disrepute	Lb3	Lm3	Y2
10	D3	middle	B3	M1	disrepute	Lb3	Lm1	Y3
11			B3			Lb3		Y3
12				M3			Lm3	Y1
13			B3	M3		Lb3	Lm3	Y2
14	D1							Y1
15	D2							Y2
16	D3							Y3
17		soft						Y1
18		Middle						Y2
19		hard						Y3
20					disrepute			Y3
21					norm			Y2
22					good			Y1
23			B1			Lb1		Y1
24			B2			Lb2		Y2
25			B3			Lb3		Y3
26				M1			Lm1	Y3
27				M2			Lm2	Y2
28				M3			Lm3	Y1

Results

In tabl. 5 and tabl. 6 summarize the results of the experiment on the DSS developed according to the sentences of six typical cases from the register of court decisions in Ukraine [4].

Table 5 Input data to experiment

Data on offense by sentence	Input variable	Term value
Case No207/2695/17		
repeatedly, with penetration into the home; material damage in the amount of 42059 UAH	*Severity*	d3=2,5
Reccurence of crime	*Burden*	b3=5,8
Contrition	*Mitigation*	m3=7,65
not working, not married, previously sentenced	*Perso-nality*	Disrepute=0,159
-	*LB*	lb3=0,635
-	*LM*	lm3=0,3
Case №206/4630/17		
penetration into the home; material damage in the amount of 762,50 UAH	*Severity*	d1=0,7
not been established by court	*Burden*	0
not been established by court	*Mitigation*	0
not working, the place of residence is characterized by a negative; abusing alcohol drinks, not convicted	*Perso-nality*	Norm=0,5
-	*LB*	0
-	*LM*	0
Case №315/1155/17		
penetration into another room, material damage for 290 UAH	*Severity*	d1=0,2
committing a crime in a state of intoxication	*Burden*	b3=1
sincere repentance and active assistance in the disclosure of the crime	*Mitigation*	m3=1
not married, not working, inclined to drink alcohol, inclined to persistent criminal activity, not convicted	*Perso-nality*	Disrepute=0,4
-	*LB*	lb3=0,5
-	*LM*	lm3=0,3
Case № 127/14282/16-к		
repeatedly, with penetration into the home; material damage in the amount of 4131,70 UAH.	*Severity*	d3=2,5
recidivism of a crime	*Burden*	b3=5,8
contrition	*Mitigation*	m3=7,65
not working, married, before convicted	*Perso-nality*	Disrepute=0,2
-	*LB*	lb3=1
-	*LM*	lm3=0,1
Case №161/13758/17		
got into the territory of the house; material damage in the amount of 516.15 UAH.	*Severity*	d1=0,7
committing a crime in a state of intoxication	*Burden*	b3=1
sincere repentance and active assistance in the disclosure of the crime	*Mitigation*	m3=1
not married, not working, before convicted	*Perso-nality*	Disrepute=0,25
-	*LB*	lb3=0,5
-	*LM*	lm3=0,3
Case №311/2510/17		

repeatedly, combined with penetration into the home; property damage for the total amount of UAH 10800,28+ UAH 8527	*Severity*	d2=2,3
not been established by court	*Burden*	0
acknowledged guilty completely, repentantly	*Mitigation*	m3=1
not married, not working, before convicted	*Perso-nality*	Norm=0,5
-	*LB*	0
-	*LM*	lm3=0,3

Table 6 Comparison of judgments and decisions made by the DSS for the output variable *Years*

Case №	Term of imprisonment by court sentence	Algorythm	DSS recomendation	Deviation
207/2695/17	3 years and 3 months (3,25)	Mamdani	3,25	0
		Sugeno	3,17	-0,08
206/4630/17	3 years	Mamdani	3,25	+0,25
		Sugeno	2,9	-0,1
315/1155/17	3 years	Mamdani	3,25	+0,25
		Sugeno	3	0
127/14282/16-к	3 years 6 months (3,5)	Mamdani	3,5	0
		Sugeno	3,1	-0,4
161/13758/17	4 years (with the establishment of probation 2 years)	Mamdani	3,25	-0,75
		Sugeno	3	-1,0
311/2510/17	4 years (Punishment with dismissal on the basis of Art.75 of the Criminal Code of Ukraine with the establishment of probation 3 years)	Mamdani	3,25	-0,75
		Sugeno	2,75	-1,25

In all cases, given in Table 5, it was considered that the decision is made by a fair judge, that is, the input variable Lawyer takes the value *Middle* with the corresponding value of the membership function 0.5.

The Mamdani algorithm for the first four cases presented in Table 6, has generated the punishment that is either coincidental or more severe on 0.25 years than was pronounced by a court sentence. The Sugeno algorithm in these cases showed an absolute deviation of -0.4 to 0 years, with reducing the term of imprisonment.

For the last two cases from Table 6 both Mamdani and Sugeno algorithms generated milder punishment compared with the term of imprisonment by court

decision. This is due to the influence of the more complex content of the sentence, which contains a reference to other articles of the Criminal Code of Ukraine. Reduce or avoid this discrepancy maybe the complication of the model (2) with the additional Condition provided in the general model (1).

Discussion

When substantiating the choice of fuzzy output algorithm, it is necessary to take into account possible errors in the generated solutions and the complexity of calculations by the chosen algorithm. Similar questions were raised for an individual case of approximation of the continuous function of one variable in the work [13].

At the level of the conducted experiment, both systems of fuzzy logic output Mamdani and Sugeno showed the adequacy of the generated results of sentences without the apparent advantage of one of the algorithms. But the linearity of the output functions of the Sugeno algorithm provides a more simple setup of the fuzzy output system and yields a gain from a computational point of view.

Both systems responded equally to the existence of additional conditions, which in practice proved to be mitigating of the court desicion. This is confirmation of the need to introduce qualitative, non-numeric parameters to the system's input. The introduction of such variables is more convenient in the system of fuzzy logic output using the Mamdani algorithm.

The following steps of improving DSS in the courts are dictated by the need of developing unified rules for initializing input variables, which will allow adjusting fuzzy production models to obtain the fair verdict in cases involving the crime in several parts of one article and / or several different articles of the Criminal Code of Ukraine.

Conclusions

The scientific novelty of the work determines the general model construction of the decision support system in court as fuzzy production system, as well as a cycle of experiments with the developed DSS on the basis of real data on convictions on cases from the database of the Unified State Register of Court Solution in Ukraine.

The practical value of this work is that the use of fuzzy logic methods is potentially productive to support fair court decisions, since it allows one to approach the formalization of the notion of fair court decision.

It appears perspective to introduct such subsystem into the system of the Single Judicial Information and Telecommunication System (SJITS) - «Electronic Court», which testing was started in 18 pilot courts of Ukraine from 04.06.2018, is considered. This will increase the level of automation of routine moments of judicial practice, bring the information society closer.

The work was carried out as the part of the research work «Mathematical modeling of socio-economic processes and systems», the registration number DB05038, at the Department of System Analysis and Computational Mathematics of Zaporizhzhya National Technical University.

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2.3 Modeling of complex diversification for centralized pharmacy network

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The modern pharmacy market of Ukraine is characterized by a fierce competition between its leaders. The consolidation of pharmacy chains is continuing actively. For 2017-2018, the share of TOP-100 pharmacy chains by sales increased by 8.4%. All this is against the background of market sales growth of 15% (up to UAH 40.6 billion in the first half of 2019) in UAH terms and a decrease of 3% in kind (up to 543.7 million packages) [1].

The decrease in demand is a reflection of the fact that the pharmacy market is subject to fluctuations, since it is almost entirely financed by the consumer and directly depends on the well-being of the population. This indicates the risks involved in managing the pharmacy network. And ignoring these risks will lead to a loss of profit, loss of financial revenues, and a decrease in the level of competitiveness of the network. For sustainable development and dynamic growth, pharmacy chains need to diversify their operations by optimally allocating their own resources across outlets. This will help to the large group of risks associated with the likely occurrence of

losses in the sale of products or services. Risk tracking allows the network to respond to internal and external changes in a timely manner, reducing financial, material, moral, human and other losses.

A pharmacy network is an amalgamation of pharmacies whose consolidation is based on certain principles. There are pharmacy networks of three types: holding; centralized; mixed [3].

Holding type pharmacy network is a collection of pharmacies and subdivisions, each of which has its own Code of the Unified State Register of Enterprises and Organizations of Ukraine. They can have their own bank accounts, act independently, but have one owner, that is, they are only formally linked.

A centralized pharmacy network is characterized by the fact that all pharmacies and units have a single Code of the Unified State Register of Enterprises and Organizations of Ukraine, and a license is generally allowed under the same license; pharmacy banks do not have their own accounts.

A mixed-type pharmacy network is a structure in which the characteristics of holding networks are combined with those of centralized ones.

The attempt of the state to influence directly the pharmacy market resulted in the Draft Law «On Amendments to the Law of Ukraine» On Medicines «on Ensuring Economic Competition and Protecting Patients' Rights in Retailing of Medicines» No. 8591 of 12.07.2018. The bill establishes significant restrictions on opening pharmacies by establishing a distance between pharmacies of at least 500 meters; the number of pharmacies in legal entities - no more than 8 pharmacies within one area, and individuals - entrepreneurs - no more than 1 pharmacy; introduction of unequal conditions of activity of municipal, state and private pharmacies. However, it should be noted that the pharmacy network - the market leader occupies just over 11% of its volume among legal entities, the top 3 hold 23.6%, the top 5 - 30% of the market. The top 100 drugstore chains accumulate 73% of the pharmacy market. Single pharmacies and pharmacy chains, which have up to 10 pharmacies, own 46% of the outlets. Megamans (more than 50 outlets) generally own 36%. All this indicates that

the pharmacy market is not monopolized with a large number of players on it, and therefore there are risks to the network in a competitive environment.

The object of the study in this paper is to manage risks in the functioning of a centralized pharmacy network by diversifying the portfolios of its structural elements and the network itself as a whole.

The purpose of the work is to build a complex of models of diversified portfolios and to study them under different operating conditions, which in particular are caused by changes in the legislation and the rapid development of the information society. A sign of such processes in Ukraine is the appearance of a National Electronic Health System in Ukraine «eHealth». [11].

Research on the functioning of the pharmacy network as a whole based on a systematic approach raises the question of determining the overall structure of the system that would provide optimal modes of functioning and adaptation. A pharmacy network is considered to be an open system consisting of several interconnected subsystems; combines goals, resources and processes that occur within and around the network.

For the pharmacy supply system, the characteristic features are the hierarchy of control systems, the presence of elements of different origin and functional orientation, a considerable number of subsystems.

Diversification (Latin diversificatio - pursuit of diversity) represents a strategic decision on the possibilities of enterprise development by managing the portfolio of different types of activities of the units or taking advantage of the competitive advantages of joining efforts to achieve a single goal; expansion of activity directions of the enterprise. Diversification is a tool for adapting the pharmacy network to achieve the strategic goals of the company, such as reducing risk, enhancing the financial stability of the network, stabilizing financial revenues, building the potential for competitiveness and insensitivity to market changes. Increasing the financial stability of the network is due to the increase in the value of working capital by obtaining the maximum financial result from the purchased goods in the least period of time [4].

The diversification process is complicated by the fact that the pharmacy network is a structure that does not have its own production base, resells the available goods and does not have the ability to influence their price and quality characteristics, but can optimally select the assortment according to the specific needs of each outlet. In addition, the pharmacy network operates in a highly competitive market, which limits its agility in the process of forming the final price of the product.

The conducted researches are based on the in-depth study of works of foreign and domestic scientists. Thus, in the field of studying the structural elements of pharmacy chains, it is possible to note the scientists O.V. Baeva, S.M. Kozikin, O.E. Loskutova, O.A. Maximkina, O.V. Pigunova, O.O. Trofimova, M.V. Novozhilova, O.V. Posilkina [4]. In the field of risk management and the formation of optimal portfolios known works of Ukrainian scientists V.V. Vitlinsky [6], B.Yu. Kishakevich [9] and among foreign ones – fundamental works of H.M. Markowitz [7] and his numerous followers [8].

A qualitative approach to managing the pharmacy network outlets in a highly competitive marketplace minimizes the risks of the actual or potential decline in the profitability of pharmacies.

Applying a portfolio approach in this paper, we examine the complex process of pharmacy network diversification, taking into account the activities of suppliers, the network itself and customers (Figure 1) over a single period of time.

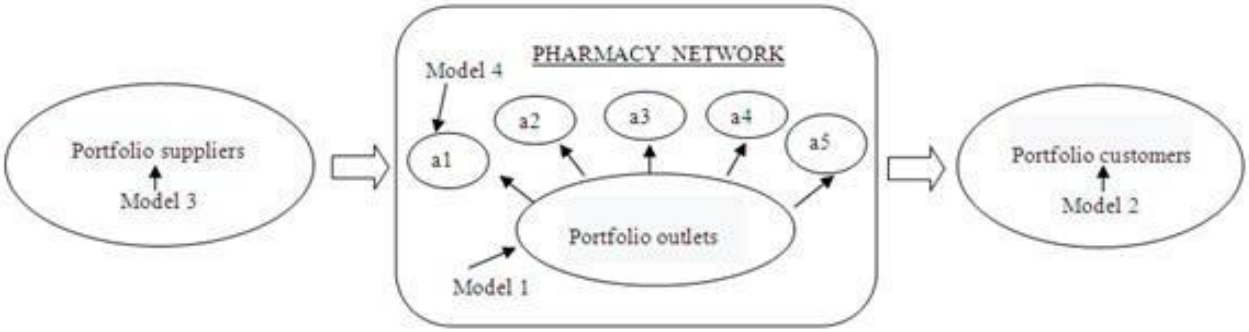


Fig. 1 Structure of activity of the centralized pharmacy network

All models 1-4 of the optimal portfolios shown in Fig. 1 have the same composition of the vector objective function, which consists of three criteria: risk - Risk, which is reduced; Sum is the portfolio yield that is desirable to increase; entropy - Entropy as a value that characterizes the level of diversification of the relevant portfolio (diversity assessment) that the pharmacy network is trying to increase in its activities. In addition, each model has its own specific system of constraints, which is determined by the business process of the pharmacy network in the structure of its activities.

Model 1. Build a formalized portfolio model of optimizing the distribution of finances between outlets of a centralized pharmacy network (Fig. 1). By distributing goods optimally across outlets, the network earns maximum profits by responding promptly to the circulation of drugs over a period of time, since demand for drugs in a particular pharmacy is not constant and goods that are not sold in one outlet can be timely sold in another and generate profits without increasing the length of the composition [5]. Trade turnover of a pharmacy network is the sum of trade turnover of its pharmacy establishments. The turnover of an individual pharmacy is estimated to be sufficient at the level of UAH 2 million, which defines additional limitations in Model 1.

Let x_i is the share of the i-th pharmacy in the turnover of the pharmacy network, which is equal to the share of allocated financial resources in the i-th pharmacy; a_i - expected turnover of this pharmacy (UAH); n is the number of pharmacies in the network.

In this model, the Risk criterion - structural risk – is the risk of irrational distribution of financial resources of a centralized pharmacy network between outlets. Structural risk is defined as the covariance of turnover of i-th and j-th pharmacies.

So we have a multicriteria quadratic programming problem.

$$\begin{cases} Risk = \sum_{i=1}^{n} (a_i - \bar{a}) \cdot (a_j - \bar{a}) \cdot x_i \cdot x_j \to \min, \\ Sum = \sum_{i=1}^{n} a_i \cdot x_i \to \max, \\ Entropy = -\sum_{i=1}^{n} x_i \ln(x_i) \to \max, \\ \sum_{i=1}^{n} a_i \cdot x_i \geq 2 \cdot 10^6 \cdot n, \\ \sum_{i=1}^{n} x_i = 1, \quad x \in [0..1]. \end{cases} \tag{1}$$

The solution to problem (1) is the vector $\bar{X}^* = (x_1, x_2, ..., x_n)$ – the optimal plan for the distribution of financial resources of the central pharmacy network between outlets.

Model 2. Any medicinal product or medical device has certain properties that are attractive to a particular segment of consumers. The more pharmacy consumers are, the lower the risk of loss of income. We will divide pharmacy customers into three groups: loyal (regular), casual and online clients. We believe that all three customer groups do not intersect. Loyal customers include pharmacy turnover and discount cards. Casual - all other visitors, with low purchase frequency. The pharmacy network's goal is to increase the average check and purchase frequency for each customer group. To formalize Model 2, we introduce the following notation:

y_1 – share of loyal customers in the pharmacy customer portfolio,

y_2 – share of casual pharmacy network customers,

y_3 – share of online pharmacy customers,

b_i – average check for the i-th group of pharmacy network clients (UAH),

$\bar{b}_i$ – expected average check for the i-th group of pharmacy network clients (UAH),

q_i – the average frequency of visits to the i-th pharmacy customer group,

$\bar{q}_i$ – expected average frequency of visits to the i-th pharmacy customer group.

The risks in this situation are the failure to obtain an average check from loyal *Risk1* customers and a decrease in the frequency of visits to casual *Risk2* clients. This model also provides two criteria that meet the goal of maximizing profitability: *Sum1*

– the total average frequency of visits to pharmacy customers and *Sum2* – the total average check across the network as a whole.

$$\begin{cases} Risk1 = \sum\limits_{i=1}^{3}\sum\limits_{j=1}^{3} y_i \cdot y_j \cdot (q_i - \bar{q}_i)^2 \cdot (q_j - \bar{q}_j)^2 \to \min, \\ Risk2 = \sum\limits_{i=1}^{3}\sum\limits_{j=1}^{3} y_i \cdot y_j \cdot (b_i - \bar{b}_i)^2 \cdot (b_j - \bar{b}_j)^2 \to \min, \\ Sum1 = \sum\limits_{i=1}^{3} y_i \cdot q_i \to \max, \\ Sum2 = \sum\limits_{i=1}^{3} y_i \cdot b_i \to \max, \\ Entropy = -\sum\limits_{i=1}^{3} y_i \cdot \ln(y_i) \to \max, \\ \sum\limits_{i=1}^{3} y_i = 1, \quad y_i \in [0;1]. \end{cases} \tag{2}$$

For problem (2), modifications generated by different combinations of *Risk1*, *Risk2*, and *Sum1*, *Sum2* criteria are possible to investigate the effectiveness or development of new loyalty programs. Another modification of the model is to deepen the study of clients' portfolio to the level of each individual outlet. Then the sum of the optimal customer portfolios of a particular outlet forms the optimal portfolio of pharmacy network clients as a whole. The solution to problem (2) is the vector $\bar{Y}^* = (y_1, y_2, y_3)$ – the optimal combination of distribution of groups of loyal, casual and Internet clients.

Model 3. We build a model of a portfolio of suppliers, for which the purchase prices for goods are taken. In the process of purchasing medicines and medical supplies from suppliers, the pharmacy network seeks to minimize costs and select the right amount at the lowest possible cost. Each pharmacy must have a compulsory set of vital and social medicines in its range. At the same time, each pharmacy network seeks to maximize the difference between the retail price and the purchase price (margin). In addition, the Decree of the Cabinet of Ministers of Ukraine of July 1, 2019 [3] establishes four groups of medicines on the National List of Essential Medicines, for which regressive retail margins are formed based on the purchase price, including taxes, and do not exceed the following amounts: group of medicines l_1 – purchase price up to 100 UAH – 25% purchase price supplement, group l_2 – purchase price from 100 to 500 UAH – 20% purchase price supplement, group l_3 – the purchase price from 500 to 1 000 UAH – a supplement to the purchase price of

15%, group l_4 – the purchase price is more than 1 000 UAH – the purchase price supplement is 10% [2].

All this imposes certain restrictions on the formation of an optimal portfolio of goods orders for the pharmacy network. Other products in the pharmacy chain that are not on the National List of Essential Medicines and are not covered by the purchase price premium are denoted as group l_5.

Let, g_{klf} – purchase volume of the k-th type of goods from the l-th group from the f-th manufacturer (pieces),

K – number of types of goods,

F – number of manufacturers,

p_{klf} – purchase price of the k-th type of goods from the l-th group from the f-th producer (UAH),

w_{klf} – the share of the f-th manufacturer of the f-th commodity from the l-th group in the pharmacy network purchasing portfolio,

s_{klf} – the price of sale in the network of the k-th type of goods from the k-th group from the k-th manufacturer (UAH).

In this case, the risks are caused by fluctuations in the purchase and sale prices of medicines and medical upplies by different suppliers. Two criteria that meet the goal of maximizing profitability are *Sum1* – the total purchase price that is minimized and *Sum2* – the total cost of sales across the network that is maximized.

$$\begin{cases} Risk = \sum_{k=1}^{K}\sum_{l=1}^{5}\sum_{f_i}^{F}\sum_{f_j}^{F}\left(p_{klf_i} - \overline{p}_{klf_i}\right)\cdot\left(s_{klf_i} - \overline{s}_{klf_i}\right)\cdot w_{klf_i}\cdot w_{klf_j} \to \min, \\ Sum1 = \sum_{f=1}^{F}\sum_{l=1}^{5}\sum_{k=1}^{K} p_{klf}\cdot w_{klf} \to \min, \\ Sum2 = \sum_{f=1}^{F}\sum_{l=1}^{5}\sum_{k=1}^{K} s_{klf}\cdot w_{klf} \to \max, \\ Entropy = -\sum_{f=1}^{F}\sum_{l=1}^{5}\sum_{k=1}^{K} w_{klf}\cdot\ln\left(w_{klf}\right) \to \max, \\ \dfrac{s_{k1f} - p_{k1f}}{p_{k1f}} \le 0.25,\ p_{k1f} \le 100, \qquad \dfrac{s_{k2f} - p_{k2f}}{p_{k2f}} \le 0.2,\ 100 < p_{k1f} \le 500, \\ \dfrac{s_{k3f} - p_{k3f}}{p_{k3f}} \le 0.15,\ 500 < p_{k1f} \le 1000, \quad \dfrac{s_{k4f} - p_{k4f}}{p_{k4f}} \le 0.1,\ p_{k1f} \ge 1000, \\ \sum_{f=1}^{F}\sum_{l=1}^{5}\sum_{k=1}^{K} w_{klf} = 1, \qquad \sum_{f=1}^{F}\sum_{l=1}^{4}\sum_{k=1}^{K} g_{klf} > 0. \end{cases} \tag{3}$$

The solution to problem (3) will be the matrix $W^* = \|w_{klf}\|$, which is the optimum plan for purchasing the k-th product from the l-th group at the f-th manufacturer for a centralized pharmacy network.

Model 4. The formation of the product portfolio of each individual outlet takes into account the peculiarities of its geographical location (traffic, proximity to medical facilities, etc.) and the expected demand for goods. Thus, for each pharmacy will be created a separate assortment portfolio, which is aimed at maximizing the satisfaction of demand for goods at each specific outlet. The risks diversified by such a portfolio are caused by fluctuations in demand for different commodities.

z_{ki} – the share of demand for the k-th type of goods in the total demand for the product portfolio of the i-th point of sale,

d_{ki} – demand for the k-th type of goods in the i-th outlet (UAH.), (Or another option is possible D_{ki} – the demand for the k-th type of goods in the i-th outlet (packages)),

$$\begin{cases} Risk = \sum_{i}^{n} \sum_{k,m}^{K} z_{ki} \cdot z_{mi} \cdot \left(d_{ki} - \bar{d}\right) \cdot \left(d_{mi} - \bar{d}\right) \to \min, \\ Sum = \sum_{i}^{n} \sum_{k}^{K} z_{ki} \cdot d_{ki} \to \max, \\ Entropy = -\sum_{i}^{n} \sum_{k}^{K} z_{ki} \cdot \ln\left(z_{ki}\right) \to \max, \\ \sum_{i=}^{n} \sum_{k}^{K} z_{ki} = 1, \qquad z_{ki} \in [0;1]. \end{cases} \tag{4}$$

The solution to problem (4) will be the matrix $Z^* = \|z_{ki}\|$, which is the optimal plan for the distribution of demand shares for the k-th type of goods by the i-th outlets in a centralized pharmacy network (product portfolio). Modifications to model (4) are also possible with the inclusion in its composition of the demand for goods expressed in the number of packages D_{ki}, as well as its deepening to the level of inclusion of the goods of the k-type in the l-th group, as shown in model (3).

The break-even condition is a balance between purchase costs and sales revenues, ie the volume of goods ordered must correspond the volume of goods sold at all outlets of the network. From models (3) and (4) we obtain the relation between the portfolio of orders from suppliers and the assortment portfolio of retail outlets of the network (in monetary units):

$$\sum_{k=1}^{K}\sum_{l=1}^{5}\sum_{f=1}^{F} g_{klf} \cdot w_{klf} = \sum_{i=1}^{n}\sum_{k=1}^{K} z_{ki} \cdot D_{ki} \,. \qquad (5)$$

Flowchart of a comprehensive diversification program is presented in Figure 2

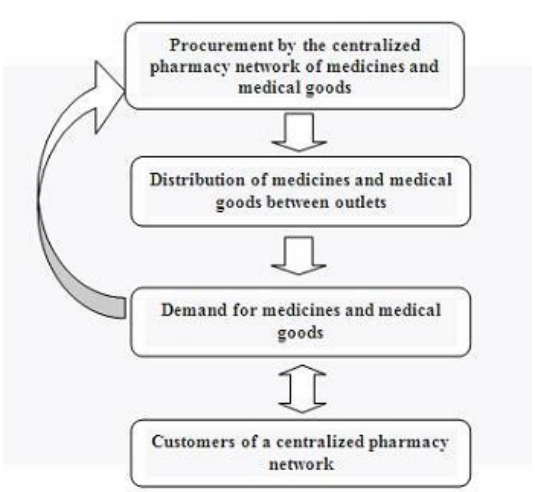
Processes	Models	Diversification plan
	Model 3	$W^* = \|\mathrm{w}_{klf}\|$ – the optimal plan of the parts purchase of the k -th type of goods from the l -th group from the f -th manufacturer
	Model 1	$\bar{X}^* = (x_1, x_2, ..., x_n)$ – the optimal plan for the distribution of financial resources of a central pharmacy network between outlets
	Model 4	$\mathrm{Z}^* = \|\mathrm{z}_{ki}\|$ – the optimal distribution plan for the central pharmacy network of the k -th type of goods by k -th outlets
	Model 2	$\bar{Y}^* = (y_1, y_2, y_3)$ – the optimal combination of loyalty, casual and online customer group distribution

Fig. 2 Flowchart of a comprehensive diversification program

We will consider in more detail the solution of multicriteria problems of complex diversification on the example of the first of complex models by the method of successive procedures [5].

The sequential assignment method for multi-criteria problems is applied when partial criteria can be ordered in descending order of importance. To choose a diversification strategy, we choose the following ratio of order: entropy, risk, revenue (*Entropy-Risk-Sum*.).

In the first step, let us determine the optimal value of the first Entropy criterion in the valid solution area.

$$\begin{cases} Entropy: -\sum_{i=1}^{n} x_i \ln(x_i) \to \max, \\ \sum_{i}^{n} \bar{a}_i \cdot x_i \geq 2 \cdot 10^6 \cdot n, \\ \sum_{i}^{n} x_i = 1, \quad 0{,}001 \leq x \leq 0{,}9. \end{cases} \qquad (6)$$

The optimal solution for the first partial criterion is $Entropy^*$. In the second step, we solve the conditional optimization problem on the next most important Risk criterion, adding to the conditions that determine the admissible solutions, the conditions for deviation of the first Entropy criterion from the found optimal value of $Entropy^*$ by no more than the value of the admissible assignment $\delta_1 > 0$. So we have the formalization of the second stage:

$$\begin{cases} Risk = \frac{2}{n}\sum_{i=1}^{n}\sum_{j=i+1}^{n}(a_i - \bar{a}_i)\cdot(a_j - \bar{a}_j)\cdot x_i \cdot x_j \to \min, \\ \sum_{i=1}^{n} x_i \cdot \ln(x_i) + \delta_1 \cdot Entropy^* \le 0, \\ \sum_{i}^{n} \bar{a}_i \cdot x_i \ge 10^6 \cdot n, \\ \sum_{i}^{n} x_i = 1, \quad 0{,}001 \le x \le 0{,}9. \end{cases} \tag{7}$$

The optimal solution according to the second criterion $Risk^*$ is obtained. Repeat the procedure for the next criterion Sum, adding to the conditions that determine the admissible solutions, the conditions for deviation of the first $Entropy$ criterion and the second Risk criterion from the found optimal values $Entropy^*$, $Risk^*$ not more than the values of allowable concessions $\delta_1 > 0$ and $\delta_2 > 0$.

$$\begin{cases} Sum: \sum_{i}^{n} \bar{a}_i \cdot x_i \to \max, \\ \sum_{i=1}^{n} x_i \ln(x_i) + \delta_1 \cdot Entropy^* \le 0, \\ \sum_{i}^{n} \bar{a}_i \cdot x_i \ge 2 \cdot 10^6 \cdot n, \\ Risk \le (1 + \delta_2)\cdot Risk^*, \\ \sum_{i}^{n} x_i = 1, \quad 0{,}001 \le x \le 0{,}9. \end{cases} \tag{8}$$

The solution obtained in the third stage is the solution of the three-criteria conditional optimization problem (1). The experiments with the models were conducted on the real data of one of the pharmacy chains operating in the city of Zaporizhzhya. All calculations were performed in the Matlab package [10].

Figure 3 shows the optimal solutions obtained in the third step of the sequential assignment method for different pharmacy size chains: small *n = 5*, medium *n = 33*, and megachain *n = 65*.

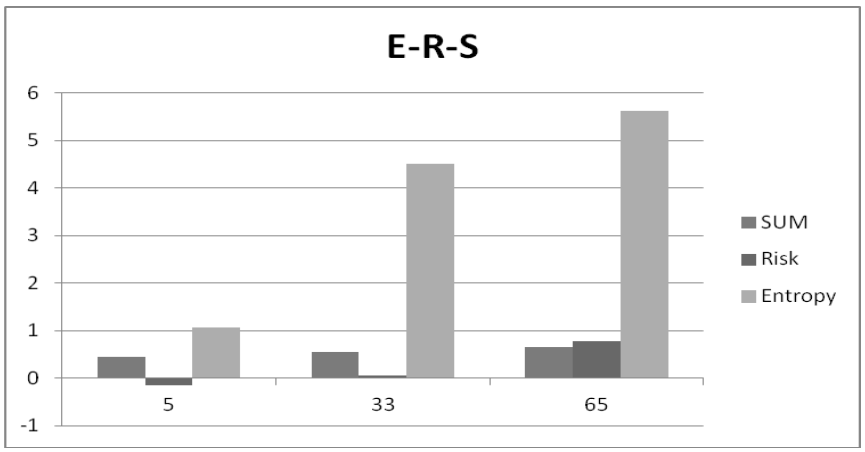


Fig. 3 Optimal solutions for different in size pharmacy networks

Figure 4 shows the solutions for the multicriteria model (1) in the three-criteria space *Entropy-Risk-Sum*, which is built in Matlab for a small network at n = 5. Black dots «○» correspond to experiments that take into account the pharmacy's overall risk, which is the sum of its own and systemic risks. Gray dots «Δ» indicate a set of portfolios in which only systemic risk was taken into account.

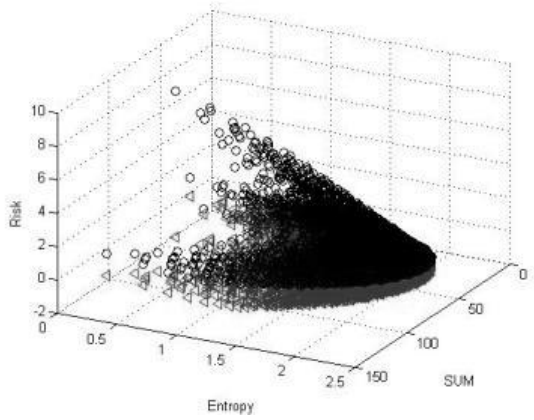


Fig. 4 Solutions to model (1) in the *Entropy-Risk-Sum* space built in Matlab

Figure 5 presents two-criteria projections that can be followed by relevant Pareto boundaries, with pareto-optimal risk management portfolios.

The sequential method developed by the tool showed how the multi-criteria conditional optimization problem was solved, resulting in many pareto-optimal portfolios for different pharmacy chains.

Managing a pharmacy network in terms of digital transformation of the healthcare system involves the effective management of their own risks, minimizing them by diversifying their own activities, leading to new challenges and enhancing the relevance of research in this area.

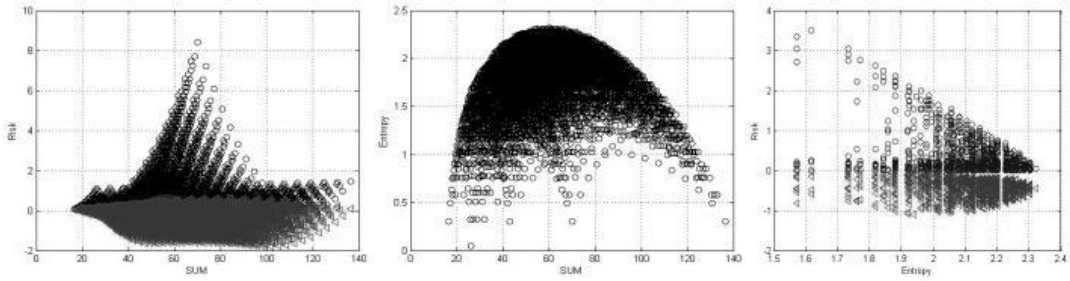


Fig. 5 Projection in Revenue-Risk, Entropy-Revenue, Entropy-Risk Spaces

The scientific novelty of this work is the formalization on the basis of portfolio theory and methods of multicriteria optimization of complex diversification models, taking into account the current conditions of functioning of pharmacy chains in a competitive market environment and changes in the legislation.

The practical value of the simulation performed in this work is confirmed by series of experiments conducted on real data, which demonstrated the possibility of using the developed tool for automatic distribution of resources of centralized pharmacy chains in the form of pareto-optimal portfolios in order to minimize risks. Among the areas of further research are conducting a number of experiments with different ways of formalizing risk in portfolio models and finding relevant analytical dependencies.

The work was carried out as a part of the research work «Mathematical modeling of socio-economic processes and systems», the registration number DB05038, at the Department of System Analysis and Computational Mathematics of Zaporizhzhya National Technical University.

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2.4 Analytical and simulation methods for sample size determination in parasitological studies: a comparison of methods and results

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Introduction

In many cases, it is useful to know the optimum sample size in order to obtain the population's actual characteristics and their confidence intervals (*CI*s). The estimated parasitological indices are often based on small sample sizes due to high time or monetary constrains, logistical problems associated with host capture or low abundance of some host populations. On the other hand, if the sample size is too large, researchers' additional time, money and other resources might be a wasted effort for minimal gain. Statistical descriptors of fish parasites were calculated based on samples from three individuals to over 1000 (Poiani, 1992; Belghyti et al., 1994; Ismen and Bingel, 1999), but it was commonly done without special attention to the effect of sample size on these estimates.

In case of natural infections, parasites typically exhibit an aggregated distribution pattern, with most host individuals harbouring low numbers of parasites and a few individuals hosting too many (Anderson and Gordon, 1982; Shaw and Dobson, 1995; Poulin, 2013). In most cases, the aggregated distribution of the parasites can be fitted to the negative binomial distribution (NBD), where smaller values of the dispersion parameter k ($k < 1$) indicate a highly aggregated distribution attributed to the most macroparasites of wildlife hosts (Shaw and Dobson, 1995). The aggregated nature of parasite distribution affects the mean abundance and the width of its *CI* (Rózsa et al., 2000). Therefore, in the determination of the optimum sample size, a compromise between representativeness of the parasitological data from small samples and unnecessary costs for collection excess data should be found. In addition, the determination of the threshold for minimum sample size depends from level of precision that should be well understood and chosen by the researchers. A few studies have focused on the effect of sample size on parasitological parameters (Gregory and Woolhouse, 1993, Jovani and Tella, 2006, Marques and Cabral, 2007). Gregory and Woolhouse (1993) claimed that if parasite sampling is not correctly selected, it may result in artefactual patterns for epidemiologic and aggregation indices. Jovani and Tella (2006) argued that a sample size around 15 fish specimens is enough to get statistically acceptable data for estimating the actual prevalence within a population. Marques and Cabral (2007) examined the effects of sample size on estimates of infection indices and demonstrated that even though samples with less than 40 individuals do not substantially influence parasite prevalence, whereas the mean intensity and mean abundance may be underestimated. Thus, sample size determination is a common problem when dealing with parasitological data.

Karandinos (1976) presented a formula for sample size calculation with precision as a fixed proportion of the mean. The formula has been subsequently developed by Ruesink (1980) for data with distribution patterns ranging from highly clumped to uniform. However, these formulae are based on several assumptions that are often not fulfilled by actual data. An alternative approach to estimating the

sample size is to use Monte Carlo simulations and bootstrapping techniques (Efron and Tibshirani, 1993).

The purpose of the present study is to explore the best method to determine the optimum sample size in parasitological surveys to obtain the true values of the mean abundance and their *CI*s. Marques and Cabral (2007) showed the power of Monte Carlo simulation and bootstrap procedures in determining the minimum sample size to estimate the mean abundance, mean intensity and prevalence. However, their work does not address the issue of parasite aggregation in the hosts. Moreover, the precision level and *CI*s for the studied indices were not considered, whereas these aspects are deliberately addressed here. The *CI* can provide information about estimation accuracy of the parasitological indices, where its width is used as a measure of estimation uncertainty and is largely determined by sample size. Marques and Cabral (2007) constrained their work to demersal flatfish and involved two species of cestodes, one acanthocephalan and one copepod. The present study focuses on monogenean parasites of *Ligophorus* spp. from the pelagic flathead grey mullet, *Mugil cephalus* L.

We considered two approaches, analytic and simulation, to estimate an adequate sample size to obtain ethically and scientifically valid values of mean abundance. To achieve this aim, the study is organized as follows. On the first stage, the required sample size was determined using a formula with predetermined precision levels. The second stage involved a simulation study based on applying the Bag of Little Bootstraps (BLB) (Kleiner et al., 2014) to empirical data sets and randomly generated parasite distributions in order to assess the optimal sample size as a balance between suitable estimates of the mean abundance and acceptable level of uncertainty in these estimates. Biases and *CI*s were used as measures of accuracy for the simulation modelling. The objective of the present paper is threefold: i) to estimate optimal sample size for parasitological surveys of *Ligophorus* spp.; ii) to evaluate the precision level and *CI*s in samples with different elements, and iii) to test the reliability of each approach to determine the optimal sample size for parasitological studies.

2. Materials and methods

2.1. Study area, fish sampling and parasite collection

This study is based on 205 dissected individuals *M. cephalus* from three localities, the Kerch Strait, the Sivash Lake and the Balaklava Bay, in the Azov-Black Seas in the period of 2001-2013 (Sarabeev, 2015) and one extra sample with 19 fish individuals from the Sivash Lake collected in 2014. The sample sizes ranged between 15 and 35 specimens. Only two-years old, and older fish within the size range of 24-65 cm (total length) were used in the analyses. Nine samples were studied across all localities, years and seasons. Collected fish were measured and surveyed for parasites within the day of capture or after freezing. Gills were carefully examined under a stereomicroscope for ectoparasites. All monogeneans were identified and counted. Taxonomic identification was attempted to the species level. Identification of *Ligophorus* spp. followed Sarabeev et al. (2013). The present study considers two species of *Ligophorus* from *M. cephalus* across the Azov-Black Sea localities, *L. cephali* Rubtsova, Balbuena, Sarabeev, Blasco-Costa & Euzet, 2006 and *L. mediterraneus* Sarabeev, Balbuena & Euzet, 2005. For each parasite species, samples with more than 6 infected hosts were considered to avoid inadequate estimation of mean abundance due to very low prevalence (Poulin, 2013). Therefore, the data sets included 197 and 192 fish individuals of which 132 and 96 were infected by *L. cephali* and *L. mediterraneus*, respectively.

2.2. Data analysis

The mean abundance was calculated according to Bush et al. (1997). The distribution pattern of parasite data was characterized by two parameters, using values of parameter *k* of the NBD and parameter *b* of the Taylor's power law (Taylor, 1961) $s^2 = a \cdot m^b$ in which s^2 is the sample variance, m is the sample mean and *a* is a scaling factor related with the sample size. The dispersion parameter *k* was estimated by using the maximum likelihood method (Bliss and Fisher, 1953; Davis, 1994; Young and Young, 1998). The chi-square statistic (Bliss and Fisher, 1953) was used to test goodness-of-fit of the NBD for empirical data.

Through use of a $\ln$ transformation the coefficient a and the exponent b are estimated by the y-intercept antilog and the slope, respectively, of the least square regression line of $\ln s^2$ on $\ln m$ as:

$$\ln s^2 = \ln a + b \cdot \ln m, \qquad (1)$$

using empirical sample means and variances. The values of a and b were tested for departure from 0 and 1, respectively, by using a two tailed t-test (Snedecor and Cochran, 1980). The coefficients of determination R^2 were calculated, to characterize the fit of Taylor's model. For each parasite species 10 mean-variance pairs (9 samples and one aggregated data set) were obtained from empirical samples.

The analytic approach to determine an optimum sample size (n) for mean parasite abundance estimation is based on the general formula (Karandinos, 1976):

$$n = \left(\frac{Z_{\alpha/2}}{D} \right)^2 \frac{s^2}{m^2}, \qquad (2)$$

in which $Z_{\alpha/2}$ is the standard normal deviate such that $P(Z > Z_{\alpha/2}) = \alpha/2$; D is a level of precision and is used to define half-width of the *CI* as a fixed proportion of the mean $(CI/2 = D \times m)$ (Wilson, 1985). For a 95% *CI*, $\alpha = 0{,}05$, then $Z_{\alpha/2}$ equals 1.96.

In the present study the optimum sample size was determined for two precision levels: D=0.5 and D=0.8. These levels are reasonable for practical applications, and are acceptable in most sampling research (Cyr et al., 1992; Mouillot et al., 1999, Opit et al., 2009).

If the dispersion pattern of the target population is well described by the NBD, Karandinos' equation (2) can be rewritten as:

$$n = \left(\frac{Z_{\alpha/2}}{D} \right)^2 \left(\frac{1}{m} + \frac{1}{k} \right). \qquad (3)$$

Incorporating Taylor's power law into Karandinos' equation (2) the sample size model becomes:

$$n = \left(\frac{Z_{\alpha/2}}{D} \right)^2 a \cdot m^{b-2}. \qquad (4)$$

The BLB using the R statistical data analysis software (version 4.0.1, R Development Core Team, 2020) was applied here in a simulation study to determine the optimal sample size. The effect of sample size on *CI* width was tested for: i) two empirical data sets of *L. cephali* and *L. mediterraneus*; and ii) five simulated data sets with fixed mean and variable *k*. The random 1000-dimension samples with the NBD were generated, parameterized by the fixed value of mean abundance equal to 5.55 and exponent *k* of the NBD ranging between 0.1 and 0.9. This range covers most variation of *k* values found for *Ligophorus* spp. (our unpublished data). The random simulation procedure was implemented using the R function *rnegbin()* in the MASS package (Ripley et al., 2017). To examine the effect of sample size on mean abundance, a bootstrapping method was applied to generate 95% *CI*s for given parasite data set: *n* elements from each data set were randomly selected 10000 times, and then we performed a bootstrap with 5000 iterations and computed the mean for each *n*-dimension sample occasion, based on samples from 10 to 100 elements in steps of 5. The 95% *CI*s for bootstrap were defined using the values that mark the upper and lower 2.5% of the bootstrap distribution. Bias significance was evaluated through *t*-test. The difference between the estimates of the mean abundance obtained based on different sample sizes was examined by Dunnett's Modified Tukey-Kramer Pairwise Multiple Comparison Test (DTK) from package «DTK» (Lau, 2015) after a logarithmic transformation of the data. The DTK test allows to conduct a pairwise multiple comparison test for mean differences with no assumption of equal population variances. A significance level of 0.05 was used for all test procedures.

According to the purpose of the study, several criteria were used to determine the appropriate sample size: the fit of empirical data to the theoretical distribution; the desired precision (*CI*s width for mean abundance); the achievement of minimal bias and the comparison of mean abundance differences based on different sample sizes. All criteria had to be met in order to accept a given *n* as the minimum sample size needed for estimation of the parasite mean abundance.

3. Results

The dispersion pattern of both helminth species could be characterized as a highly aggregated distribution with the variance being substantially larger than the mean values. Obtained values of *k* were lower than 1, also indicating on a highly aggregated distribution of these species in the host (Table 1). The chi-square test revealed that *L. cephali* data set does not fit to the NBD, thus not allowing to determinate the optimal sample size using parameter *k* of the NBD in formula (3). For both parasite species, the ordinary least square regression showed a very strong relationship between the means and variances (R^2 =0.82 and 0.84, $P<0.0001$) with values of $b>2$ that also indicates a high degree of aggregation. Because the slope *b* exceeded 2, formula (4) based on Taylor's power law could not be used (Shelton and Trumble, 1991). For *L. mediterraneus*, minimum sample sizes needed to reach the predetermined precisions D=0.5 and D=0.8 based on formula (3) are 76 and 30, respectively.

Table 1 Summary data for samples of Mugil cephalus surveyed from the Azov-Black Seas with information on abundance, variance and aggregation indices of two helminth species (ln *a*: *y*-intercept, *b*: slope, *SE*: standard error, *t*: *t*-test result, R^2: coefficient of determination, *k*: negative binomial parameter, χ^2: chi-square statistic)

	Mean abundance	Variance	ln *a* (SE, *t*-value)	*b* (SE, *t*-value)	R^2	*k* (SE, χ^2)
Ligophorus cephali	15.65	1908.92	-0.16 (1.11, -0.14*)	2.64 (0.43, 6.1)	0.84	0.25 (0.03, 26.02)
L. mediterraneus	5.55	221.25	0.98 (0.67, 1.47*)	2.33 (0.42, 5.59)	0.82	0.21 (0.03, 2.48**)

*No significantly differs from 0 ($P>0.05$). **The NBD model fits to data ($P>0.05$)

For both parasite species, the mean abundance values obtained by the BLB were close to empirical values of the mean, and no significant biases were found in the estimates. The distribution of mean abundance estimates obtained by simulations was highly right-skewed and the median values were always under-estimating the

empirical value at low sample size (Fig.1). The results showed overlapping between the medians of bootstrapping means and the empirical mean abundance beginning from the sample with 40 elements for both examined species. The pairwise statistical comparison between mean abundance values across sample sizes using the 95% *CI*s is represented in Figure 2. Following the TDK test the estimates related to sample sizes up to 30 and 20 specimens were convincingly different from all others, while there were moderate differences between samples over 40 and 30 fish specimens for *L. cephali* and *L. mediterraneus*, respectively.

The bootstraped 95% *CI*s were non-symmetric, which correspond to the asymmetry of the underlying mean parasite abundance distributions, and became narrower as sample size increased for both parasite species (Fig. 3). The effect of sample size on *CI* width as a fixed proportion of the mean for variable values of *k* is shown in Figure 4. The simulation results revealed that as *k* decreases *CI* width was more strongly affected by sample size. The width of the 95% *CI* is not markedly narrowed with increases in sample size for samples above 25 for *k*=0.9, 30 for *k*=0.5, 40 for *k*=0.2, 45 for *k*=0.15 and 50 for *k*=0.1 elements. For empirical data sets of both species studied here, the largest decrease in *CI* width (exponential phase) was found for sample sizes below 40 individuals, while the further increase of samples resulted in a slow linear decrease in *CI* width (linear phase). This means that the *CI* markedly decreases with increasing sample size up to ca. 70-80 specimens. However, further increase of sample size did not really narrow the *CI*. The width of the 95% *CI*s was decreased from values (1.6 x mean) for sample size with 35 elements to (1 x mean) for sample size with 70 elements in both model species. For *L. cephali* and *L. mediterraneus*, which have close values of the parameter *k* (0.25 versus 0.21) and different values of the mean abundance (15.65 versus 5.55), the variation of the *CI* width was either small or negligible.

4. Discussion

In the present study, the BLB analysis showed that the minimum required sample size depends greatly on the actual aggregation of the parasite population. The higher degree of variability in the size of parasite infrapopulation, the larger sample

size needs to be examined in order to obtain the true value of the mean abundance (Wilson et al., 2002). On the other hand, the measure of aggregation will tend to underestimate true aggregation in small samples. This is because heavily infected hosts are rarely found in wild populations and therefore, most likely the probability to be observed in small sample sizes is low (Poulin, 2013). Similarly, the mean abundance calculated from low sample sizes will be underestimated if we do not account for the distribution tail (Marques and Cabral, 2007).

The mean abundance estimates should be reported along with *CI*s, which will allow researchers to assess the biological significance of presented findings (Steidl et al., 1997). From a practical point of view, the level of precision is the dominant factor in determining the sample size. Following Buntin (1994), one of the ways to determine the precision is to express it as a confidence interval such that the estimate of the mean should be within a certain value of the true mean with a given probability. Most investigators prefer narrow *CI*s that require large sample sizes for aggregated populations. It stimulates researchers to look for the balance between the limitations of the time and effort required for sample collection, on the one hand, and the essential degree of precision of parasitological indices on the other hand. Because of heterogeneity in parasite infection, it is difficult to apply a theoretical approach for this purpose. Therefore, the simulation bootstrap procedure based on an empirical data set is a much more robust tool. For small samples, the 95% bootstrap *CI*s for estimates of the mean abundance are typically very large and skewed upwards. The exponential decrease in the *CI* width as sample size increases indicates the rapidly decrease in the level of uncertainty, and in this way, sample size becomes reasonable for estimation of mean abundance. The further slow linear decreases in the *CI* with sample size increases could be explained by a high total number of non-zero values in such samples. In the example of *L. mediterraneus* and *L. cephali* it was shown that the *CI* becomes more precise and less skewed upwards when sample size is between 35 and 70 fish individuals. Possibly for the reason that such samples are less variable in a number of parasite individuals per host.

Depending on the study aims, researchers may seek higher confidence with a wider interval. For *Ligophorus* species, the reasonable precision level could be chosen between 0.8 and 0.5. If the purpose is to get a general idea about the population abundance, the sample size required could be reduced by lowering the level of precision to *D*=0.8 (Opit et al., 2009). If this lower level of precision is used, the sample size with 35 fish specimens is recommended for the estimation of mean abundance for both studied here *Ligophorus* spp. However, for highly aggregated populations, the sample size needs to be sufficiently large to provide a statistically acceptable data for estimation of less abundant parasites (Fig. 4). According to Rózsa et al. (2000), the mean abundance is strongly dependent on a few heavily infected individuals; therefore, more specimens may be needed to improve the *CI*s.

Obtained minimum sample size did not substantially depended on the mean abundance of the studied monogeneans, although the difference was about three times fold. The similarity in the sample size required for studied model species could be related to their congeneric relationships that could have the effect on the parasite dispersion pattern. The distributions of both examined species are characterized as a highly aggregated with close values of parameters *k* and *b*. Metazoan gill parasites of fish form non-saturated, multispecies and rich infracommunities in which aggregation ensures cross-fertilization and was found to be an important factor determining the distribution on the gills (Rohde et al., 1995; Bagge et al., 2005). Monogeneans tend to be more aggregated at lower abundances, what happen because more aggregation is needed as the distance to a potential mate increases with decreasing number of conspecifics (Bagge et al., 2005). Our results for the required minimum sample size are in accordance with those of Marques and Cabral (2007) obtained for a system of flatfishes and their parasites.

The values of sample size obtained by the analytical formula show a good correlation with estimates based on the simulation technique. However, the *CI*s based on normal theory are less accurate for skewed distributions, in particular for cases where sample sizes are small (Rózsa et al., 2000). Therefore, by utilization of the BLB method a more precise bootstrap *CI*s can be obtained.

The results from this study allowed a direct comparison of sample size estimation by two approaches, analytic and simulation. The advantage of using formulae is the possibility to analyze effects of the precision level, mean abundance, parameter *k* of NBD and parameters of Taylor's model on sample size. The most apparent weakness of the analytic approach is the requirement of the fit of sample data to the theoretical distribution. The application of the formula (3) with parameter *k* of the NBD requires that the *k* value was estimated accurately. For highly aggregated parasite populations, according to the formula (3), the sample size strongly depends on the dispersion of value *k* and the precision of *D*, while the mean abundance >1 does not significantly affect the sample size. Although the Taylor's power law has been widely used due to its statistical stability, the formula (4) for sample size calculation based on the Taylor's model is useful only when $b<2$. This is a significant limitation (Shelton and Trumble, 1991) because the aggregation leads to an increase of coefficient *b* to the critical value 2, or in some cases more than 2. Since the analytic approach is often impossible to apply the non-parametric BLB method is preferable for optimum sample size determination. The primary advantage of bootstrapping is that no assumptions are made on the distribution of the initial data set. Researchers need to assume only that the sample data are independent and representative of the population. The accuracy of estimates obtained by bootstrapping depends on the number of observations in the original sample and the number of resamples. Obviously, large samples are likely to be more representative than small samples.

5. Conclusions

The holistic approach applied here offers a wide range of appropriate methods to sample size computation and to understand the expected precision level for the mean. While the formulae for sample size estimation may not be very meaningful in practice, their value is that they can provide some strategy in sampling plan before a study. Monte Carlo simulations and bootstrap procedures are powerful techniques for sample size determination. In case of small samples, bootstrapping methods are especially useful to compute the descriptive statistics with associated *CI*s. Such

approach is reasonable when dealing with critically endangered species for which low sample sizes are often unavoidable. Regarding sample sizes for parasite data sets with a highly aggregated dispersion pattern, sample size equal 80 or more host individuals allows accurate and precise estimation of mean abundance, whereas for the host sample size in range between 25 and 40 individuals, the median estimates showed minimal bias but the sampling distribution skewed to low values. A sample size of 10 host individuals yields to unreliable estimates, particularly for highly aggregated parasite data sets. These findings will help guide prospective design of sampling plan and will aid researchers in understanding the precision level for the estimated mean abundance in parasitological surveys. At the same time, for the studies aimed to compare epidemiological parameters the question about the optimum sample size remains open. Therefore, the next studies should be focused on the investigating the optimum sample size for comparative studies in parasitology and epidemiology.

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Figure

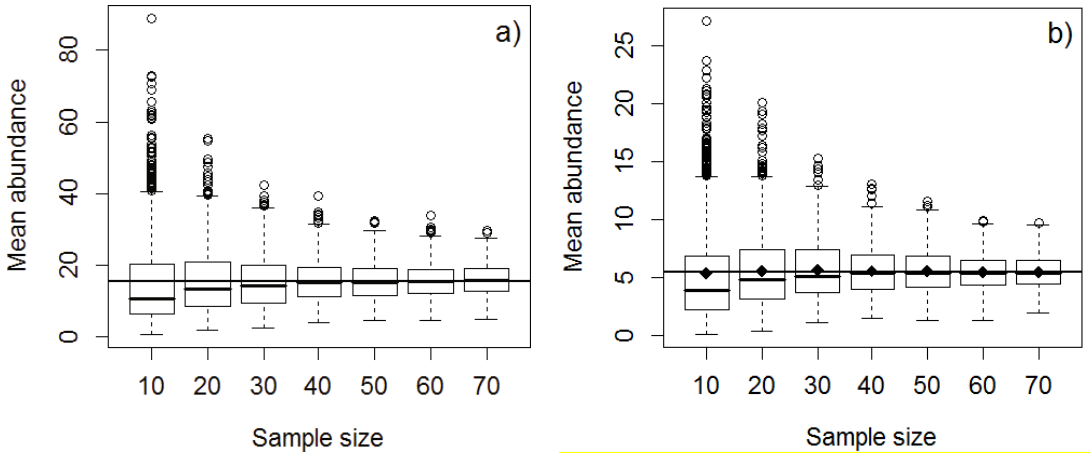

Fig. 1 Distribution of mean abundance obtained from empirical parasite data sets by BLB for different sample sizes for *Ligophorus cephali* (a) and *L. mediterraneus* (b). The box spans the first and third quartiles; the median is marked inside the box by thick horizontal line; minimum and maximum values excluding outliers (whiskers) and outliers (circles); the straight line is the empirical mean abundance.

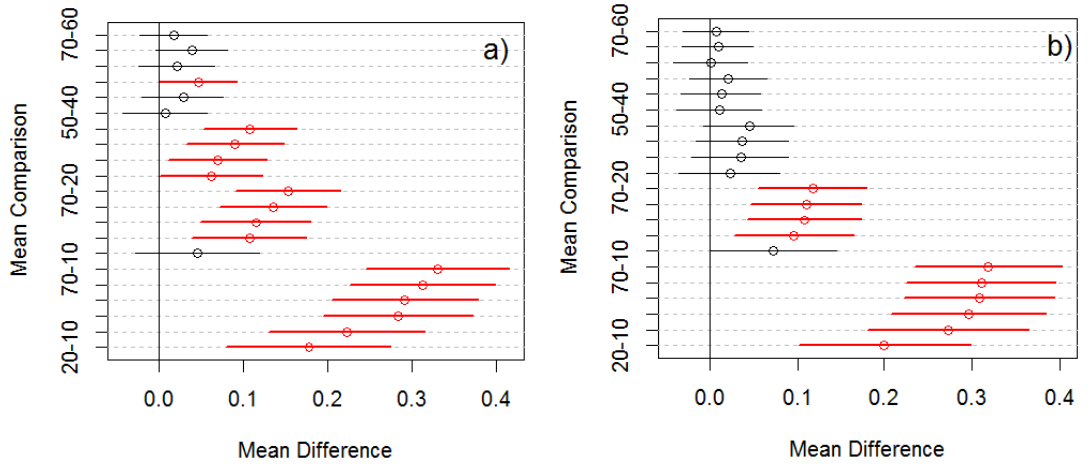

Fig. 2 Simultaneous confidence intervals for all pairwise comparisons of group means. Intervals were computed by the Dunnett's Modified Tukey-Kramer Pairwise Multiple Comparison Test for the mean abundance data of *Ligophorus cephali* (a)

and *L. mediterraneus* (b) across different sample sizes. If the interval does not include a zero, the corresponding means are significantly different.

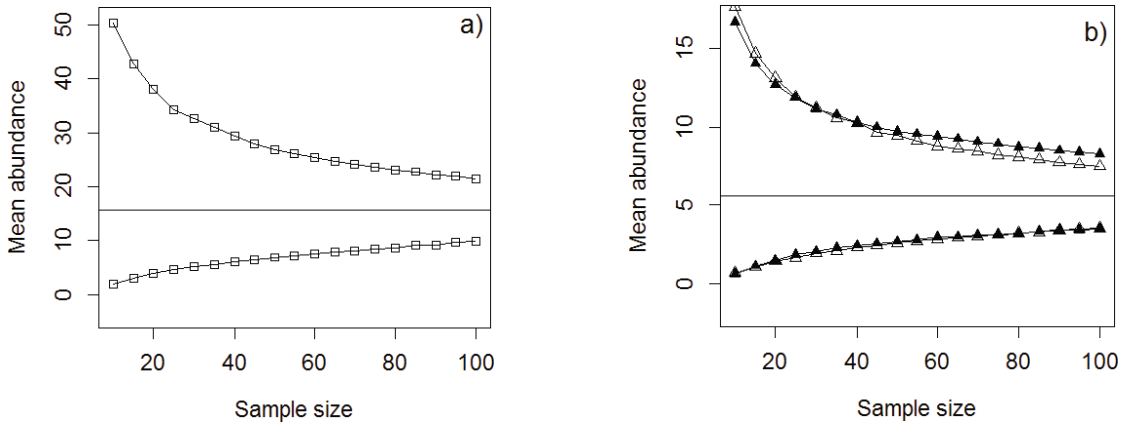

Fig. 3 Mean abundance and its 95% *CI*s calculated by BLB for different sample sizes for *Ligophorus cephali* (a) and *L. mediterraneus* (b); bootstrap *CI*s based on empirical data set for *L. cephali* (open square); bootstrap *CI*s based on randomly generated and empirical data sets for *L. mediterraneus* (filled and open triangle, respectively); the straight line is the empirical mean abundance.

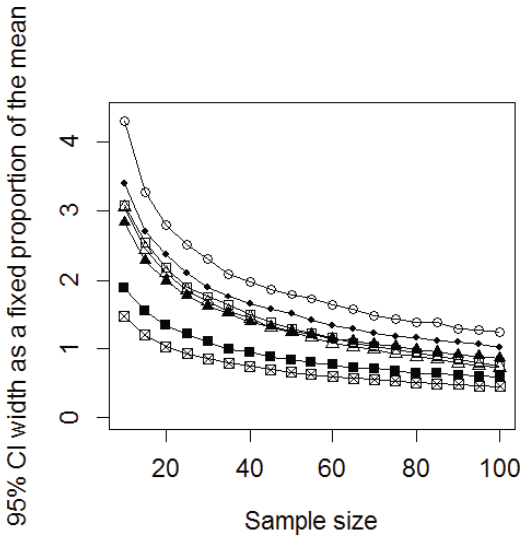

Fig. 4 Width of the 95% CIs as a fixed proportion of the mean abundance determined by BLB from the empirical parasite data sets for *Ligophorus mediterraneus* and *L. cephali* (open triangle and open square, respectively) and randomly generated data with fixed mean abundance of 5.55 and variable *k* of 0.1,

0.15, 0.2, 0.5 and 0.9 (open point, filled point, filled triangle, filled square and square cross, respectively).

Supporting information

```
# generating random data and calculating the bootstrap mean values
R> library(MASS) # load package
R> sim <-rnegbin(1000, mu = 5.55, theta = 0.2) # generate random variates from the NBD with mean mu and parameter theta
R> outp10 = matrix(nrow=10000, ncol=2) # create a matrix
R> for(i in 1:10000){ # «for loop» to calculate 10000 bootstrap mean values
R> subsample<-c(sample(sim,10)) # create a subsample
R> boot <-numeric(5000) # create a vector to store the calculated values
R> for (j in 1:5000) boot[j] <-(mean(sample(subsample,replace=T))) # bootstrap
R> mean(boot) # bootstrap mean values for subsample
R> outp10[i,] = c(i,mean(boot)) # write the bootstrap mean values
R> }
# tests for multiple comparison
R> mysam<-read.table(«sampls.txt», sep= «\t», head=TRUE) # read the data set
R> attach(mysam) # access the variables from dataframe
R> hist(mysam$mean,breaks = 100,xlab=«Mean abundance», main=«Histogram of Mean abundance») # histogram of response variable (mean) is plotted for visually analyzing the normal distribution
R> aov.sam= aov(mean~sample) # calculate the anova
R> summary(aov.sam, intercept=T) # show the anova summary table
R> qqnorm(residuals(aov.ex1)) # q-q plot
R> qqline(residuals(aov.ex1)) # line
R> plot(fitted(aov.ex1),residuals(aov.ex1)) # plot
R> res<-aov. sam$residuals # residuals of the model
R> hist(res,main=«Histogram of residuals»,xlab=«Residuals») # histogram of the residuals
R> library(car) # load package
R> bartlett.test(log(mean)~as.factor(sample),data=mygr) # the Bartlett's test for equality of variances
R> leveneTest(mean~as.factor(sample),data=mygr) # the Levene's test for equality of variances
# following test assumes that the data should be approximately normally distributed and should show homogeneity of variance
R> TukeyHSD(aov.sam) # Tukey test for multiple comparison
R> plot(TukeyHSD(aov.sam, conf.level=.95),cex.axis=1.5, cex.lab=1.5) # plot the Tukey confidence intervals
R> library(DTK) # load package
# following test does not assume homogeneity of variance
R> DTK.result <-DTK.test(x=mysam$mean,f=as.factor(mysam$sample),a=0.05) # Dunnett's Modified Tukey-Kramer Pairwise Multiple Comparison Test
R> DTK.result
R> DTK.plot(DTK.result) # plot simultaneous confidence intervals
```

2.5 Asymptotic approach to inventory management under changing environment

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At present, the economic situation in the world is characterized by an exacerbation of global crisis phenomena caused by various factors, including the consequences of the pandemic. There are numerous software products in the market that help improve the quality and efficiency of the logistic process management under changing environment. Mainly functions of accounting and movement of goods are implemented and used in them but there are almost no effectively implemented functions of calculating purchase volumes and replenishment time. This significantly limits the effectiveness of the proposed software products. Insufficient development of analytical tools, models, and methods of inventory management is one of the causes of the absence of effective implementation of these functions.

Modeling of logistic systems at the present stage of their development requires the use of mathematical optimization tools that have proven their effectiveness, especially in the field of inventory management. The existing models used in the management decision-making process in functional logistics have many limitations, such as invariance of input parameters of the model which significantly narrows possibilities of their use in practice. Divergences of a simplified economic and mathematical model from a real one which describes the company’s logistic system may differ. In the case when input parameters of the system undergo minor changes, divergences in simulation results may be economically small in the area of input parameters. In this case, asymptotic methods of «perturbations» can be used to model logistic processes. This makes it possible to obtain an approximate solution of the problem with an acceptable error and in an analytical form convenient for use.

Moreover, asymptotic methods make it possible to use the earlier obtained analytical solutions of applied problems to solve similar but more intricate problems by establishing relations between them.

The use of asymptotic methods to solve applied economic problems in the field of logistics will allow the company's management to obtain clear and simple analytical calculation formulas. These formulas will provide an opportunity to optimize the company’s overall logistics costs and improve the competitiveness of the companies that will use them.

Of the recently published studies of asymptotic methods, it is necessary to note the study [1] in which asymptotic ideas and methods are presented at a level understood by many readers. The main ideas of asymptotic approaches were stated and peculiarities of their application in various fields investigated. An overview of the perturbation theory methods for solving differential equations describing problems of applied physics and mechanics was given and the advantages of these methods and fields of their application were discussed in [2].

The study [3] is devoted to the definition of the essence of the perturbation methods which consists in the fact that the problem solution is sought in a form of serial expansion by the small parameter powers. This parameter appears in the model either naturally or is artificially entered for convenience. The method assumes that a corresponding asymptotic sequence which in the simplest and most common variant is taken as the power function of the small parameter ε^n is chosen for the study of an applied problem.

Perturbation methods are used in mechanics of solid structures [5] and in differential equations [6-7].

Application of perturbation methods to the problems of mechanics of solid structures and differential equations is explained by the fact that they enable the construction of an approximate analytical solution and estimation of the system sensitivity to the changes in input parameters. These methods have not yet been used in applied economic studies because of their narrow specialization and predominant focusing on the study of the behavior of mechanical objects. However, the scope of

these methods can be extended to the problems of optimizing economic processes and making managerial decisions. The analytical formulas obtained through the application of perturbation methods are convenient for enterprise managers and can also expand the scope of the economic models, in particular, the inventory management models.

Problems of inventory management were studied in [8–29]. Features of construction of deterministic single-product and multi-product models of procurement logistics which help managers in the decision-making process were studied in [8, 9]. However, input parameters of these models are considered constant which limits fields of their practical use.

An EOQ model of procurement logistics with the emergence of a shortage caused by the possibility of the presence of defective products in the ordered batch was developed in [10]. This model is limited in terms of accounting minor discrete changes in the order fulfillment costs. A dynamic model of procurement logistics with the emergence of a shortage in demand linearly depending on time was constructed in [11]. This model makes it possible to estimate optimal order quantity, order periodicity, and total costs under this assumption. However, it does not take into account changes in the order fulfillment and inventory storage costs. Further source [12] concerns the study of the behavior of the model of purchasing perishable goods in the presence of inflation and possible delays in payments. The issue of possible payment delays was analyzed in [13] but the models did not take into account possible fluctuations in the demand for the proposed products. A model of inventory management under the condition of the demand fluctuation and inventory damage caused by suboptimal warehouse location, improper storage conditions, etc. was studied in [14]. In this case, the rate of inventor damage was distributed according to the Weibull function and the inventory maintaining cost was considered a discrete variable. The use of fixed costs for order fulfillment can be considered a disadvantage of this model. The EOQ models constructed in [15] for perishable products take into account possible deterioration of product quality, possible penalties presented in a form of exponential and linear functions. Further study [16] concerned

the construction of an integrated inventory management model for one supplier and one customer with a reduction in order costs depending on the time of the order fulfillment but the variability of storage costs was not taken into account. Study [17] was also devoted to the improvement of the single-product model. The study considered peculiarities of the procedures of EOQ-optimization of the supply chain. Such procedures will take into account the feasibility of sharing several vehicles for each order and specifics of payment of the storage costs both in a form of rent and paying only for the occupied warehouse space. However, there are no analytical formulas convenient for application and further analysis by the company's management. Application of the asymptotic approach to determining the single-product order quantity under the condition of variable costs of order fulfillment was given in [18]. However, the cost of inventory storage was calculated taking into account the area occupied by the warehouse for a certain period, and the spatial dimensions of the product unit.

Some researchers consider variations of real situations in the company's logistics management system, namely inflation, sudden rises and falls in demand, etc. and present their models of inventory management in an uncertain environment. For example, a problem of determining economic order quantity (EOQ) for the case when input parameters are probabilistic and optimal probability distribution functions are calculated using a geometric programming model was studied in [19]. A stochastic problem of finding EOQ in a certain time interval was solved in [20]. However, the study was mainly theoretical in nature and did not focus on a practical application.

The study [21] was devoted to the development of an inventory management model that would optimize costs and order quantity taking certain non-deterministic parameters as fuzzy numbers. Demand and related costs are taken in the study [22] as fuzzy variables, and the Jaeger ranking method for fuzzy numbers was used to determine an optimal inventory management policy. However, the obtained models are difficult to apply in practice for want of convenient analytical formulas.

The study [23] has proposed a multi-product inventory management model for a double-level supply chain under the condition of incentive-sensitive demand

marketing. In this case, the supplier offers the retailer an opportunity to delay the payment of the purchase price of finished products. Modeling of logistic processes at an enterprise in conditions of ordering a wide range of products from one supplier using asymptotic methods was proposed in [24]. Under the conditions of variable supply costs, a model was obtained that makes it possible to adapt the enterprise's logistic system to the existing business conditions. However, insufficient attention was paid to determining optimal order quantity under conditions of the variability of solely order fulfillment costs. Further development of the asymptotic approach to multi-item supply was given in [25] which takes into account changes in the storage costs but at a constant demand for the proposed products.

A model of inventory management at the retail level in a system with reverse logistics which allows the company to maximize profits taking into account volumes of supplies and their timing was considered in [26]. However, the proposed model takes into account price variability and not the variability of other input parameters.

Most studies do not take into account transport costs in the analysis of the EOQ or consider the transport costs as a constant part of the order cost which is taken into account in [27] but researchers use an iterative method difficult in application.

A model taking into account limited resources for storage of products, namely allocation of space in refrigeration equipment in retailing is another modification of the EOQ model [28]. This implies the presence of additional costs to maintain a certain storage temperature but the results do not take into account changes in the order fulfillment and inventory storage costs.

Some researchers [29] address the problems of developing analytical tools to determine EOQ but these tools are imperfect and need further study.

The optimization methods analyzed in the known studies can effectively solve the problems of inventory management but they are often incomprehensible to practicing managers because of their high complexity (the use of iterative processes in calculations, complicated mathematical apparatus, etc.). Both researchers and managers find it more convenient to use analytical models that describe the object behavior according to clear formulas and taking into account variability of order

fulfillment and inventory storage costs as well as fluctuation of demand for the proposed products.

The study objective is to optimize the inventory management model under conditions of minor changes in input parameters with the application of perturbation methods. This will expand the scope of this model application in practice.

To achieve this objective, the following task has been set: to derive an asymptotic formula of the EOQ model under the condition of periodic fluctuation of the demands for products.

The economic order quantity model (the EOQ model) or Wilson's formula used to estimate the order quantity can be presented as follows [4]:

$$q_{opt} = \sqrt{\frac{2C_0 S}{h}}, \quad (1)$$

where q_{opt} is the EOQ; C_0 is the cost of the fulfillment of one order, S is the amount of demand in a certain period of time; h is the cost of storage of a product unit for a certain period of time.

The cost of delivery is one of the main components of the order fulfillment costs which is constantly rising because of rising fuel prices. Assuming that the order costs increase by i % during a certain period of time (for example, each month), then it will reach $C_0 \cdot \left(1+\frac{i\%}{100\%}\right)^n$. after n periods of time. Taking the ratio $\varepsilon = \frac{i\%}{100\%}$ ($\varepsilon << 1$) for a small parameter, the order cost is obtained in this form: $C_0 \cdot (1+\varepsilon)^n$. Since the ε parameter is the small parameter, we can assume that deviation from the initial value of C_0 is insignificant and the condition of constant order fulfillment costs is satisfied.

In practice, in addition to the changes in order fulfillment costs demand S for products may also fluctuate depending on various exogenous and endogenous factors, such as seasonality, etc.

Take the order fulfillment costs as $C_0(1+\varepsilon)^n$. Periodic changes in demand S can be represented as a function $S\left(1-\beta \sin\frac{\pi n}{2}\right)$, where $\beta << 1$ is the small parameter.

Using the procedure described above, the order quantity q^*_{opt} was defined as the asymptotic expansion of two small parameters ε and β while neglecting the members ε^3, $\varepsilon^2\beta$ and the members of higher orders:

$$q^*_{opt} = \left(q_0 + \beta \cdot q_1\right) + \left(\tilde{q}_0 + \beta \cdot \tilde{q}_1\right) \cdot \varepsilon + q_2 \cdot \varepsilon^2 + \ldots . \qquad (2)$$

The asymptotic formula for the «perturbed» order quantity takes the form:

$$q^*_{opt} = \sqrt{\frac{2C_0 S}{h}} \cdot \left(\begin{array}{l} 1 + \frac{n}{2} \cdot \varepsilon - \frac{1}{2}\beta \sin\frac{\pi n}{2} - \\ -\frac{n}{4}\varepsilon \cdot \beta \sin\frac{\pi n}{2} + \frac{n \cdot (n-2)}{8} \cdot \varepsilon^2 \end{array} \right). \qquad (3)$$

As can be seen from formula (3), the «perturbed» order quantity differs from Wilson's formula (1) in the multiplier:

$$\left(1 + \frac{n}{2} \cdot \varepsilon - \frac{1}{2}\beta \sin\frac{\pi n}{2} - \frac{n}{4}\varepsilon \cdot \beta \sin\frac{\pi n}{2} + \frac{n \cdot (n-2)}{8} \cdot \varepsilon^2\right).$$

Depending on the value of the sine function, the value of the order quantity will undergo periodic changes in the direction of increase or decrease relative to the value given by Wilson's formula (1).

Fig. 1 shows the deviation of the «perturbed» order quantity from the economic one under the condition of a gradual increase in the order fulfillment costs and insignificant fluctuations in demand (while fixing the amplitude of demand fluctuation β=0.02).

As can be seen in Fig. 1, the increase in the order fulfillment cost and insignificant demand fluctuations cause fluctuations in the order quantity. Moreover, the larger the value of the perturbation parameter ε, the more significant is a deviation from the economic size of the order calculated by formula (1). For example, the deviation of the order quantity from the optimal one is +6.4 % at ε=0.015 in the 7th period and this deviation is as high as +8.24 % at ε=0.02.

Fig. 2 shows sensitivity of the economic order quantity to the amplitude of demand fluctuations at fixed rates of growth of the order fulfillment costs (ε=0.01 was recorded in Fig. 2).

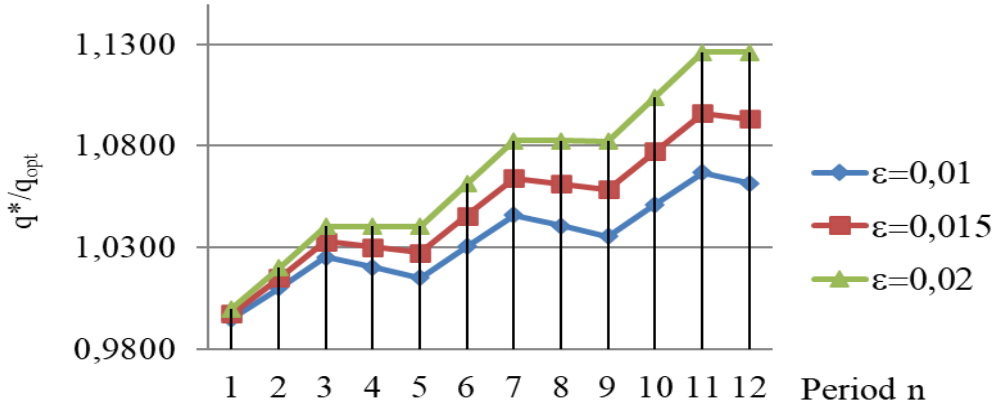

Fig.1 Sensitivity of deviation of the perturbed order quantity from the optimal one (q^*/q_{opt}) to a gradual increase in the order fulfillment costs depending on the period n at insignificant demand fluctuations

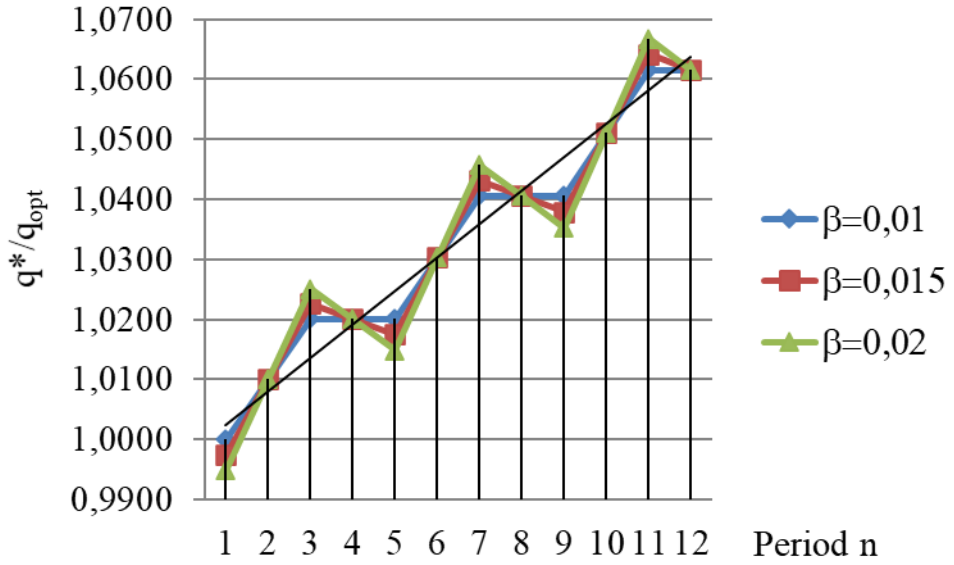

Fig. 2 Sensitivity of the order quantity (q^*/q_{opt}) to the amplitude of demand fluctuations depending on the period n at fixed rates of growth of the order fulfillment costs

Fig. 2 shows that provided the parameter ε is fixed, an increase in the amplitude of the demand fluctuations leads to an increase in the order quantity in odd periods n=3, 7, 11,…. On the contrary, in odd periods n=5, 9,…, it decreases

depending on the form of the function chosen for the demand approximation. Therefore, the company's management must take these fluctuations into account when deciding on an order.

Let us consider, for example, period 3 when the order fulfillment costs increase by 1 % (ε=0.01) and the amplitude of demand fluctuations is 1.5 % (β=0.015). The «perturbed» order quantity increases by 2.26 % compared to the economic order quantity and the deviation will be +6.4 % in the 11th period under these conditions. However, if the order is fulfilled in the 5th period, the deviation will decrease.

Fig. 3 shows the sensitivity of deviation of the order quantity to the gradual increase in the order fulfillment costs at insignificant demand fluctuations. To build the graph, it is necessary to fix the amplitude of demand fluctuations (the value of parameter β=0.015) and change ε in the range from 0 to 0.02 (the rate of change of the order fulfillment costs does not exceed 2 %).

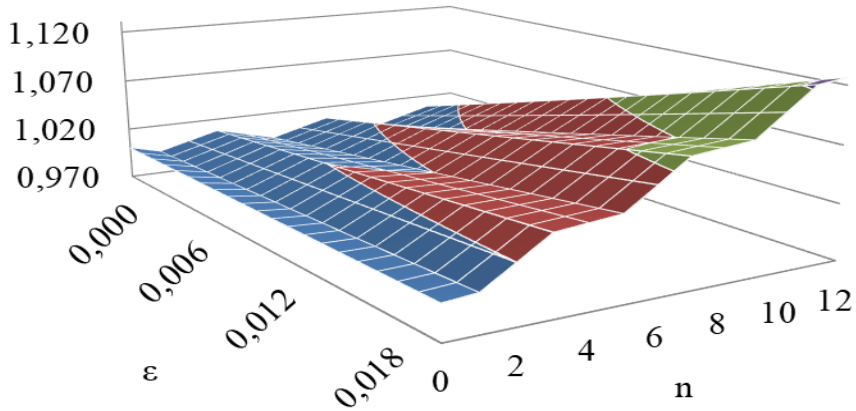

Fig. 3 Sensitivity of deviation of the order quantity to the gradual increase in the order fulfillment costs (ε) in periods *n* at insignificant demand fluctuation amplitude

Fig. 4 shows the dependence of deviation of the order quantity on the amplitude of demand fluctuations at an insignificant increase in the order fulfillment costs. To

build a graph, fix ε=0.01 (growth rates for the order fulfillment are 1 %) and change β, i.e. the amplitude of demand fluctuations from 0 to 0.2. Thus, Fig. 3, 4 make it possible to visually assess the nature of the dependence of deviation of the «perturbed» order quantity from the optimal one calculated from Wilson's formula.

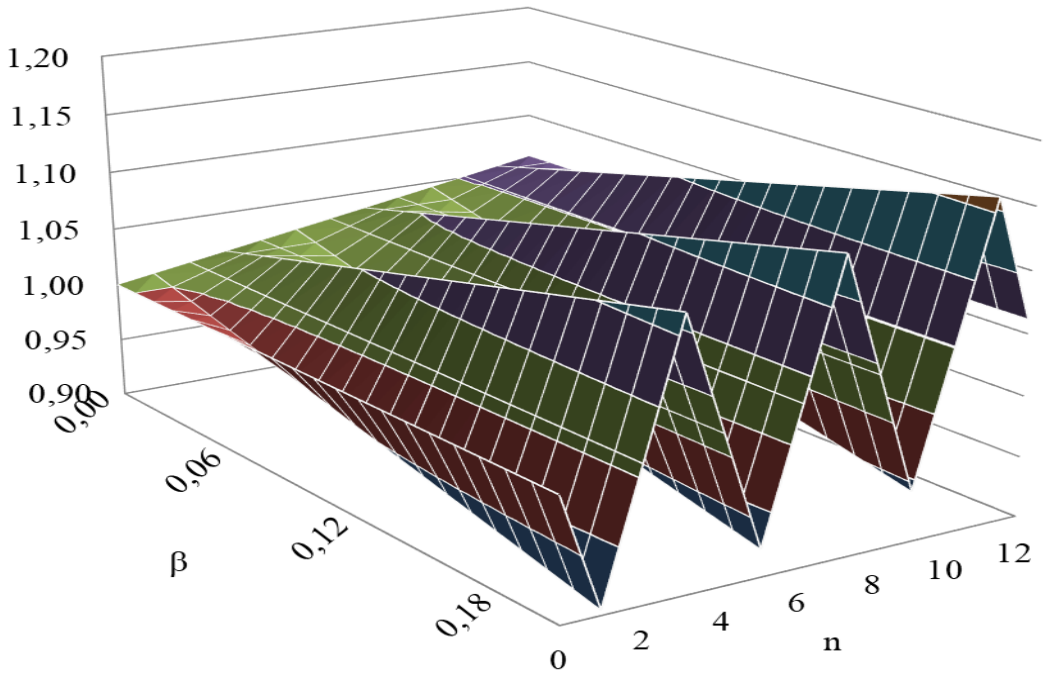

Fig. 4 Sensitivity of deviation of the order quantity to the amplitude of demand fluctuations (β) at a slight increase in the order fulfillment costs in periods *n*

The proposed asymptotic approach to the development of the inventory management model using perturbation methods makes it possible to find a solution to the problem in a small range of the input parameter variation. This significantly expands the field of application of the EOQ model. A small parameter in the problem of finding the optimal order size can be understood as the percentage rate of growth of the storage and order fulfillment costs, the amplitude of demand fluctuations, and other factors.

In this study, the range from 0 to 0.025 (that is, 0–2.5 %) was adopted as the range of variation of the small parameter ε which characterizes rates of growth of the order fulfillment costs.

The derived formulas of the EOQ model contain parameters *n* that characterizes the intervals of changes in the order fulfillment costs.

The solution of the EOQ problem under the condition of growing costs of order fulfillment and periodic fluctuations in demand for the proposed products was obtained in the form of formula (3). The nature of the dependence of deviation of the order quantity on the increase in the order fulfillment costs at minor demand fluctuations is shown in Fig. 3. Changes in the optimal order quantity from −1 % to +12 % occur with an increase in the order fulfillment costs. Dependence of deviation of the perturbed order quantity on the amplitude of the demand fluctuations with increasing costs of the order fulfillment (Fig. 4) is multidirectional. The nature of changes depends on the period. For example, the minimum order quantities were in periods 1, 5, 9 and maximum order quantities were in periods 3, 7, 11. The order quantity varied from −10 % to +15 %.

However, the use of selected forms of functional dependence of the order fulfillment costs as well as demand for the company's products is a limitation inherent in this study.

In contrast to [4–7], the proposed method of «perturbations» applied to the model of inventory management is the development of analytical tools for procurement management and inventory logistics. In particular, the proposed asymptotic formulas make it possible to model the inventory management system of the enterprise under the condition of variable order fulfillment and inventory storage costs, as well as take into account fluctuations in demand for goods and services offered by the company in the market. The available user-friendly model that takes into account changes in demand and costs makes it possible to introduce timely adjustments to the procurement process of the enterprise, minimize overall costs and improve the company's competitiveness in the market.

Conclusion. A two-parameter model was obtained taking into account the discrete increase in the order fulfillment costs and the periodic nature of fluctuation of demand for the proposed products under the condition of minor expenditure changes. It contains two small parameters characterizing the percentage change in the

order fulfillment costs and the amplitude of fluctuations in the demand for products. The sensitivity of deviation of the perturbed order quantity from the optimal one at a gradual increase in the order fulfillment costs depending on the period with minor demand fluctuations was from −2 % to +13 %. Percentage deviation of the order quantity from the optimal one depending on the amplitude of demand fluctuations and the period *n* at a fixed rate of growth of the order fulfillment costs was from −1 % to +6.5 %. According to the study results, the rate of growth of the order fulfillment costs has a greater impact on the optimal order size than the amplitude of fluctuations in the demand for products which are small parameters of the constructed model. This model is of practical importance for the company's management because, in addition to changes in the order fulfillment costs, demand for the company's products may also fluctuate because of the changes in various internal and external factors.

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2.6 Optimization of logistics business processes by perturbation methods

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The current economic situation is characterized by an aggravation of the global crisis phenomena caused by various factors including the pandemic consequences. It affects many countries and leads to the loss of productive capacity and opportunities for the development of both the global and local economies caused by breakage of existing logistic links, disturbance of transport corridors, and fall of consumption and production.

Production potential of a modern enterprise depends on available fixed and circulating assets and other factors. Because of long-term work in conditions of quarantine and economic constraints, circulating assets of enterprises and organizations decreased and fell to a critical minimum in some cases. The companies planning to continue their activities are forced to look for opportunities to resume financing of circulating assets. In conditions when external borrowings are limited in the number and interest rates, own financial assets of enterprises are the most available sources.

Companies face a problem of optimizing the use of circulating assets which is possible, in particular, by improving their inventory management system and

logistics. This necessitates that managers applied new approaches and methods of material flow management. Such methods make it possible to consider the management of material resources as a part of the basic strategic priorities of the company development and application of corresponding modern and effective software. This ensures quick analysis of available material resources coordinating them with the needs of consumers and peculiarities of interaction with suppliers.

The use of asymptotic methods to solve applied economic problems in the field of logistics will allow the company's management to obtain clear and simple analytical calculation formulas. These formulas will provide an opportunity to optimize the company’s overall logistics costs and improve the competitiveness of the companies that will use them.

Of the recently published studies of asymptotic methods, it is necessary to note the study [1] in which asymptotic ideas and methods are presented at a level understood by many readers. The main ideas of asymptotic approaches were stated and peculiarities of their application in various fields investigated. An overview of the perturbation theory methods for solving differential equations describing problems of applied physics and mechanics was given and the advantages of these methods and fields of their application were discussed in [2].

The study [3] is devoted to the definition of the essence of the perturbation methods which consists in the fact that the problem solution is sought in a form of serial expansion by the small parameter powers. This parameter appears in the model either naturally or is artificially entered for convenience. The method assumes that a corresponding asymptotic sequence which in the simplest and most common variant is taken as the power function of the small parameter ε^n is chosen for the study of an applied problem.

Perturbation methods are used:

– in mechanics of solid structures (for example, solution of the problem of stability of a circular cylindrical shell of variable thickness under axial compression was developed in [4] with the help of asymptotic approach; a variant derivation of the

changed Bress-Tymoshenko equations with the asymptotic approach was offered in [5]);

– in differential equations. For example, the perturbation method was applied in [6] to the problem of vibration of a piezoelectric sandwich plate taking into account the effect of shear force. A hybrid method based on a combination of analytical asymptotic WKB approach and numerical Galerkin method was used in [7].

Application of perturbation methods to the problems of mechanics of solid structures and differential equations is explained by the fact that they enable the construction of an approximate analytical solution and estimation of the system sensitivity to the changes in input parameters. These methods have not yet been used in applied economic studies because of their narrow specialization and predominant focusing on the study of the behavior of mechanical objects. However, the scope of these methods can be extended to the problems of optimizing economic processes and making managerial decisions. The analytical formulas obtained through the application of perturbation methods are convenient for enterprise managers and can also expand the scope of the economic models, in particular, the inventory management models.

Problems of inventory management were studied in [8–29]. Features of construction of deterministic single-product and multi-product models of procurement logistics which help managers in the decision-making process were studied in [8, 9]. However, input parameters of these models are considered constant which limits fields of their practical use.

An EOQ model of procurement logistics with the emergence of a shortage caused by the possibility of the presence of defective products in the ordered batch was developed in [10]. This model is limited in terms of accounting minor discrete changes in the order fulfillment costs. A dynamic model of procurement logistics with the emergence of a shortage in demand linearly depending on time was constructed in [11]. This model makes it possible to estimate optimal order quantity, order periodicity, and total costs under this assumption. However, it does not take

into account changes in the order fulfillment and inventory storage costs. Further source [12] concerns the study of the behavior of the model of purchasing perishable goods in the presence of inflation and possible delays in payments. The issue of possible payment delays was analyzed in [13] but the models did not take into account possible fluctuations in the demand for the proposed products. A model of inventory management under the condition of the demand fluctuation and inventory damage caused by suboptimal warehouse location, improper storage conditions, etc. was studied in [14]. In this case, the rate of inventor damage was distributed according to the Weibull function and the inventory maintaining cost was considered a discrete variable. The use of fixed costs for order fulfillment can be considered a disadvantage of this model. The EOQ models constructed in [15] for perishable products take into account possible deterioration of product quality, possible penalties presented in a form of exponential and linear functions. Further study [16] concerned the construction of an integrated inventory management model for one supplier and one customer with a reduction in order costs depending on the time of the order fulfillment but the variability of storage costs was not taken into account. Study [17] was also devoted to the improvement of the single-product model. The study considered peculiarities of the procedures of EOQ-optimization of the supply chain. Such procedures will take into account the feasibility of sharing several vehicles for each order and specifics of payment of the storage costs both in a form of rent and paying only for the occupied warehouse space. However, there are no analytical formulas convenient for application and further analysis by the company's management. Application of the asymptotic approach to determining the single-product order quantity under the condition of variable costs of order fulfillment was given in [18]. However, the cost of inventory storage was calculated taking into account the area occupied by the warehouse for a certain period, and the spatial dimensions of the product unit.

Some researchers consider variations of real situations in the company’s logistics management system, namely inflation, sudden rises and falls in demand, etc. and present their models of inventory management in an uncertain environment. For

example, a problem of determining economic order quantity (EOQ) for the case when input parameters are probabilistic and optimal probability distribution functions are calculated using a geometric programming model was studied in [19]. A stochastic problem of finding EOQ in a certain time interval was solved in [20]. However, the study was mainly theoretical in nature and did not focus on a practical application.

The study [21] was devoted to the development of an inventory management model that would optimize costs and order quantity taking certain non-deterministic parameters as fuzzy numbers. Demand and related costs are taken in the study [22] as fuzzy variables, and the Jaeger ranking method for fuzzy numbers was used to determine an optimal inventory management policy. However, the obtained models are difficult to apply in practice for want of convenient analytical formulas.

The study [23] has proposed a multi-product inventory management model for a double-level supply chain under the condition of incentive-sensitive demand marketing. In this case, the supplier offers the retailer an opportunity to delay the payment of the purchase price of finished products. Modeling of logistic processes at an enterprise in conditions of ordering a wide range of products from one supplier using asymptotic methods was proposed in [24]. Under the conditions of variable supply costs, a model was obtained that makes it possible to adapt the enterprise's logistic system to the existing business conditions. However, insufficient attention was paid to determining optimal order quantity under conditions of the variability of solely order fulfillment costs. Further development of the asymptotic approach to multi-item supply was given in [25] which takes into account changes in the storage costs but at a constant demand for the proposed products.

A model of inventory management at the retail level in a system with reverse logistics which allows the company to maximize profits taking into account volumes of supplies and their timing was considered in [26]. However, the proposed model takes into account price variability and not the variability of other input parameters.

Most studies do not take into account transport costs in the analysis of the EOQ or consider the transport costs as a constant part of the order cost which is taken into account in [27] but researchers use an iterative method difficult in application.

A model taking into account limited resources for storage of products, namely allocation of space in refrigeration equipment in retailing is another modification of the EOQ model [28]. This implies the presence of additional costs to maintain a certain storage temperature but the results do not take into account changes in the order fulfillment and inventory storage costs.

Some researchers [29] address the problems of developing analytical tools to determine EOQ but these tools are imperfect and need further study.

The optimization methods analyzed in the known studies can effectively solve the problems of inventory management but they are often incomprehensible to practicing managers because of their high complexity (the use of iterative processes in calculations, complicated mathematical apparatus, etc.). Both researchers and managers find it more convenient to use analytical models that describe the object behavior according to clear formulas and taking into account variability of order fulfillment and inventory storage costs as well as fluctuation of demand for the proposed products.

The study objective is to optimize the inventory management model under conditions of minor changes in input parameters with the application of perturbation methods. This will expand the scope of this model application in practice.

To achieve this objective, the following tasks were set:

– to obtain an asymptotic formula of the EOQ model with an insignificant discrete increase in the order fulfillment costs;

– to obtain an analytical formula for the EOQ model at variable costs of order fulfillment and inventory storage which depend on the «small parameter»;

The economic order quantity model (the EOQ model) or Wilson's formula used to estimate the order quantity can be presented as follows [4]:

$$q_{opt} = \sqrt{\frac{2C_0 S}{h}}, \quad (1)$$

where q_{opt} is the EOQ; C_0 is the cost of the fulfillment of one order, S is the amount of demand in a certain period of time; h is the cost of storage of a product unit for a certain period of time.

The cost of delivery is one of the main components of the order fulfillment costs which is constantly rising because of rising fuel prices. Assuming that the order costs increase by *i* % during a certain period of time (for example, each month), then it will reach $C_0 \cdot \left(1+\frac{i\,\%}{100\,\%}\right)^n$. after *n* periods of time. Taking the ratio $\varepsilon = \frac{i\,\%}{100\,\%}$ (ε<<1) for a small parameter, the order cost is obtained in this form: $C_0 \cdot (1+\varepsilon)^n$. Since the ε parameter is the small parameter, we can assume that deviation from the initial value of C_0 is insignificant and the condition of constant order fulfillment costs is satisfied.

The «perturbed» EOQ, q^*_{opt}, can be represented as an asymptotic expansion of the artificially introduced small parameter ε:

$$q^*_{opt} = q_0 + q_1 \cdot \varepsilon + q_2 \cdot \varepsilon^2 + \ldots . \tag{2}$$

Formulas for determining the order quantity take the form (3):

$$q_0 + q_1 \cdot \varepsilon + q_2 \cdot \varepsilon^2 + \ldots = \sqrt{\frac{2C_0(1+\varepsilon)^n S}{h}}. \tag{3}$$

When squaring both parts of equation (3), series expansion in the Taylor row $(1+\varepsilon)^n$ and neglecting the members of order ε^3 and more, we have:

$$\begin{aligned} &\left(q_0 + q_1 \cdot \varepsilon + q_2 \cdot \varepsilon^2 + \ldots\right)^2 = \\ &= \frac{2C_0 S}{h}\left(1 + n \cdot \varepsilon + \frac{n \cdot (n-1)}{2} \cdot \varepsilon^2 + \ldots\right), \end{aligned} \tag{4}$$

$$\begin{aligned} &q_0^{\,2} + 2q_0 \cdot q_1 \cdot \varepsilon + q_1^{\,2} \cdot \varepsilon^2 + 2q_0 \cdot q_2 \cdot \varepsilon^2 + \ldots = \\ &= \frac{2C_0 S}{h}\left(1 + n \cdot \varepsilon + \frac{n \cdot (n-1)}{2} \cdot \varepsilon^2 + \ldots\right). \end{aligned} \tag{5}$$

By equating the coefficients at the same powers of the parameter ε, the equation for determining the unknown q_0, q_1, q_2 is obtained:

$$\varepsilon^0 : q_0^{\,2} = \frac{2C_0 S}{h}, \tag{6}$$

$$\varepsilon^1 : q_0 \cdot q_1 = \frac{C_0 S}{h} \cdot n, \tag{7}$$

$$\varepsilon^2 : q_1^{\,2} + 2q_0 \cdot q_2 = \frac{C_0 S}{h} \cdot n \cdot (n-1). \tag{8}$$

The solution to equations (6) to (8) gives:

$$q_0 = \sqrt{\frac{2C_0S}{h}},\ \ q_1 = \frac{n}{2}\cdot\sqrt{\frac{2C_0S}{h}},\ q_2 = \frac{n\cdot(n-2)}{8}\cdot\sqrt{\frac{2C_0S}{h}}. \tag{9}$$

To obtain an asymptotic representation of formula (1), the found values (9) are to be substituted into expansion (2). As a result, formula (10) is obtained.

$$q^*_{opt} = \sqrt{\frac{2C_0S}{h}}\cdot\left(1+\frac{n}{2}\cdot\varepsilon+\frac{n\cdot(n-2)}{8}\cdot\varepsilon^2\right). \tag{10}$$

As can be seen from formula (10), the «perturbed» order quantity differs from that obtained from Wilson's formula (1) by a multiplier

$$\left(1+\frac{n}{2}\cdot\varepsilon+\frac{n\cdot(n-2)}{8}\cdot\varepsilon^2\right).$$

The total company's costs under the condition of an insignificant discrete increase in the cost of order fulfillment are as follows:

$$\begin{aligned} TC\left(q_{opt}\right) &= \frac{C_0(1+\varepsilon)^n S}{q_{opt}} + \frac{hq_{opt}}{2} = \\ &= \sqrt{\frac{C_0Sh}{2}}\cdot\left(2+n\cdot\varepsilon+\frac{n\cdot(n-1)}{2}\cdot\varepsilon^2\right), \end{aligned} \tag{11}$$

$$\begin{aligned} TC^*\left(q^*_{opt}\right) &= \frac{C_0(1+\varepsilon)^n S}{q^*_{opt}} + \frac{hq^*_{opt}}{2} = \\ &= \sqrt{\frac{C_0Sh}{2}}\cdot\left(2+n\cdot\varepsilon+\frac{n\cdot(n-2)}{4}\cdot\varepsilon^2\right). \end{aligned} \tag{12}$$

As can be seen from the obtained formulas, the total costs corresponding to the economic (1) and «perturbed» order quantities (10) at a slight increase in the order fulfillment costs reach a minimum at q which corresponds to (10).

Let us analyze the sensitivity of the obtained model of determining the EOQ to a change of input parameters, namely the order fulfillment costs. Calculate the relative deviation of the optimal batch volume at variable order fulfillment costs by varying the ε parameter. The percentage deviation of the «perturbed» order quantity from the economic one calculated according to formula (10) is presented in Fig. 1.

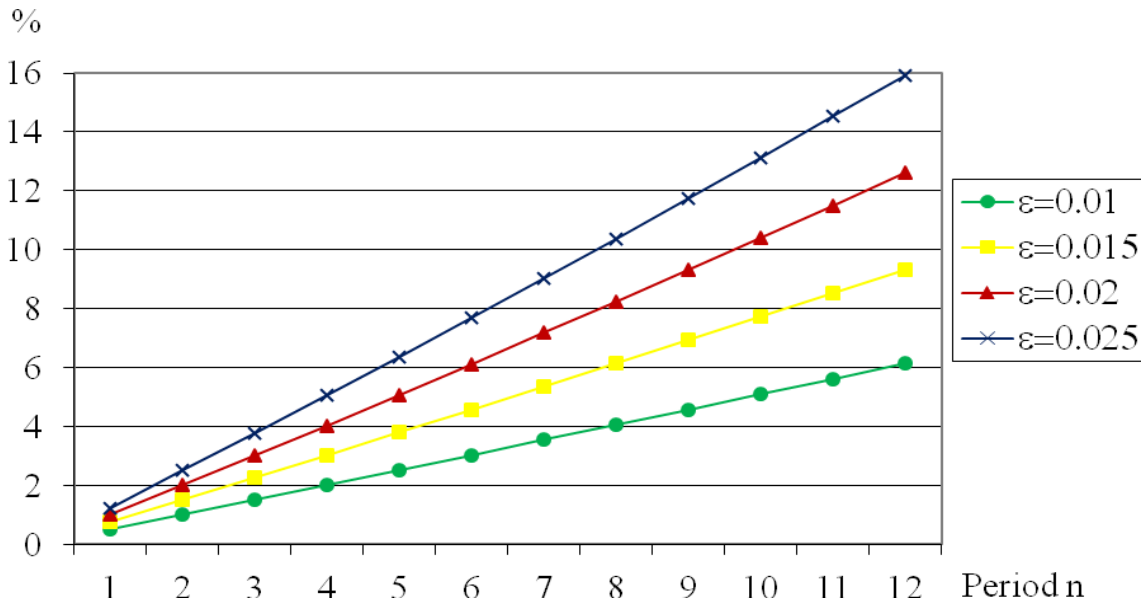

Fig. 1 Deviation (%) of the «perturbed» order quantity from Wilson's formula under the condition of increase in the order fulfillment costs in periods *n*

Let us consider the cases when there is an increase in the order fulfillment costs by 1 % (ε=0.01), 1.5 % (ε=0.015), 2 % (ε=0.02) and 2.5 % (ε=0.025) in each period. As can be seen in Fig. 1, a gradual increase in the order costs by 1 % (ε=0.01) leads to an increase in the order quantity by 3.03 % and 6.15 % in periods 6 and 12, respectively. If the order cost gradually increases with each period, for example, by 2.5 % (ε=0.025), the value of deviation is 7.69 % in period 6 and 15.94 % in period 12.

Let us test the constructed model for optimization of the inventory management model under the condition of insignificant changes in input parameters on an example of the purchase of coffee and tea by an enterprise working in the HoReCa segment. The initial data and calculation of the model parameters are given in Table 1. The optimal order quantity was calculated from Wilson's formula (1). The perturbed order quantity was determined under the condition of increasing the order fulfillment costs at ε=0.025 using formula (10). Values of the perturbed order quantity q_{opt}^{*} at the end of the year, i.e. *n*=12 are given in Table 1. As can be seen, the

absolute deviation of the order quantity at the end of the period is 43 packs (15.93%) for tea and 12 packs (15.58%) for coffee.

Table 1 Initial data and results of the calculation of coffee and tea delivery

Product type	Annual demand S, q_{opt} packs	Storage costs, h, mon. un.	Order fulfillment costs, C_0, mon. un.	Order quantity, packs.		Total costs, mon.un.	
				q_{opt}	q^*_{opt}	TC	TC^*
Tea (10 filter packs)	700	1.0	52	270	313	315.9	312.8
Coffee-beans (1 kg)	240	4.5	56	77	89	407.1	403.2

Comparative analysis of total costs calculated from formulas (11), (12) makes it possible to note that the costs corresponding to the perturbed order quantity are less than the costs corresponding to the order quantity calculated by Wilson's formula (1).

In practice, not only the order fulfillment costs but also the inventory storage costs increase because of rising expenses (for example, rising prices for electricity, utilities, etc.). Let us assume that the storage costs increase with each period of time by j%. Taking the value $\beta = \frac{j\%}{100\%}$ ($\beta << 1$) as the small parameter, dependence of the storage costs is obtained in the form: $h \cdot (1+\beta)^m$.

A change in the delivery costs as one of the main components in the structure of order fulfillment costs and rising utility prices which, accordingly, increase storage costs, often occur in various time periods. Thus, due to various reasons, prices for resources and materials increase and this is reflected in the transport tariffs.

It is advisable to take into account various combinations of values of n and m, ε and β parameters in the EOQ model taking into account the fact that the interval m of changes in storage costs is usually smaller than the interval n of changes in the order fulfillment cost. The β parameter which characterizes an increase in the storage costs may exceed the value of the parameter ε which characterizes the increasing costs of order fulfillment.

If the change in the storage costs is delayed compared to the change in the order fulfillment costs, the relationship between parameters n and m can be

expressed, e.g. by putting $m=\left[\frac{n}{4}\right]$, $m=\left[\frac{n}{6}\right]$, etc., where [$n$] means an integer part of the number. Because of small values of the parameters ε and β, assume that deviations from the initial values of C_0 and h are small and the requirements occurring in the model (1) are satisfied.

By representing q^*_{opt} as an asymptotic expansion by two small parameters ε and β and neglecting members of the order of ε^3, β^3, $\varepsilon^2\beta$, $\varepsilon\beta^2$ and above, formula (13) is obtained:

$$\begin{aligned} q^*_{opt} &= q_0 + q_1 \cdot \varepsilon + q_2 \cdot \beta + \\ &+ q_3 \cdot \varepsilon^2 + q_4 \cdot \varepsilon \cdot \beta + q_5 \cdot \beta^2 + \dots . \end{aligned} \tag{13}$$

When decomposing the functions $(1+\varepsilon)^{\frac{n}{2}}$ and $(1+\beta)^{-\left(\frac{m}{2}\right)}$ into a Taylor series, asymptotic formulas for two parameters ε and β for the «perturbed» order quantity take the following form (14):

$$q^*_{opt} = \sqrt{\frac{2C_0S}{h}} \cdot \left(\begin{array}{l} 1 + \frac{n}{2} \cdot \varepsilon - \frac{m}{2}\beta + \frac{n \cdot (n-2)}{8} \cdot \varepsilon^2 - \\ -\frac{m \cdot n}{4} \varepsilon \cdot \beta + \frac{m \cdot (m+2)}{8} \beta^2 \end{array} \right). \tag{14}$$

Total costs TC at a condition of insignificant increase in the order fulfillment and inventory storage costs for the economic (1) and «perturbed» order quantity (14) are obtained in the form:

$$TC\left(q_{opt}\right) = \sqrt{\frac{C_0Sh}{2}} \times \left(\Omega + \frac{1}{2}\left(n \cdot \varepsilon - m \cdot \beta\right)^2 \right), \tag{15}$$

$$TC^*\left(q^*_{opt}\right) = \sqrt{\frac{C_0Sh}{2}} \times \left(\Omega + \frac{1}{4}\left(n \cdot \varepsilon - m \cdot \beta\right)^2 \right), \tag{16}$$

where

$$\Omega = \left(2 + n \cdot \varepsilon + m \cdot \beta - \frac{n}{2} \cdot \varepsilon^2 - \frac{m}{2} \cdot \beta^2 + m \cdot n \cdot \varepsilon \cdot \beta \right).$$

It can be seen that the total costs TC (16) corresponding to the «perturbed» order quantity is less than (15) which corresponds to the economic quantity.

To analyze the sensitivity of the order quantity to the change in the cost of order fulfillment and the cost of inventory storage, the ratio of the «perturbed» order

quantity (14) to the optimal one (1) was calculated. Different values of input parameters ε, β and different intervals of cost changes *n* and *m* were used.

Percentage deviation of the «perturbed» order quantity from the value of economic order quantity (1) provided that the cost of the order fulfillment is fixed (ε=0.0) is shown in Fig. 2.

As can be seen in Fig. 2, a gradual increase in the storage costs by 5 % (β=0.05) in periods *n*=4, *n*=8 results in a decrease in the order quantity by 2.41 %, 4.75 %, respectively. If the storage costs change significantly, for example, increases by 20% (β=0.2) each quarter (periods *n*=4, *n*=8, and *n*=12), the order quantity decreases by 8.5 %, 16 %, and 22.5 % respectively.

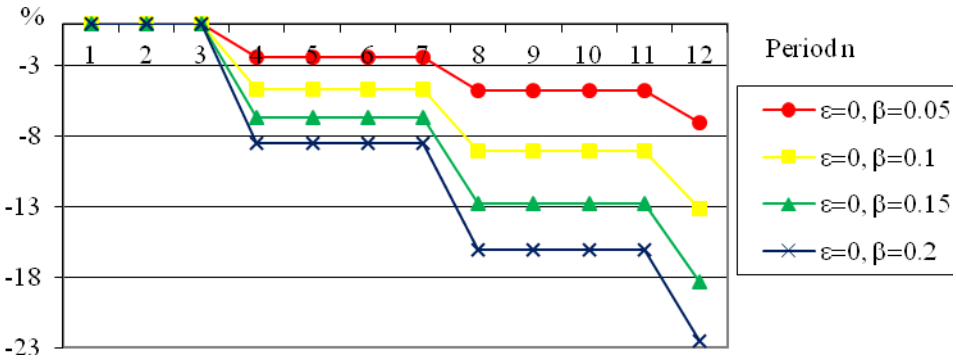

Fig. 2 Deviation (%) of the «perturbed» order quantity from the economic one depending on the period *n* provided that the costs of the order fulfillment are fixed, $\left(\varepsilon = 0,\ m = \left[\frac{n}{4}\right]\right)$

The ratio of the «perturbed» order quantity (14) to the economic one (1) and the percentage deviation provided that the order fulfillment costs and the of storage costs undergo minor changes are given in Table. 2.

Data in Table 2 show that an increase in storage costs every 4 months leads to a significant reduction in the «perturbed» order quantity compared to the economic one. For example, when *n*=4 and *m*=1 at ε=0.01, β=0.1, the order quantity decreases by 2.7 %; when ε=0.01, β=0.2, there is a decrease in the order quantity by 6.7 %. In the next period, *n*=8 and *m*=2 at ε=0.01, β= 0.1, the order quantity decreases by 5.3 %; and at ε=0.01, β=0.2, the order quantity decreases by 12.7%. The changes in costs that occur within one specified period (4 months) *m*=1 and a further increase in the

costs of order fulfillment (*n* varies from 4 to 7) lead to a gradual decrease in deviation from the undisturbed value.

Table 2 The ratio of «perturbed» order quantity to the economic one, subject to changes in the order fulfillment costs and the storage costs

Period		ε=0.01, β=0.1		ε=0.01, β=0.2		ε=0.02, β=0.2	
N	*m*	$\frac{q^*_{opt}}{q_{opt}}$	%	$\frac{q^*_{opt}}{q_{opt}}$	%	$\frac{q^*_{opt}}{q_{opt}}$	%
0	0	1.0	0	0	0	1.0	0
1	0	1.005	+0.5	1.005	+0.5	1.010	+1.0
2	0	1.010	+1.0	1.010	+1.0	1.020	+2.0
3	0	1.015	+1.5	1.015	+1.5	1.030	+3.0
4	1	0.973	–2.7	0.933	–6.7	0.951	–4.9
5	1	0.978	–2.2	0.938	–6.2	0.961	–3.9
6	1	0.983	–1.7	0.942	–5.8	0.970	–3.0
7	1	0.987	–1.3	0.947	–5.3	0.980	–2.0
8	2	0.947	–5.3	0.873	–12.7	0.906	–9.4
9	2	0.951	–4.9	0.877	–12.3	0.915	–8.5
10	2	0.956	–4.4	0.881	–11.9	0.924	–7.6
11	2	0.961	–3.9	0.885	–11.5	0.933	–6.7
12	3	0.921	–7.9	0.819	–18.1	0.865	–13.5

Let us consider, for example, a situation when *n*=4, and *m*=1 at a constant percentage increase in the storage costs (β=0.2) and a percentage increase in the order fulfillment costs (from ε=0.01 to ε=0.02). Deviation of the «perturbed» order quantities from those calculated by formula (1) decreases from −6.7 % to −4.9 % and from −12.7 % to −9.4 % at *n*=8 and *m*=2.

Table 3 shows the sensitivity of the «perturbed» order quantity to the economic one depending on the rate of growth of the storage costs. The change in costs occurs once every 3 periods in the first case $\left(m=\left[n/3\right]\right)$, and once every 4 periods in the second case $\left(m=\left[n/4\right]\right)$.

As can be seen from Table 3, dynamics and interval of increase in the storage tariff rate affects the order quantity. For example, the deviation of the order quantity is −6.3 % at *n*=6, ε=0.01, and β=0.1 if storage costs change every 3 periods and −1.7

% when storage costs change every 4 periods. At n=6, ε=0.01 and β=0.2, these changes are more significant, namely −13.6 % and −5.8 %, respectively.

Table 3 Sensitivity of the «perturbed» order quantity to the storage costs

Period		ε=0.01, β=0.1	ε=0.01, β=0.2	Period		ε=0.01, β=0.1	ε=0.01, β=0.2
n	m	$\frac{q^*_{opt}}{q_{opt}}$	$\frac{q^*_{opt}}{q_{opt}}$	n	m	$\frac{q^*_{opt}}{q_{opt}}$	$\frac{q^*_{opt}}{q_{opt}}$
0	0	1.0	1.0	0	0	1.0	1.0
1	0	1.005	1.005	1	0	1.005	1.005
2	0	1.010	1.010	2	0	1.010	1.010
3	1	0.968	0.929	3	0	1.015	1.015
4	1	0.973	0.933	4	1	0.973	0.933
5	1	0.978	0.938	5	1	0.978	0.938
6	2	0.937	0.864	6	1	0.983	0.942
7	2	0.942	0.868	7	1	0.987	0.947
8	2	0.947	0.873	8	2	0.947	0.873
9	3	0.908	0.807	9	2	0.951	0.877
10	3	0.912	0.811	10	2	0.956	0.881
11	3	0.917	0.815	11	2	0.961	0.885
12	4	0.880	0.758	12	3	0.921	0.819

Dependence of the ratio of «perturbed» order quantity to the optimal one on parameters ε and β at n=4 is shown in Fig. 3.

Fig. 3 shows the nature of deviation of the «perturbed» order quantity from the economic one under different conditions of gradual increase in the order fulfillment and inventory storage costs.

By modeling the nature of changes in the order fulfillment costs and utility tariffs in a short term, managers can make appropriate adjustments to the organization of the company's procurement by determining the order quantity by means of an asymptotic formula (14).

The proposed asymptotic approach to the development of the inventory management model using perturbation methods makes it possible to find a solution to the problem in a small range of the input parameter variation. This significantly expands the field of application of the EOQ model. A small parameter in the problem

of finding the optimal order size can be understood as the percentage rate of growth of the storage and order fulfillment costs, the amplitude of demand fluctuations, and other factors.

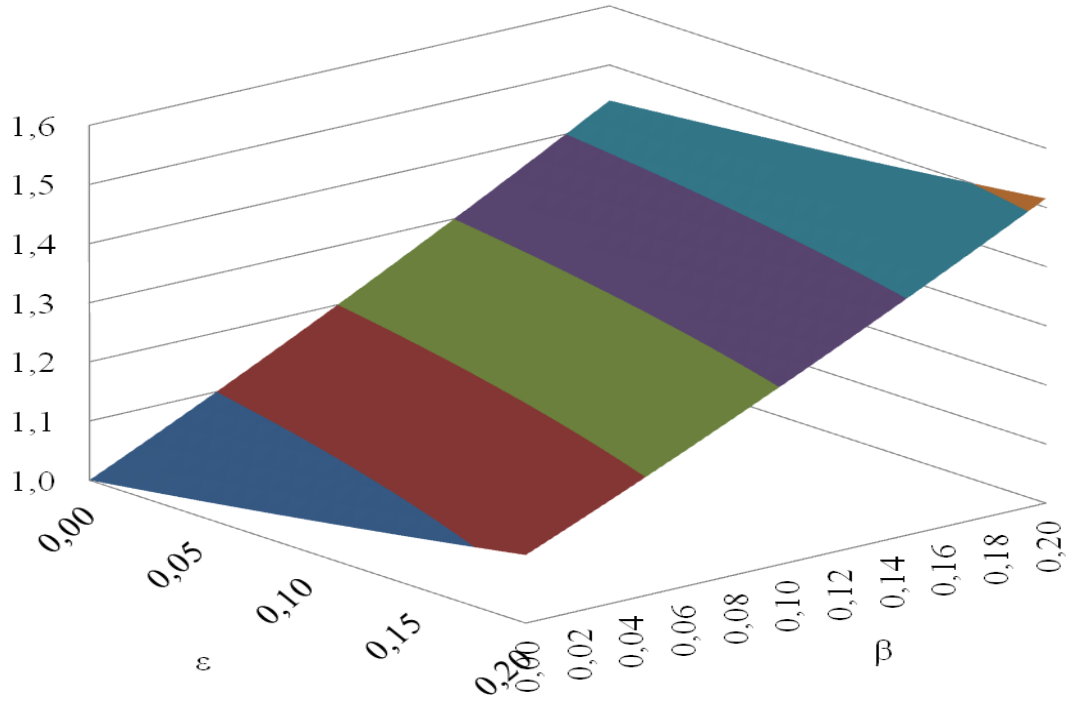

Fig. 3 Dependence of the ratio of «perturbed» order quantity to the optimal one on the parameters ε and β

In this study, the range from 0 to 0.025 (that is, 0–2.5 %) was adopted as the range of variation of the small parameter ε which characterizes rates of growth of the order fulfillment costs. The range from 0 to 0.2 (that is, 0–20 %) was chosen as the range of variation of the parameter β which determines the rate of growth of the storage costs. Such values of parameters are determined by the specificity of each of them. The parameter β takes values larger than the parameter ε due to a significant increase in utility costs (water, electricity, heating, etc.). However, since members of the order of smallness greater than ε^2 and β^2 were neglected during the model construction, the calculation error is insignificant from the economic point of view.

The derived formulas of the EOQ model contain parameters *n* and *m* which describe the dependence of the inventory storage and order fulfillment costs. They

characterize the intervals of changes in the inventory storage costs (m) and changes in the order fulfillment costs (n). In practice, the change in the storage costs is delayed compared to the change in the order fulfillment costs, so the relationship between parameters n and m can be expressed using a mathematical function of the integer part of the number $y=[x]$.

Analytical solution of the problem of determining the EOQ under the condition of a discrete increase in the order fulfillment costs was obtained in the form of a one-parameter formula (10). According to it, formula (12) was derived for calculating the total costs of the order fulfillment and the inventory storage. The application of formula (10) instead of Wilson's formula (1) reduces the company's overall costs (12). Evaluation of the sensitivity of the EOQ model has shown that the relative deviation of the optimal order quantity (Fig. 1) at insignificant changes of the order fulfillment costs varied from 1 % to 15 % depending on the period.

An asymptotic solution of the problem of determining the EOQ under the condition of variation of the order fulfillment and inventory storage costs was obtained using the perturbation method in the form of a two-parameter formula (14) which reduces total costs (16) of the company in this case. The study of the sensitivity of the order quantity to the changes in the order fulfillment and the inventory storage costs (Fig. 2, 3) has found that it depends on the periods of change in the input parameters and the percentage change in the corresponding costs. Calculation of deviation of the order quantity according to formula (14) relative to Wilson's formula (1) (Tables 2, 3) at different values of input parameters has shown a multidirectional dynamics. For example, the deviation can range from +3 % to −16 % for respective periods.

The obtained one-parameter and two-parameter solutions of the EOQ model are of practical significance as analytical asymptotic formulas are convenient for analysis and use by company managers. They can be used in further studies provided that the nature of cost variation changes.

The total costs corresponding to the order quantity obtained from the asymptotic formulas in this paper did not differ significantly from those that

correspond to the order quantity of the classical EOQ model. However, cost reduction can be significant in the scale of general enterprise procurement.

The prospects for further studies are connected with the adaptation of the method of «perturbations» to other logistics models in which the small parameters having economic significance can be identified. In addition, it is advisable to develop analytical asymptotic models for managing logistic processes in the case of variable input parameters of the system. In particular, the method of «perturbations» can be applied to the construction of a model of multi-item deliveries under the condition of variable system parameters.

Conclusion. Based on the method of perturbations, an asymptotic formula was derived to determine economic order quantity on conditions that there is a small discrete increase in order fulfillment costs. This formula contains a small parameter that characterizes variation of the order fulfillment costs depending on periods. It is easy to use and it enables obtaining refined values of the order quantities and total costs which allows the company's management to optimize logistic processes. Deviation of the disturbed order quantities was in the range from 1 % to 15 % depending on the period. Comparative analysis of total costs calculated using the Wilson formula and the asymptotic formula has made it possible to state that taking into account changes in order quantities corresponding to the perturbed order quantity leads to a decrease in total logistic expenditures of the company.

A two-parameter inventory management model was constructed. It takes into account both minor changes in order fulfillment and inventory storage costs. Asymptotic formulas with two small parameters were derived to determine the optimal order quantity and total costs corresponding to the order quantity determined by Wilson's formula (1) and the perturbed quantity. The study of the nature of deviation of the «perturbed» order quantity from the economic one under different conditions of gradual increase in the order fulfillment and the inventory storage costs has shown that it is mostly linear due to the small input parameters of the model. Deviation of the disturbed order quantities was in a range from +3 % to −16 % for the corresponding periods.

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2.7 Prognostic model of industry sustainable development (the example of coal mining)

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Total resources of coal in Ukraine are 112,3 billion tonnes, proved coal reserves – 51,9 billion tonnes, including 17,1 billion tonnes of coking coal (30,5 %) and 7,6 billion tonnes of anthracite (13,5 %). Reserves of coking coal and anthracite amount to 31,5 % and 14,3 % of total resources of coal in Ukraine. However, there is a need to develop system of rational treatment for this important mineral. Coal industry is one of the basic sectors of the national economy. It is also the key to the national energy security. Armed hostilities in the East of Ukraine which began in 2014 led to the destruction of the infrastructure, damage and destruction of coal mines, so domestic coal sector is in the clutch. Today, the coal deficit in Ukraine, offset by forced imports, is 27%. That is why there is a need to build system for managing national needs in coal under the condition of saving approach to its extraction and rational use.

We consider that it is possible to ensure rational use of Ukraine's coal resources by balancing mining, production of feed coal and its further use in the subsequent production processes. Coke is produced from coke coal, which is then used in metallurgical production. Anthracite is used by thermal power plants and thermal heating and power plants, as well as in the industrial production. It makes sence to set relations between coal mining and its use (consumption).

In order to be able to determine the optimal development of coal mining, it is possible to use a multifactor economic and mathematical model for predicting the development of complex systems. The model will be used for the following systems: 1) cast iron production; coking of coal and production of coke and semi-coke; 2)

thermal energy production; extraction of anthracite and other coal and production of anthracite (including loss of production).

In order to determine the optimal development of coal mining, it is possible to use a multifactor economic and mathematical model for predicting the development of complex systems. The model will be used for the following systems: 1) cast iron production; coking coal mining, and coke and semi-coke production; 2) thermal energy production; anthracite and other coal mining, and production of anthracite (including mining losses).

To describe the interdependent processes of cyclical development of the complex system`s mentioned elements, taking into account interconnections between them, system of differential equations will be applied:

$$\begin{cases} \frac{dN_1}{dt} = N_1(\varepsilon_1 + \gamma_1 N_2), \\ \frac{dN_2}{dt} = N_2(\varepsilon_2 + \gamma_2 N_1), \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ \frac{dN_i}{dt} = N_i(\varepsilon_i + \gamma_i N_{i-1}) \end{cases} \quad (1)$$

where i – number of subsystems in complex system; N – cast iron production; coking coal mining, coke and semi-coke production (1st model); thermal energy production; anthracite and other coal mining , anthracite production (2nd model); ε – increment rate of the listed values, if there is no correlation with other amounts (coefficient of proportionality, which demonstrates the ratio of mining growth rate $\frac{dN}{dt}$ to N), γ - need increment rate.

Taking into consideration that each model has three components, system (1) contains three equations. Further analysis and forecasting will apply the following indicators, namely basic growth rate (n) and mean value (K). Correlation between them is: $n = N/K$, $K = \varepsilon/\gamma$; $\varepsilon = \frac{\ln \frac{N}{N_0}}{t - t_0}$.

The model was verified on the basis of official statistics on coking coal, anthracite and other coal mining data disseminated by the State Scientific Geological Fund of Ukraine; on coke, semi-coke and anthracite production; cast iron and thermal

energy production data presented by the State Statistics Service of Ukraine («Statistical Yearbook of Ukraine»)

Figures 1-3 illustrate calculations` results for the 1st model: cast iron production, coking coal mining, coke and semi-coke production.

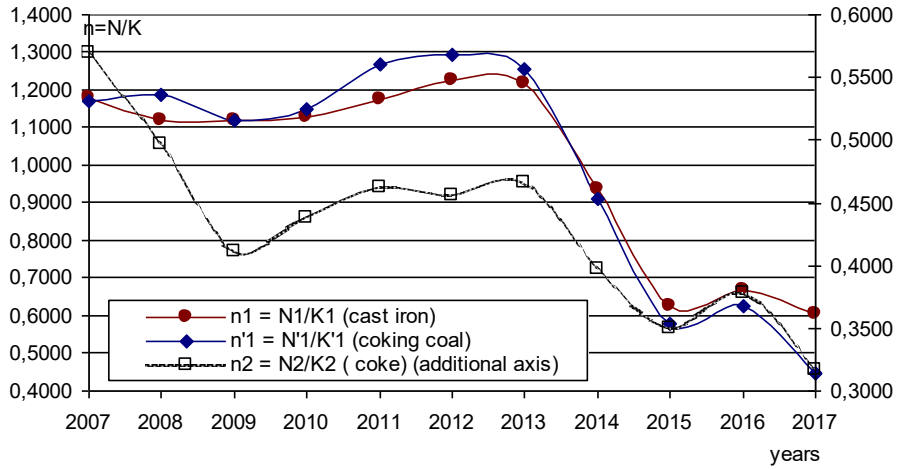

Fig. 1 Dynamics of basic cast iron production growth rates, coking coal mining, coke and semi-coke production during 2007-2017.

Fig.1 shows basic growth rates. Cast iron increment rates $\varepsilon_1(t)$, coking coal mining $\varepsilon'_1(t)$ coke and semi-coke production $\varepsilon_2(t)$. Dependencies of increment rates $\varepsilon_1(t)$, $\varepsilon'_1(t)$ i $\varepsilon_2(t)$ characterize each models` value autonomously (Fig. 2).

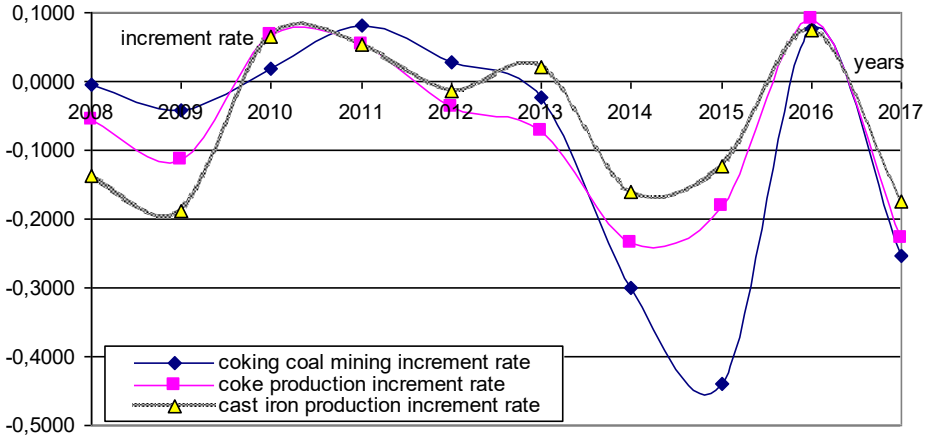

Fig. 2 Dynamics of increment rates of coking coal mining, coke and semi-coke production, cast iron production during 2007-2017 without correlation.

Solution of the system of equations (1) reveals the dependence of the increment rate of coking coal mining $\lambda_1'(t) = \varepsilon'_1(t) + \gamma'_1(t)\ N_2(t)$, coke and semi-coke production`s increment rate depending on coking coal mining $\lambda_2'(t) = \varepsilon'_2(t) + \gamma'_2(t)\ N_1(t)$, cast iron increment rate $\lambda_1(t) = \varepsilon_1(t) + \gamma_1(t)\ N_2(t)$, coke and semi-coke production`s increment rate depending on cast iron production $\lambda_2(t) = \varepsilon_2(t) + \gamma_2(t)\ N_1(t)$ if there is correlation between indices (Fig.3).

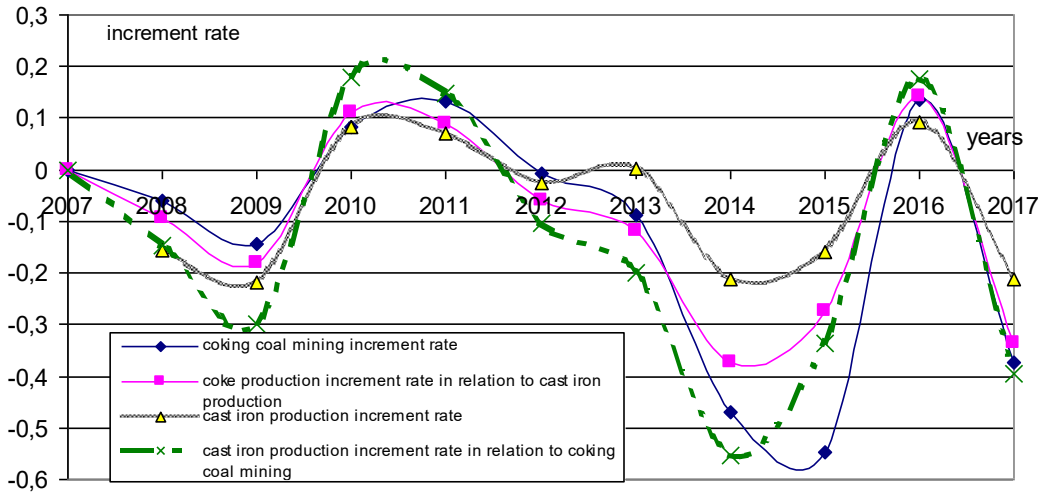

Fig. 3 Dynamics of increment rates of coking coal mining, cast iron production, coke and semi-coke production in relation to cast iron production and cast iron production in relation to coking coal mining during 2007-2017 with correlation.

Thus, the proposed model allows to forecast coking coal mining correlating to coke and semi-coke production and metallurgical industry demand (cast iron production), taking into account its cyclical development.

Figures 4-6 give information about calculations` results for the 2nd model: thermal energy production; anthracite and other coal mining, anthracite production.

Fig.4 illustrates basic growth rates. Fig.5 shows increment rates of thermal energy production $\varepsilon_1(t)$, anthracite and other coal mining $\varepsilon'_1(t)$ and anthracite production $\varepsilon_2(t)$. Dependencies of increment rates $\varepsilon_1(t)$, $\varepsilon'_1(t)$ і $\varepsilon_2(t)$ characterize each index`s dynamics autonomously.

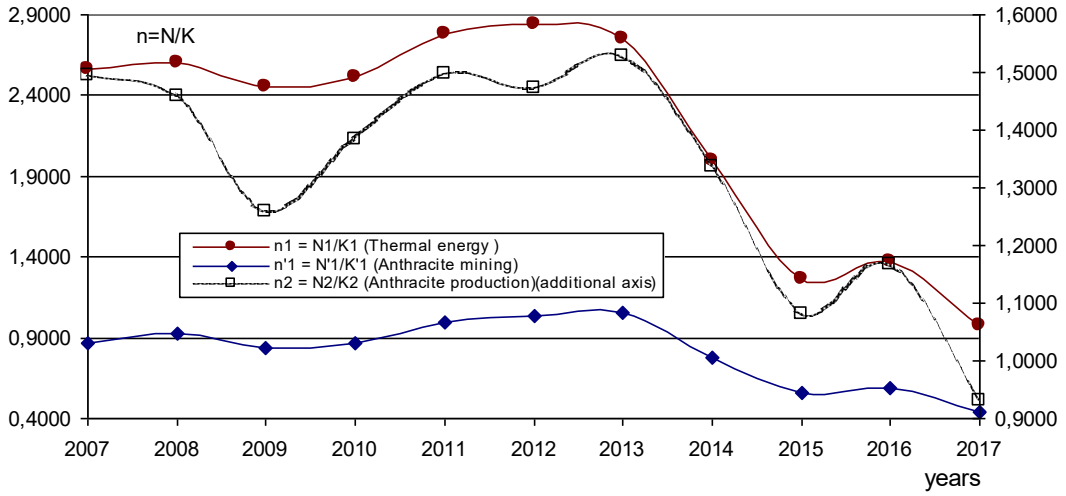

Fig. 4 Dynamics of basic thermal energy production growth rates, anthracite and other coal mining, anthracite production during 2007-2017

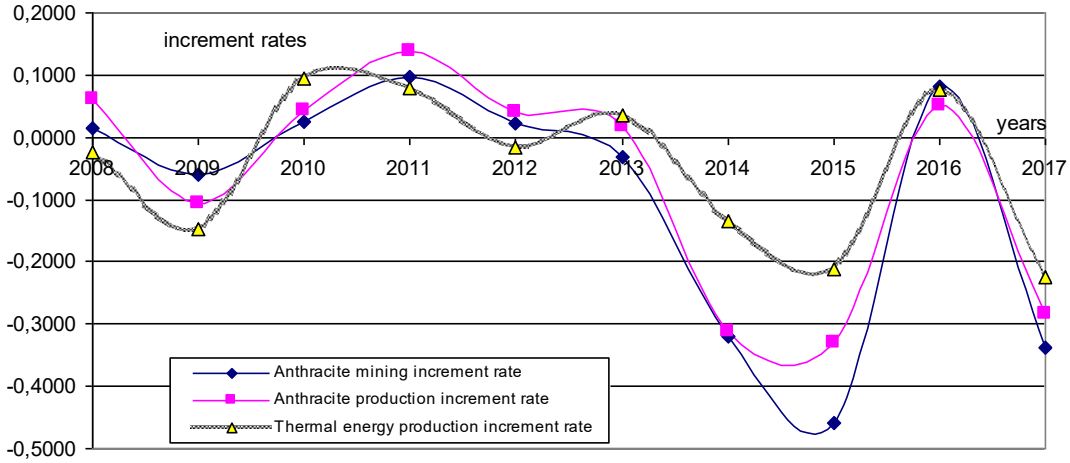

Fig. 5 Dynamics of increment rates of anthracite and other coal mining, production and thermal energy production during 2007-2017 without correlation.

Solution of the system of equations (1) makes it possible to find out correlation between anthracite and other hard coal mining`s increment rate, anthracite and other hard coal production`s increment rate depending on anthracite and other hard coal mining, thermal energy production`s increment rate, anthracite and other hard coal production`s increment rate depending on thermal energy production, if there is correlation between indices (Fig.4).

With this result, the proposed model allows to predict anthracite and other coal production, depending on their and thermal energy production, taking into account the cyclical nature of power industry development.

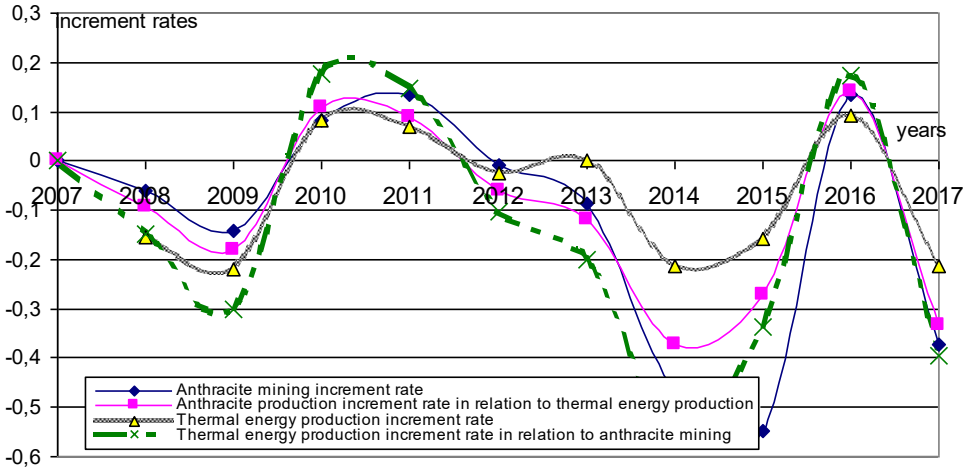

Fig. 6 Dynamics of increment rates of coal, coking coal, anthracite and other coal mining during 2007-2017 if correlated to extraction.

The study of correlation between coking coal mining and production growth rates, coke production, export and import of coke, cast iron production during 2008–2017s has been carried out. The results are presented in Fig.7.

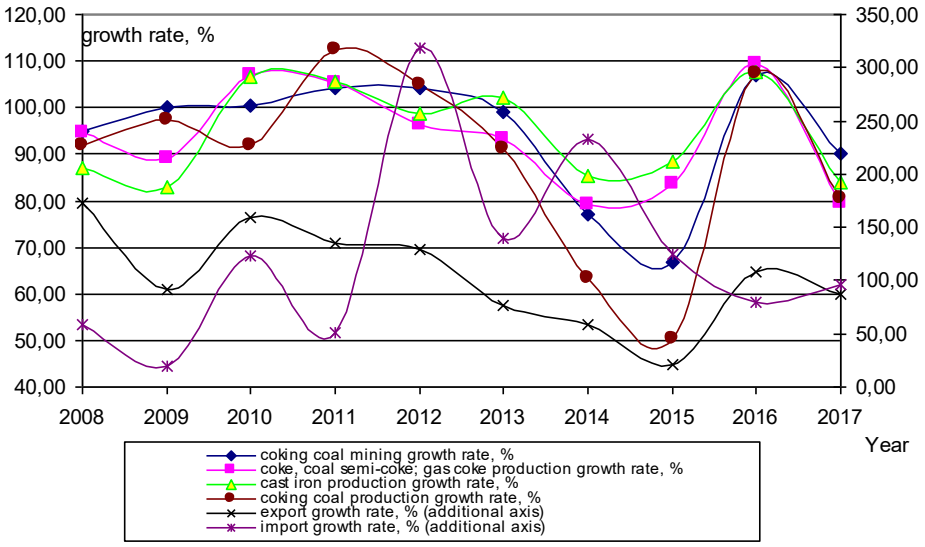

Fig. 7 Dynamics of coking coal mining and production growth rates, coke production, coke exports and imports, cast iron production during 2008 – 2017.

During 2008 – 2013s the dynamics of coking coal mining did not correspond with the relative indices of coal, coke, coal semi-coke production and metallurgy (cast iron production). The discrepancy in the dynamics of mining and production of coal can be explained by the different level of its losses in the process of mining.

Coking coal production increased by 2013, but other indices changed on a periodic basis. The significant drop in production in 2015 can be explained by the beginning of armed hostilities in Donbass, as a result part of mines came to be in temporarily uncontrolled territories. The dynamics of coke production since 2013 coincides with the dynamics of coal production. During the reviewed period, the dynamics of exports of coke were fully consistent with trends in coke production. By 2011 Ukraine imported coke during the period, when domestic coal production grew. Since 2021 the pattern has changed, import rose when production declined. Since 2013, all the named indices fit the trend – cyclical, as the small cycle period is three years.

One to one correlation coefficient was used to identify relationship between coking coal mining, coke production, its export and import. The function characterizes density of connections between each element of time series of dependent (resultant) y_t and explanatory x_t variables` values relatively shifted to one time lag τ. One to one correlation coefficient is determined by the formula:

$$r_\tau = \frac{(n-\tau)\sum_{t-1}^{n-\tau} y_t x_{t-\tau} - \sum_{t-1}^{n-\tau} y_t \sum_{t-1}^{n-\tau} x_{t-\tau}}{\sqrt{[(n-\tau)\sum_{t-1}^{n-\tau} y_t^2 - (\sum_{t=1}^{n-\tau} y_t)^2][(n-\tau)\sum_{t-1}^{n-\tau} x_{t-1}^2 - (\sum_{t=1}^{n-\tau} x_{t-\tau})^2]}} \quad (2)$$

where y_t and x_t – elements of vector of dependent (resultant) and explanatory variables relatively shifted to one time lag τ; n – number of quantitative r_τ. values.

Calculations are presented graphically in Figure 8.

As we can see, the process of coke production and its export has the highest level of interconnection. Processes of coking coal production, coke production and its application in metallurgical production are characterized by almost the same interconnection level. The correlation between import of coke and its production is low, but the level has increased in recent years.

To specify export-import transactions` peculiarities we compared coke and semi-coke exports and imports growth rates; as well as of retort carbon`s (code 2704 UCGEED) and corresponding price indexes. The obtained results are presented in Fig. 9.

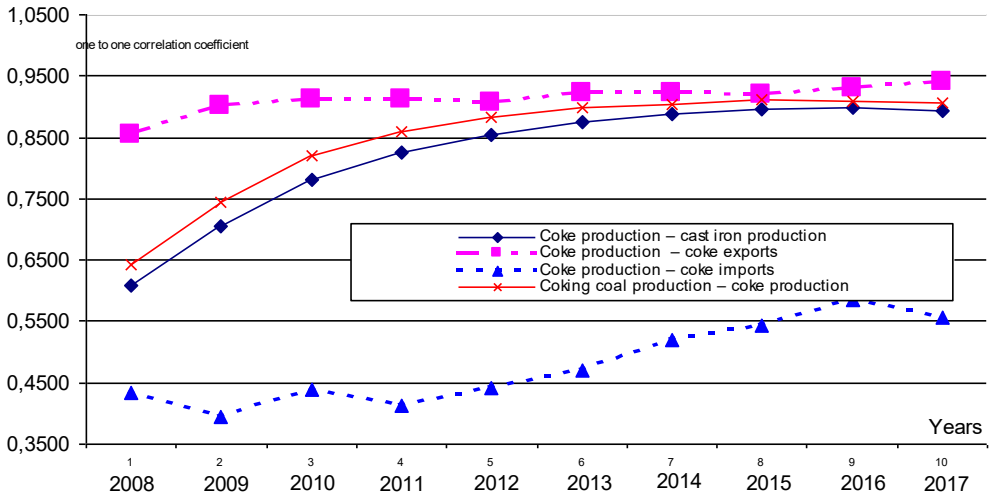

Fig. 8 One to one correlation functions for coking coal mining, coke production, exports, imports and application in metallurgy.

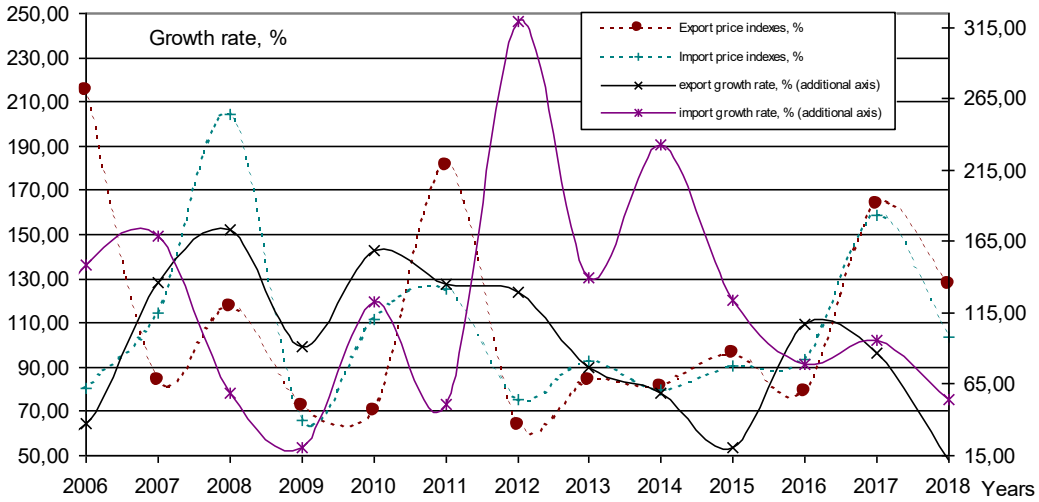

Fig. 9 Dynamics of coke and semi-coke exports and imports growth rates; retort carbon (code 2704 UCGEED) and corresponding price indexes during 2006 – 2017.

The analysis of Figure 8 shows that the frequency of export and import prices` growth rate changes coincides. Thus, we have small cycles lasting 3-4 years.

Comparison of import growth rates and corresponding price growth rates proves that these indices change in counter-phase, that is, import prices increase, if imports decrease and vice versa. Interdependence between export prices and export reveals matching trends, i.e. export prices go up with export volumes, except the period of 2013 – 2015s, which is explained by the production drop as a result of armed hostilities in Donetsk and Luhansk regions.

Thus, coking coal imports are significantly dependent on price trends and are almost unrelated to the needs of Ukraine's metallurgical sector. Therefore, in our opinion, management system of the country's coking coal potential should include balanced flows of coal mining, coke and semi-coke production depending on the needs of national metallurgical sector. Taking into account cyclical nature of metallurgical sector development, coking coal mining and coke, semi-coke production have to be cyclic too. The small cycles` period is 3-4 years.

Let us make similar assessment of steam coal – anthracite. Analysis` results are shown in Fig.10. As we can see, there is correlation between anthracite mining growth rates, other coal / anthracite production, coal exports and imports, anthracite (code 2701 UCGEED) and thermal energy production during 2008–2017s. Dependencies have periodic nature, indicating small cycles lasting 3-4 years. 2017 was the exception for exports and imports.

Figure 11 illustrates the results of correlation analysis on anthracite mining and production, exports and imports, its application in the process of thermal energy production. As we can observe, unlike the situation with coking coal, there is high level of correlation between the analyzed values regarding anthracite. Besides, since 2014, correlation between production and exports has become even more significant.

We will analyze the import growth rates and corresponding rates and prices (Fig. 12). Exports and imports growth rates are identical as the same are price indexes. The trend for imports is economically justified, as when import prices drop down, its volume goes up. Application of the same approach for exports is not economically justified, because it brings losses. The situation has changed since

2015, both export and import prices, as well as volumes began to rise. We consider, that the increase in anthracite imports is consequence of lower production caused by the armed hostilities in Donetsk and Luhansk regions, where most of the mines are concentrated. In the situation, higher exports of the deficit resource having strategical importance for the national energy security may be unjustified.

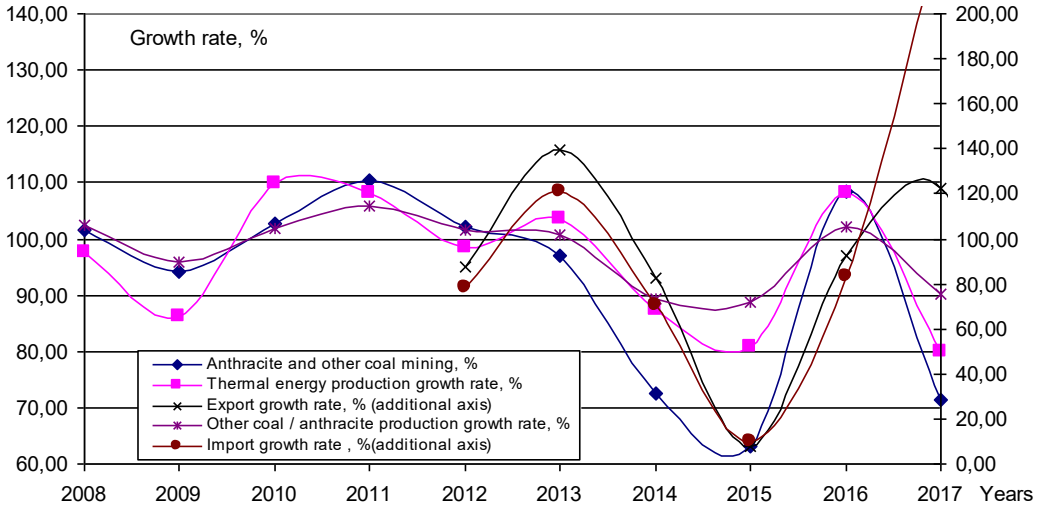

Fig. 10 Dynamics of anthracite mining, other coal / anthracite production, coal exports and imports, anthracite (code 2701 UCGEED) and thermal energy production during 2008 – 2017

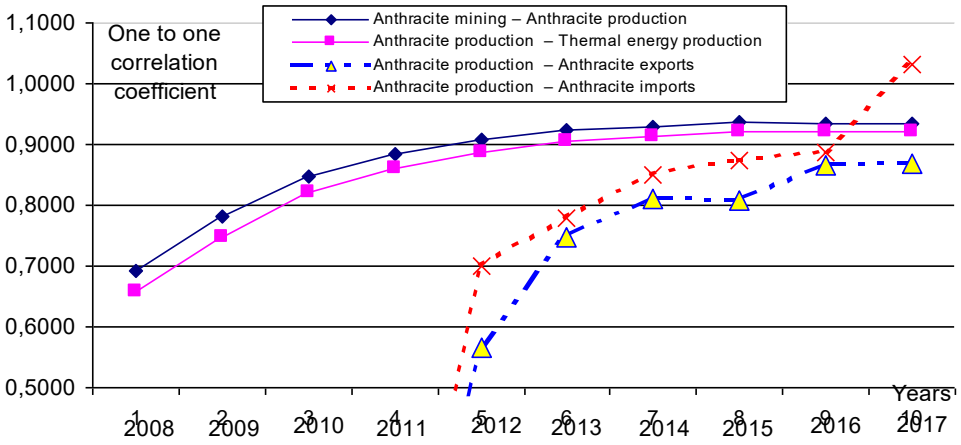

Fig. 11 Functions of one to one correlation for anthracite mining and production, exports and imports, its application for thermal energy production.

National coking coal sustainability managerial model for balancing flows of coal and semi-coal mining depending on metallurgy needs (cast iron production) has been proposed. The model of sustainable anthracite and other coal mining management for balancing coal mining and production depending on electric power energy needs (thermal energy production). The correctness and adequacy of the developed models` application is confirmed by official statistics.

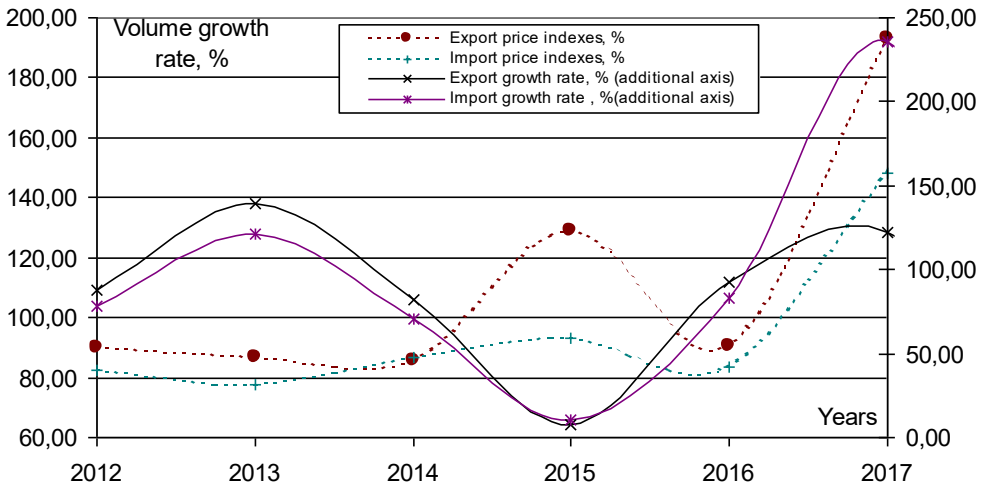

Fig. 12 Dynamics of coal exports, imports growth rates, anthracite (code 2701 UCGEED) and corresponding price indexes during 2012 – 2017

Thus, it is possible to solve the problem of systematic rational management of the country's coal resources by balancing coal mining and its consumption in metallurgy and energy. In order to take into account cyclical nature of economic processes when planning and forecasting coal mining and production in Ukraine, it is proposed to use a multifactor economic and mathematical model for predicting the development of complex systems. The application of the proposed model will allow to form complex of managerial decisions and project proposals for ensuring mining industry`s sustainable development, taking into account strict requirements for environmental safety of the entire product life cycle and territories balanced development where mineral extraction, in particular, coal mining is carried out. Current and strategic tasks of rational coal mining can be solved only by taking into

account alternative resource strategies and forecasting industry`s market needs for the mid- and long term.

The mechanism for Ukrainian coal mining industry`s sustainable development management has been formed as a result of the study. It has been proved that balancing mining, production of coal raw materials and their subsequent use in the production processes are the ways to ensure rational use of coal resources of Ukraine. The processes for coking coal is metal production, and for anthracite - thermal energy production. Relationship between growth rates of coking coal mining and production, coke mining, exports and imports of coke and ironmaking during 2008-2017s have been studied. It has been demonstrated that imports of coking coal essentially depends on the market pricing and has little to do with the needs of the metallurgical industry of Ukraine. It has been shown that the system for rational use of coking coal`s capacity in Ukraine should include balancing flows of coal mining, coke and semi-coke mining according to the needs of national metallurgical industry, taking into account cyclical nature of its development. The necessity of coordinating the volumes of anthracite extraction, production and consumption and taking into account short cycles of heat power development has been defined.

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2.8 Application domain and analysis of the existent state of methodologies of exposure radioactive and chemical contaminations of locality

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Radioactive and chemical contaminations of locality is a powerful factor, rendering substantial influence on the vital functions of population, work of administrative agencies and organs of state administration on the whole.

In a peace-time can the sources of radiocontammant be:

accidents of nuclear power installations with the troop landing of foods of reaction;

destruction of depositories (containers) with radionuclide's;

destruction of active zone or system of coolant-moderator of nuclear power installations as a result of assassinations;

destruction of burial grounds of radioactive wastes.

In turn there can the sources of chemical contamination be a loss and accidents on the enterprises of chemical industry (production of ammonia, acids, polymers);

Ordered all structures of management at the estimation of situation to study her radiation and chemical constituent [1 - 4].

An exposure and estimation of radiation and chemical situation come true, as a rule, in two stages. During the first stage a prognosis comes true on the basis of data about the sources of radioactive and chemical contamination of locality and meteorological situation. During the second stage an actual radiation and chemical situation comes to light from data of secret service (control). The results of prognosis can be drawn on only for the benchmark estimate of radiation and chemical situation [5]. It is necessary especially to mark that these prognostications must be necessarily specified by radiation and chemical secret service [4].

Such order of work is characteristic both for the checking of radiation and chemical situation systems and for CASS of management of military-oriented. CAS of control of radiation and chemical situation of one of tasks must have an exposure and estimation (on a prognosis and fact sheets) of scales and consequences of worsening of ecological situation on the controlled territory and objects [5].

Thus, there is a necessity of decision of task of exposure of actual radiation and chemical situation for CASS of control and CASS of management of military-oriented. Thus CASS of control can be examined in two aspects:

as the system intended for the operative providing of management organs by state information the controlled objects and environment;

as the subsystem of CASS of management of military-oriented, intended for realization of one of measures of radiation, chemical and biological defence on providing of radiation and chemical safety.

Consequently, the decision of task of exposure of actual radioactive and chemical contamination of locality must come true both in CASS of control and in CASS of management of military-oriented.

Presently there is a row of methodologies allowing, at one or another terms, to conduct the exposure of radioactive and chemical contamination of locality. This article is sanctified to their analysis.

Complication and considerable volume of calculations at the decision of these tasks stipulated a necessity application of electronic calculable machines with the use of programmatic complexes. Till recently basic efforts at development of methodologies of exposure of radioactive and chemical contamination of locality were sent to being (clarification) of the zones of contamination, limited to the standard or set doses (by powers of doses of radiation) or concentration of poison substances. Such information appeared to the public servant for the estimation of situation and making of suggestions on further actions. Conservative calculable processes were thus automatized only, and all creative part of work was given to the man.

A new tendency was lately designated in the question of automation of processes of exposure and estimation of radiation and chemical situation. So, in works [6, 7] the idea of the intellectual system of support of decision-making was offered that, being realized as procedure a man is a machine, allows to accelerate some creative functions related to the decision-making. This approach, undoubtedly, does not diminish the role of man, as a choice of some variant of actions from a few alternative and the acceptance of final decision remains the prerogative of public servant.

The similar intellectual systems produce additional requirements to methodologies of processing of data of radiation and chemical secret service and exposure of radioactive and chemical contamination of locality, because take into account the degree of authenticity of information ("reliable", "unreliable", "small reliable"). It allows to examine at processing of data about radioactive and chemical

contamination of locality the greater amount of informative situations is considerable, what it is accepted presently.

On the other hand, complication of the most subject domain, a necessity to have a base of knowledge of not only products but also procedural supposes, that it contingently the necessity of realization of frequent calculations on the different variants of actions at liquidation of consequences of emergencies. Consequently, in a time of realization of such calculations additional limitations will be laid on.

A question about the necessary closeness of points of control of radiation and chemical situation deserves separate consideration. So, researches conducted in [8] showed that optimal volume of information about actual radiation and chemical situation provided at presence of one measuring on 3 – 6 км^2 at regional level and on 25 – 30 км^2 - in the public organs of management. These researches were conducted on tracks of fully corresponding and did not take into account the error of work of devices model. Other researches are in this area [8], conducted already taking into account the errors of measuring of power of dose of radiation or concentration of dangerous chemicals, showed that at regional level a necessary closeness will make 2,3 – 2,9 км^2, and in the scale of the state – 3,2 – 4,0 км^2 on one point.

It is presently accepted [5], that at the conduct of radiation and chemical secret service one measuring must be conducted on the area of 3 – 6 км^2. It should be noted that determination of necessary closeness of control points was conducted calculating on the use of method of interpolation. Application of other methods [7] for renewal of descriptions of the radiation and chemical field, the topology of that is near to model, showed possibility of exposure of actual radioactive and chemical contamination of locality at presence of one measuring on 10 км^2. The method of linear optimal interpolation, allowing to promote authenticity of information in the process of treatment, behaves to such methods.

Thus, at the estimation of authenticity of the information educed from data of radiation and chemical secret service, it is necessary to take into account the errors of measuring of power of dose of radiation or concentration of dangerous chemicals and closeness of control points, but also topology of the field of radioactive and chemical

contamination of locality and method that is used for processing of data not only. We will conduct the analysis of concrete methods of processing of data of radiation and chemical secret service on purpose to estimate possibility of their use in CASS of control and management of radiation and chemical situation.

On the example of model of distribution of radioactive cloud in the frontier layer of atmosphere [9] we will consider possibility to expect power of dose of radiation on track of radioactive cloud at the accident of nuclear reactor. In basis of model next dependences are fixed:

$$\dot{X}_1 = \frac{(1-0.9\tau^{-0.18})W_{EL}\eta R}{V^{\beta}X^{\gamma}} K \exp\left(-\frac{Y^2}{2\sigma_y^2}\right), \qquad (1)$$

where $\dot{X}_1$ – is power of dose of radiation on track of radioactive cloud in a hour after an accident, R/h;

τ – duration of company, twenty-four hours. Standard company of nuclear chancellors on territory of Ukraine about three years or 1100 twenty-four hours;

W_{EL} – electric power of nuclear reactor, MVt;

η – stake of the troop landing of radionuclide's from a nuclear reactor, %.

If the stake of the troop landing is unknown (a typical situation is in the initial stage of accident), then she is accepted by equal 10 %, thus for the nuclear contour reactors of high-powered of the 25% troop landing is considered a cloud, and 75 % troop landing a stream is considered. For nuclear water aquatic power reactors 75 % troop landing a cloud is considered and 25 % a stream is considered;

R – coefficient the size of that depends on the type of nuclear reactor and category of stability of atmosphere;

V – speed of wind in a layer a 0 – 200 m, m/s;

X – distance from an emergency nuclear reactor to direction of wind, kilometer;

K – coefficient, taking into account diminishing of power of dose on the initial area of track;

Y – distance of point from the axis of track, kilometer;

σ_y – dispersion of lateral rejection of track in the distance X kilometer from a nuclear power plant.

Knowing the value of power of dose of radiation in a point on track of cloud on 1 hour after an accident it maybe to count the level of radiation on any time:

$$\dot{X}_t = \dot{X}_1 \, f(t), \tag{2}$$

where $$f(t) = \begin{cases} t^{-0.165} & if \quad t \le 63 \quad h \\ t^{-0.43} & if \quad 63h < t \le 2160 \quad h; \end{cases}$$

t – time from the moment of stop of nuclear reactor, h.

Within the framework of development of this model [9] methodology of calculation of distribution of power of dose of radiation was offered on track of radioactive cloud. In the direction of track distribution of power of dose of radiation is determined:

$$\dot{X}_x = \frac{10^{\alpha} K K_W}{V^{\beta} X^{\gamma}}, \tag{3}$$

where α – is a coefficient the size of that depends on the type of nuclear reactor and stability of atmosphere;

K_W – coefficient, taking into account the amount of emergency nuclear reactors (n), their electric power (W_{EL}, MVt) and stake of the troop landing of radionuclide's from a nuclear reactor at an accident.

Distribution of power of dose of radiation in direction perpendicular to the axis of track described by next equalization:

$$\dot{X}_{xy} = \dot{X}_x \exp\left(\frac{-Y^2}{2\sigma_y^2}\right), \tag{4}$$

where Y – is distance from the axis of track, kilometer;

σ_y^2 – dispersion of distribution of admixture is in the crossrunner of track of cloud.

Coming from foregoing a model allows to define the geometrical sizes of zones of radiocontammant of locality. Length of zone of contamination :

$$L_x = \sqrt{\frac{K_W \cdot K \cdot A \cdot 10^{\alpha}}{V^{\beta} \cdot \dot{X}_3}}. \quad (5)$$

Width of track of radioactive cloud :

$$L_y = \sqrt{2\sigma_y^2 \left(\ln \dot{X}_{1/2L_x} - \ln \dot{X}_3 \right)}, \quad (6)$$

where $\dot{X}_{1/2L_x}$ – is power of dose of radiation on the axis of track in the distance *1/2Lx* from a nuclear power plant on 1 hour after the stop of nuclear reactor;

$\dot{X}_3$ – power of dose of radiation on the external border of the determined zone on 1 hour after the accident of nuclear reactor;

A – is day's stake of the thrown out radionuclide's from their general amount, %.

As an analysis of this model shows, the offered algorithm specified well enough. However as basic data plenty of variables the value of that is unknown is present, at least in an initial period of development of accident. To such parameters behave: stake of the troop landing of radionuclide's from a nuclear reactor; distance from a nuclear power plant to the point in that power of dose of radiation in two times less than maximal on the axis of track (X_{50}); day's stake of the thrown out radionuclide's from their general amount (*A*) and some other. An appropriation to the unknown parameters of model of the fixed values, undoubtedly, worsens model quality on the whole.

In addition, this model does not take into account pulsating character of the troop landing of radionuclide's from an emergency reactor, that fully probably, as experience of accident showed on the Chernobyl nuclear power plant.

In our view this model can be used for drafting of prognosis of radiocontammant of locality in that case if the active phase of development of nuclear reaction ceases after the troop landing of radionuclide's in an atmosphere.

The approximation model of radiocontammant of locality is based on the use of approximation equalization :

$$m = \frac{A \cdot L_x^2 + B \cdot L_x + C}{(L_x + 5)^2}, \quad (7)$$

where *A, B, C* – are approximation coefficients, the size of that depends on the type of nuclear reactor, vertical stability of air and speed of wind.

Power of dose of radiation on track of radioactive cloud settles accounts on equalization:

$$\dot{X} = m \cdot K_y \cdot K_w, \quad (8)$$

where K_w – is a power-factor of nuclear reactor and stake of the radionuclide's thrown out from a reactor at an accident;

K_y – a change of approximation coefficient of m is in the crossrunner of radioactive track :

$$K_y = \exp\left(-\frac{L_y}{2\sigma_y^2}\right), \quad (9)$$

σ_y – mean quadratic deviation of calculation point :

$$\sigma_y = \frac{\alpha \cdot L_x}{\sqrt{1 + 0.1 \cdot L_y}}, \quad (10)$$

L_y – moving away of calculation point from the axis of track, kilometer;

α – constant of degree of vertical stability of air (0,15 is a convection, 0,06 - isothermal, 0,02 is an inversion).

Count power of dose of radiation on the set time comes true on correlation:

$$\dot{X}_{set} = \dot{X} \cdot K_t, \quad (11)$$

where K_t – is a coefficient of slump of activity at times:

$$K_t = \left(\frac{t_{count}}{t_{meas}}\right)^{-n}, \quad (12)$$

where t_{count} – is time of count of power of dose, ч;

t_{meas} – time of measuring (or primary calculation) of power of dose in relation to an accident, h;

n is an index of slump of activity, the size of that changes from 0,5 to 0,3 after three years after an accident on a nuclear power plant.

The analysis of the considered methodology shows that she is the simplified variant of model of distribution of radioactive cloud in the frontier layer of atmosphere and, consequently, saves all her defects. Dignity of approximation model is considerable simplification of calculations. In this connection offered approach can be applied at primary, «rough» prognostication, or in default of the computing engineering. However here it should be remembered that both every simplification of the worked out mathematical model conduces to worsening of her quality and in this case it is necessary to expect appearance of additional errors.

Incident of nuclear power installation can have the pulsating character stretched in time on comparison valid for one occasion troop landing of radionuclide's. There is a task of treatment of results of measuring, when the process of expiration of radionuclide's did not yet come to an end from a reactor. Other no less important task consists in determination of descriptions and dynamics of distribution of aerosol radioactive cloud.

In this connection, interest presents the methodology of exposure of radiocontammant, worked out in [7]. In this work for basis the model of distribution of admixture is taken in the ground layer of Pasquill-Gifford. However the described approach is acceptable and for other models.

Almost stationary approach according to that in a certain time Δt_j domain meteorological terms are considered permanent is realized in the examined methodology. Then, the integral concentration of radionuclide's in mid air at passing of radioactive cloud of the troop landing will be equal:

$$\chi(x,y,z)=\sum \frac{\bar{Q}_j\cdot\Delta t_j}{2\pi\cdot\sigma_y\left(\tilde{x}_j\right)\cdot\sigma_z\left(\tilde{x}_j\right)\cdot u_j}\exp\left(-\frac{\tilde{y}_j^{\,2}}{2\sigma_y^2\left(\tilde{x}_j\right)}\right)\cdot$$
$$\left\{\exp\left[-\frac{(Z-H)^2}{2\sigma_y^2\left(\tilde{x}_j\right)}\right]+\exp\left[-\frac{(Z+H)^2}{2\sigma_y^2\left(\tilde{x}_j\right)}\right]\right\}\cdot f_R\cdot f_F\cdot f_W, \qquad (13)$$

Where $\bar{Q}_j$ – is power of the troop landing of *j*-th radionuclide's in a time of Δt_j domain, Bk/s;

Δt_j – duration of time during that meteorological terms are saved by unchanging domain, with;

$\tilde{x}_j$ – projection of vector $\vec{r}(x, y)$ having beginning in a point with the coordinates of source of radiocontammant and end in the examined point, on the axis of the track formed by a wind transfer in a time Δt_j, m domain;

$\tilde{y}_j$ – distance from a point with coordinates (x, y) to the axis of the track formed by a wind transfer in a time Δt_j, m domain;

σ_y – coefficient of dispersion, Smith-Hosker expected on a formula;

H – height of the troop landing, m;

f_R – amendment on impoverishment of cloud due to a radioactive-decay;

f_F – amendment on impoverishment of cloud due to washing of radionuclide's sinking;

f_W – amendment on impoverishment of cloud due to the pin besieging or adsorption;

u_j – speed of wind, m/s.

The post of control of CAS of control gets information about a concentration in mid air of rare radioactive gases, all isotopes of iodine and all the beta of activity of aerosols. For renewal of size of the troop landing the concentration of *i*–th radioactive substance of rare radioactive gas is determined in times of passing of cloud Δt_j:

$$\chi_i\left(\tilde{x}_j, \tilde{y}_j, t\right) = \frac{Q_{iП} \cdot \exp\left(-\lambda_i t\right)}{\sum_i Q_{iП} \cdot \exp\left(-\lambda_i t\right)} \chi_{изм} = \alpha_{iП} \cdot \chi_{изм}, \qquad (14)$$

where $\chi_{изм}$ – is the measured concentration of rare radioactive gases in times of t on the post of control with coordinates $\left(\tilde{x}_j, \tilde{y}_j\right)$, Bk/m^3;

$Q_{iП}$ – activity of the troop landing in the atmosphere of radioactive substance of rare radioactive gas for the accident of corresponding level, Bk;

λ_i – permanent radioactive-decay of *i*-th radioactive substance of rare radioactive gas, s;

$\alpha_{iП}$ – stake of activity of *i*-th radioactive substance of rare radioactive gas from all activity of rare radioactive gases for the accident of corresponding level, relative units.

The concentration of every (*i*-th) radioactive substance of iodine is like determined.

The concentration of other radionuclide's being in an aerosol form settles accounts coming from next correlation:

$$\chi_{ia}\left(\tilde{x}_j, \tilde{y}_j, t\right) = \frac{Q_{ian}\cdot\exp\left(-\lambda_i t\right)}{\sum\limits_i Q_{anП}\cdot\exp\left(-\lambda_i t\right)}\cdot\left(\chi_{\beta изм} - \chi_{Iизм}\right) = \alpha_{ian}\left(Q_{\beta изм} - Q_{Iизм}\right), \qquad (15)$$

where Q_{ian} – is activity of the troop landing in the atmosphere of *i*-th radioactive substance being in an aerosol form, for the accident of corresponding level, Bk;

$\chi_{\beta изм}, \chi_{Iизм}$ – measured concentration (β-active aerosols and radioactive iodine for time _on the post of control with coordinates $\left(\tilde{x}_j, \tilde{y}_j\right)$ accordingly, Bk/m^3;

α_{ian} – stake of activity of *i*-th radioactive substance in an aerosol form from all activity (β-aerosols for the accident of corresponding level, relative units.

After it the reverse task of transfer of admixture decides in an atmosphere:

$$Q_j \Delta t_j = \sum_n \frac{Q_j \Delta t}{n} =$$

$$= \sum_n \sum_{k=1}^{3} \frac{\chi_{ik}\cdot 2\pi\sigma_y(\tilde{x})\cdot\sigma_z(\tilde{x})\cdot u_j}{\exp\left(-\frac{\tilde{y}^2}{2\sigma_y^2(\tilde{x})}\right)\cdot\left\{\exp\left[-\frac{(Z-H)^2}{2\sigma_y^2(\tilde{x})}\right] + \exp\left[-\frac{(Z+H)^2}{2\sigma_z^2(\tilde{x})}\right]\right\}\cdot f_R\cdot f_F\cdot f_W}, \qquad (16)$$

where n – is an amount of control posts;

k – is an amount of groups of radionuclide's activity of that is measured by the sensors of CAS of control (groups of rare radioactive gases, iodine and β-active aerosols). At the change of speed of wind and his direction a task decides like.

Thus, the considered methodology allows, at presence of corresponding data, to expect integral power of the troop landing of every radioactive substance in an aerosol form for some time domain. In future, the obtained data it is assumed to use for renewal of dynamics of distribution of radioactive aerosol cloud and prognostication of radiocontammant of locality.

This methodology can be used in CASS of control of objects of atomic energy. Receipt of reliable results about integral power of the troop landing of radionuclide's it is necessary to expect in case that the real processes flowing in an emergency reactor are full enough described.

The analysis of different models of radiocontammant of locality showed that presently most perspective is almost stationary approach allowing to take into account the specific of emergency situations on the objects of nuclear energy, consisting in the relatively protracted expiration of radioactive foods from an emergency reactor.

The methodology of Pasquill-Gifford, oriented to the features of CASS of control of radiation situation, allows to specify model parameters on the testimonies of sensors and to promote her authenticity the same. In too time, at certain terms, a model can incorrectly describe the radiocontammant of locality, thus, than more time passed from the moment of accident, the below model authenticity.

The analysis of different models shows that prognostication of radiocontammant of locality at an accident on nuclear power installation it is expedient to conduct in a next sequence:

design of radioactive cloud on the basis of methodology of Pasquill-Gifford with the use of almost stationary approach;

processing of data of radiation secret service of posts of radiation control of object with the purpose of clarification of model parameters, in particular

determinations of power of the troop landing, amount of settleable on locality radionuclide's et cetera;

design of radiocontammant of locality on the basis of methodology of distribution of cloud in the frontier layer of atmosphere taking into account the refined data and by the use of almost stationary approach, i.e. taking into account imposition of the radioactive tracks formed in different moments of time at expiration of radionuclide's from an emergency reactor.

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3 INVESTMENT POTENTIAL OF TERRITORIAL-ECONOMICAL SYSTEMS

3.1 Analysis of the international investment position and strategic ways to attract foreign investment to Ukraine

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The economic development of the state depends on many factors, and, in particular, on the course of international investment processes. Foreign investments are an effective factor of the country's economy development. The efficiency of foreign investment depends considerably on the investment climate of the investment importing country. Internationally, various indicators and ratings are applied to determine the country's investment attractiveness, including the data of the «international investment position of the country» (IIP). Therefore, the issue of improvement in the international investment position of Ukraine is relevant. To improve the international investment position of Ukraine, it is expedient to improve fiscal policy, including tax legislation. A sound tax policy of the state promotes investments into the country's economy, can structurally improve the investment position, promote foreign investment and prevent uncontrolled capital outflows. Many countries have recognized this fact and reformed their tax codes according to new global needs and changes in the international financial environment [1].

Among the researchers, whose works are devoted to the problem of IIP assessment and investment development in Ukraine, it is possible to distinguish the following authors: M. Denysenko, M. Krupka, I.V. Alekseiev, V. Maiorova. However, the possibilities for improvement in the international investment position of Ukraine considering tax policy changes remain under investigated. Issues relating to the features of Ukrainian tax system functioning are considered by such Ukrainian scientists as T.I. Yefimenko, Yu.B. Ivanov, A.I. Krysovaty, O.M. Desiatniuk,

K.I. Shvabiy, and others. In recent years, the tax system of Ukraine has undergone significant changes, its «modernization» has taken place and a number of innovations have been introduced. These steps have increased the scientists' attention to the study of investment attractiveness of Ukrainian economy due to the introduction of innovations in the tax area.

Bringing foreign investments into the nation's economy depends on a number of factors, including internal political stability; the nature and pace of market reforms; economic legislation stability; guarantees of inviolability of private property and foreign investments; favourable foreign economic conditions [2, p. 452].

In modern globalized world capital is extremely mobile. Enterprises may invest in any project in different countries around the world to find the highest level of profitability. It means that enterprises will look for projects and countries with lower investment rates in order to maximize profit after tax payment. If the tax rate in the country is too high, it will contribute to investment «outflow» to other countries, which will slow down economic growth. Additionally, high marginal tax rates may lead to tax evasion. In the ranking of investment attractiveness among the nation of economies of the world ((BDO) International Business Compass (IBC)) in 2018, Ukraine ranked 131 among 174 countries [3]. The country lost its position by 42 points compared to 2015 (89 in 2015).

In the conditions of free capital flows and development of global financial environment, the assessment of the country investment position is of great importance. The investment position determines the future strategic development of the country and its financial security. The net international investment position is determined by the difference between foreign assets and liabilities of the country [4]. Depending on the net investment position, countries are divided into net debtors and net lenders. The analysis of net lenders and debtors makes it possible to identify future geopolitical leading countries, as well as those countries which may face debt repayment crisis. The largest net debtors in the world are the USA, Spain, Australia, and Brazil [5]. There is a tendency to net liabilities increase in such countries as: the USA, France, Ireland and Turkey. Spain, Brazil and Eurozone countries have reduced

their net debt obligations (table 1). Among the largest net lenders in the world there are Japan, Germany, China, and Switzerland. Such countries as Germany and China, the Netherlands and Canada are gaining a positive balance of NIIP [6].

Table 1 Net IIP, Top 5 Economies with deficit and surplus, billions of US dollars [5]

Країна	2013	2014	2015	2016	2017
Net IIP (Deficit) Top 5 Economies					
United States	-5368,6	-6945,4	-7461,6	-8181,6	-7725,0
Spain	-1334,5	-1234,2	-1053,1	-1006,2	-1172,6
Euro Area	-1983,5	-1488,1	1313,6	-806,5	-823,6
Australia	-752,2	-695,2	-674,2	-699,8	-757,1
Brazil	-723,9	-705,9	-347,7	-585,5	-659,3
Net IIP (Surplus) Top 5 Economies					
Japan	3093,3	3012,4	2815,0	2879,2	2909,1
Germany	1344,2	1449,3	1539,2	1689,2	2124,4
China, P.R.:Mainland	1996,0	1602,7	1672,8	1950,4	1814,1
China, P.R.: Hong Kong	758,0	870,2	1003,1	1153,8	1421,2
Norway	640,5	709,0	696,8	734,8	886,0

Negative net investment position is observed in Ukraine during the entire period of independence, which is a negative trend [7]. The largest liabilities (debts) and assets were in 2012-2013, after 2013 there is a tendency to decrease the debts and assets (Fig. 1.).

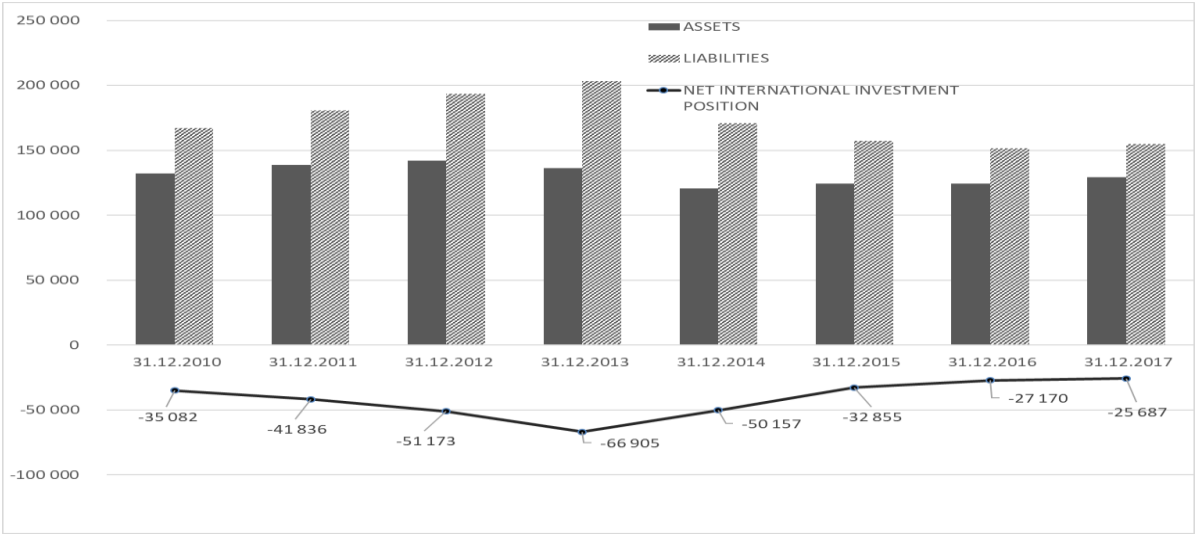

Fig. 1 The main indicators of Ukraine's international investment position in 2010-2017 (millions of US dollars) [7]

Comparing the indexes of the international investment position with GDP, one may obtain the information about the possible impact of IIP on the economy. The country's largest commitments to GDP were in 2015, up to 173%. Beginning from 2015, assets and commitments as a percentage of GDP tend to decrease. It should be noted that over the last 18 years Ukraine has slightly improved its net international investment position (Fig.2).

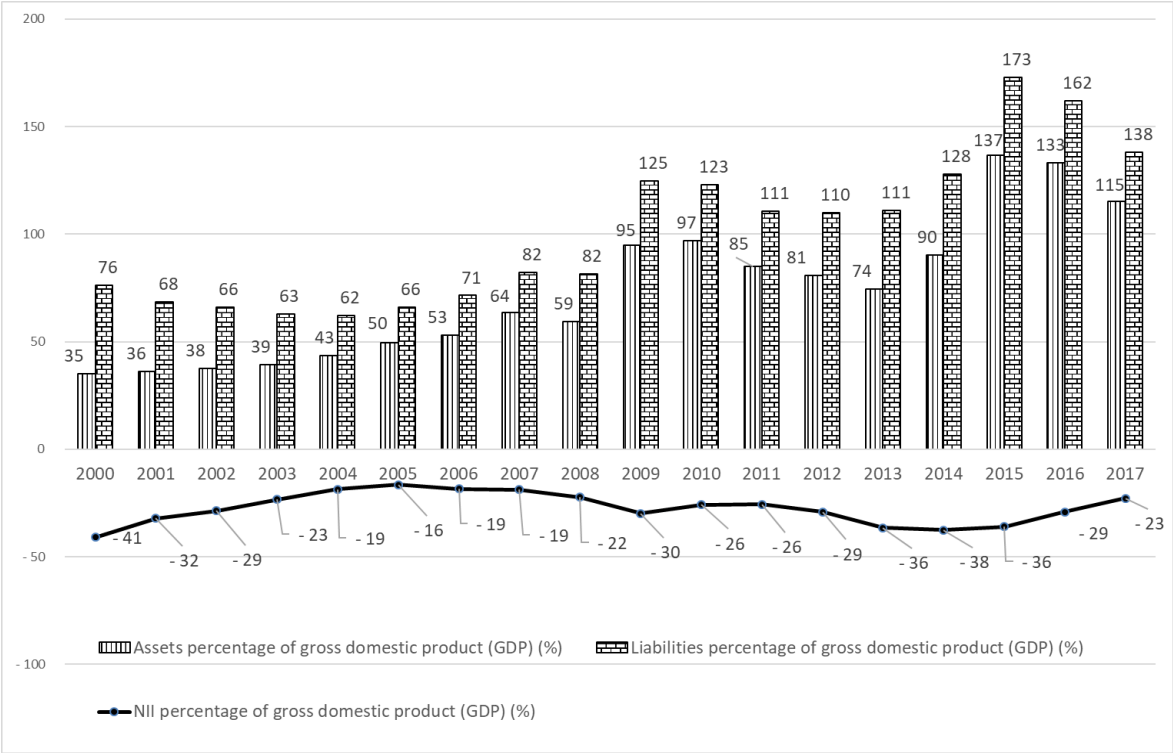

Fig. 2 The main indicators of Ukraine's international investment position in 2010-2017,% of GDP [7]

The analysis of IIP is essential for understanding the factors of sustainability and vulnerability of the economy, and the level of liquidity of the country. The main indexes of the IIP can be used to determine the rates of profitability, to assess the economic structure and identify interdependencies between the internal and external sources of funding. Compared to the majority of the EU countries, Ukraine has a normal investment position. Thus, in recent years most European countries have had a negative net investment position as a percentage of GDP. It leads to a debt crunch

in the EU, which may cause significant financial and political problems there in future.

Particularly significant negative indexes show such countries as Ireland, Greece, Spain, Poland, and Portugal. Their NIIP deteriorates in the course of time and affects further economic development [8] (Fig.3).

The total foreign assets and liabilities value may indicate the degree of involvement of the country in the international flows of capital. For more profound assessment of Ukraine's position as an international lender and debtor, analysis of the dynamics of assets and liabilities structure is vital, which largely determines the solvency of Ukraine.

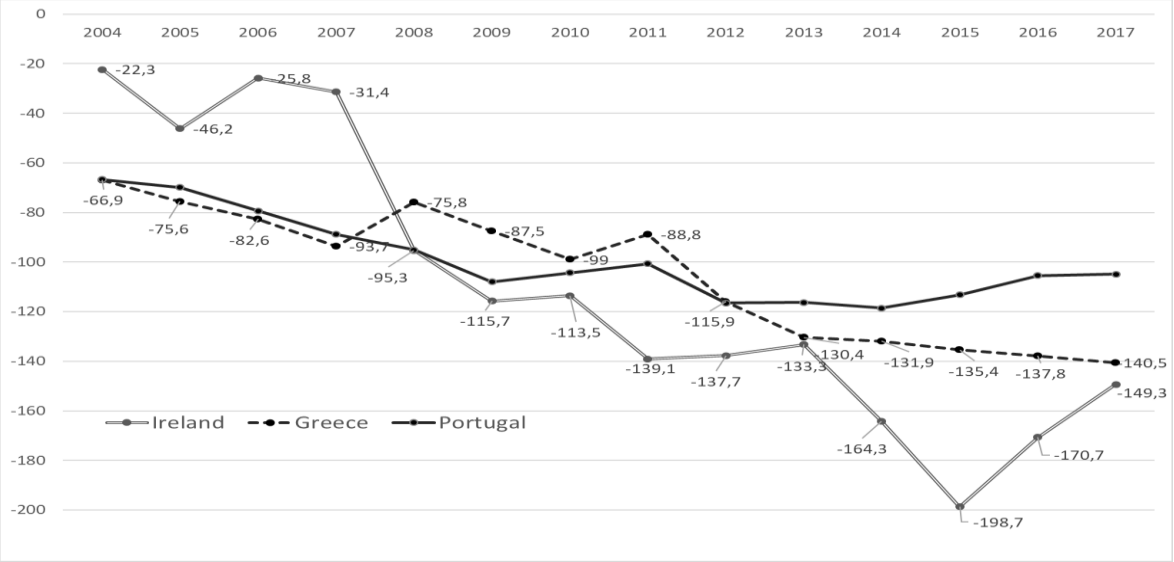

Fig. 3 Net investment position in% of GDP in some European countries [6]

The share of foreign direct investment (FDI) in the structure of IIP assets of Ukraine is increasing, which can be considered as a positive trend (in 2017 they amounted to 6.31%). Direct foreign investment may positively impact on the receiving country through the transfer of capital, technologies, and managerial resources, which in turn can stimulate its economic growth. Direct investments into Ukraine are 6 times more than investments from Ukraine. Almost 94% of direct investments from Ukraine were directed to Cyprus mainly into professional, scientific and technical activities.

A significant share of direct investments from Ukraine comes from Donetsk region. Direct foreign investment creates preconditions for transnationalization of Ukrainian companies, integration of the Ukrainian economy into the world economic space. Portfolio investments are not widespread in Ukraine at all; they take up only 0.08% of assets (Fig.4).

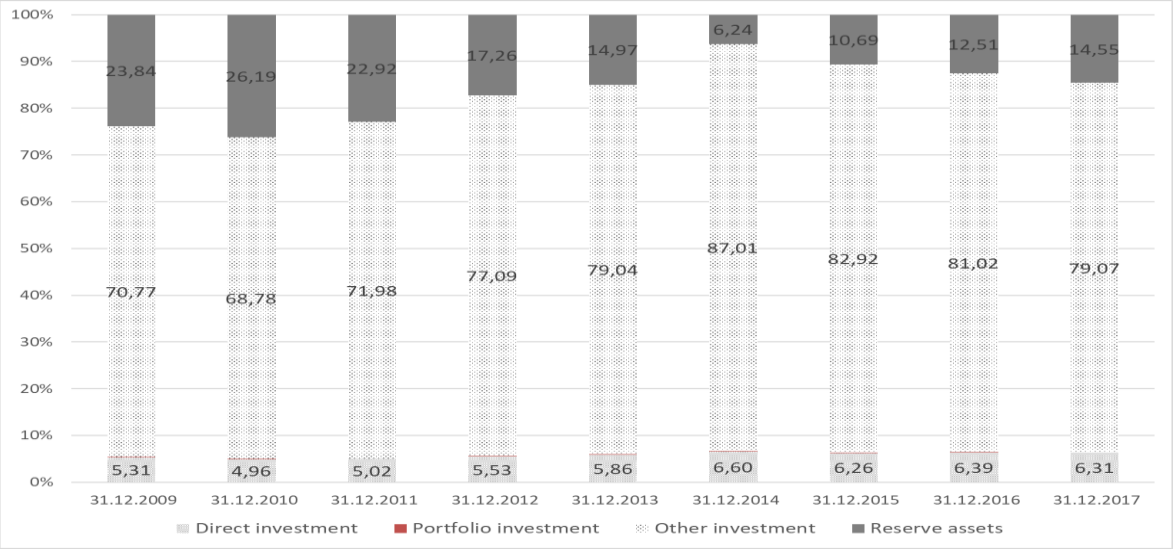

Fig.4 Structure of assets of IIP of Ukraine (%) [7]

The largest share in the structure of assets is taken up by other investments (79.07%), a significant share of which (82%) is represented by cash currency in extra-banking sector (its amount increased by 13.5 times over the past 18 years), which indicates high dollarization rate, as well as shadow economy growth, and a significant share of cash in the total money supply. All these factors reduce the efficiency of NBU's efforts to stabilize the national currency rate and increase the inflationary risks.

Regarding reserve assets, their dynamics is constantly changing, with the lowest rate of 6.24% in 2014, and the largest one - almost in half - in 2005 (45.4%). Due to the chronic deficit of the current account balance, there is a need to increase reserve assets. The structure of reserve assets was significantly affected. Thus, in 2000 the biggest share in their structure took up cash currency and deposits (75%), and in 2017 it was reduced to only 4%. In 2017, the largest share in reserve assets is taken up by long-term securities - 79%. In 2016-2017, the share of reserve assets of

special drawing rights was increasing as a result of active cooperation between Ukraine and the IMF in recent years.

In the structure of liabilities the share of other investments is gradually decreasing, portfolio investments are increasing, while direct investments into Ukraine have significant fluctuations in dynamics (Fig.5).

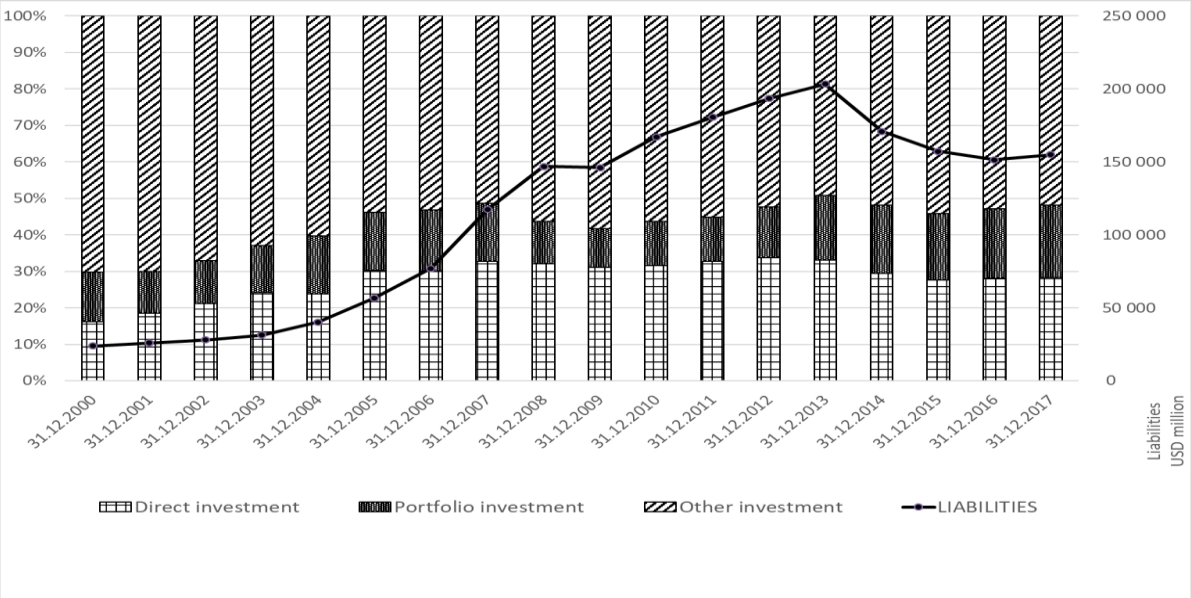

Fig. 5 Dynamic (millions of US dollars) and structure (%) of liabilities in the IIP of Ukraine [7]

According to the analysis of FDI source countries, most FDI come into Ukraine via large financial centers. According to many experts, it means that a significant part of FDI may, in fact, be the so-called «circular FDI», which originally belonged to domestic shareholders, and then come into Ukraine via financial centers such as Cyprus.

However, it should be emphasized that not all FDI coming from financial centers is circular one. Investors from other countries also use large financial centers because of loyal regulation and low taxes. According to the studies of German Advisory Group, foreign direct investment is beneficial for the recipient country. In Ukraine FDI companies in which a foreign investor holds no less than 10% of the authorized capital make up only 4.6% of all Ukrainian companies. However, this comparatively small number of enterprises accounts for over 20% of the labour pool

of Ukraine, 24% of the total capital of Ukraine and almost 35% of the gross value added - the index of production. Thus, FDI companies are not only considerably larger than enterprises with solely domestic investments; they are also much more efficient. Therefore, the economic benefits of FDI in Ukraine are significant. They are the following: more rational application of investments, transfer of new technologies; managerial and marketing experience from abroad; entry of the national companies into international markets; new job formation and an increase of state and local budgets revenues. But international investment has its own economic disadvantages, such as interest and dividends payment in currency, which may increase capital outflows from the country; limited decision making in the companies with foreign capital; focusing on import of products and technologies transfers etc [9].

Foreign investment helps to increase the sources of financing for expanded reproduction. If the country manages foreign investment effectively, then it will eventually be able to significantly improve the competitiveness of its economy and ensure sustainable development. An increase in foreign investment helps the country to cope with the crisis, and integrate into the world economic space. Foreign investment improves the balance of payments, strengthens the national currency exchange rate, but, on the other hand, there are some potential threats, especially if investment is directed to low-tech sectors (it may cause environmental pollution, reduce financial independence of the country, increase future transfers of capital abroad, etc.).

Ukraine is a developing country and therefore needs foreign investment. Ukraine’s development depends considerably on international investment processes. International investments play an essential role in foreign economic priorities of the country. Direct investments into Ukraine decreased by 27% compared to 2014. In 2017 the largest investors of Ukraine were Cyprus - 25.6%, the Netherlands - 16%, the Russian Federation - 11.7% and Germany - 4.6%. The main areas for direct investments are industry (27.3%), including processing (20.63%), wholesale and retail trade - 13.13%, financial and insurance activities - 26%.

There are significant disparities in the regional structure of FDI in Ukraine. Thus, Kyiv and Dnipropetrovsk region receive 70% of investments (60% and 9.7% respectively). Long-term debt securities of the general government sector account for a significant share (68% in 2017) in portfolio investment, indicating a significant increase in public sector debt.

Loans, trade credits and advances are increasing in the structure of other investments, while currency and deposit liabilities are gradually decreasing. It should be noted that since 2006 other investment in liabilities has had a tendency to rapid growth. In the structure and dynamics of loans the loans from other sectors and sectors of general government are dominated. Thus, the structure of IIP of Ukraine is not optimal, and threatens with debt crisis to occur in future.

To improve IIP, it is necessary to incorporate certain changes to the tax legislation of Ukraine. After reduction of the UST rate, introduction of more than one hundred amendments to the Tax Code, and creation of a mechanism for automatic VAT refund, recently among the economic scientists and practitioners an interest has been arisen by the government initiative, which is related to the possible introduction of the so-called capital transfer tax. In Ukraine this model of taxation has been under discussion since the end of 2015. For the first time it was proposed in the liberal bill № 3357. The idea of tax on transferred capital was too innovative for Ukraine, so it wasn't adopted by the Parliament. Although the National Council of Reforms has approved the introduction of capital transfer tax since 2018, still the adoption of the bill is indefinitely postponed. Today, the bill on capital transfer tax lives its own life, and its authors actively co-operate with the Verkhovna Rada of Ukraine Committee on Tax and Customs Policy.

Basically, the idea of this tax is not a new one; this model of taxation has been valid in Estonia since 2000. The main positive factors which contributed to the improvement of the investment climate in Estonia were the following: the country ranks the first among 138 countries in the overall International Tax Competitiveness Index (2018) rating [1]; the level of investment growth in 2000-2004 amounted to

39%, which exceeded the level of neighboring Latvia and Lithuania; domestic companies began to invest into the renovation of fixed and financial assets.

Despite the fact that Estonia has adopted a fundamentally different mode of tax income than in other EU countries, this model corresponds to the OECD principles of Base Erosion and Profit Shifting (BEPS) and the EU Directives.

Therefore, in our legislative environment after the adoption of the draft law on the capital transfer tax, it is necessary to adopt a package of anti-BEPS laws against tax evasion and disclosure of other jurisdiction property information. Without such a package of documents there is a risk that companies will use liberal legislation to evade tax via offshore or transfer capital to the accounts of related parties.

The characterization of IIP naturally complements the stratum of information reflecting the financial situation and position of the country in the world monetary system. IIP shows, on the one hand, the owner and the amount of foreign assets (claims in foreign currency), and on the other – the debtor and the amount of external debt (foreign currency liabilities to non-residents). From IIP analysis it can be noted that the structure of assets is unacceptable, a greater share of assets is represented by other investments, there is no portfolio and direct investments, and loans are growing rapidly in liabilities. In recent years portfolio debt securities have increased due to an increase in public sector liabilities. As in assets and liabilities, such results were caused almost exclusively by long-term debt securities. Under analytical interpretation of the changes in the investment position it should be taken into account that the stocks of international assets and liabilities at the end of the period are adjusted considering the exchange rate fluctuations, which are very significant in Ukraine, as well as the revaluation component.

Such trends are a negative factor that can lead to a solvency crisis and worsen the financial position of the country. In order to improve the investment position of Ukraine, it is sensible to make changes in the tax policy toolkit, namely in terms of introducing capital transfer tax and fiscal stimulation of attracting investments into the country.

The main advantages of this model of taxation are: 1) creation of incentives for entrepreneurial and investment activity (as experience of Estonia confirms, inflows of foreign investments increase considerably); 2) there is no need to reduce the financial result of an enterprise; therefore, financial reports of enterprises may become more transparent and attractive for investors and banks; 3) it is easy to check tax liabilities, since it is difficult to conceal transactions relating to objects of taxation. Taxpayers will have sufficient control over the implementation of such transactions. Consequently, the controversial issues in determining the cost of goods and services will disappear. This issue is currently the reason for discussions and often manipulations by taxpayers as well as corrupt practices from the side of fiscal services.

Thus, investment position is influenced by the economic environment, as it can be expected that macroeconomic and regulatory factors will affect the relative profitability of external and internal investments. Other factors to improve IIP include the implementation of trade agreements aimed at removing obstacles to cross-border capital and labor flows. Implementation of all measures will allow to fundamentally change IIP of Ukraine, increase revenues and accumulate the assets of the country.

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3.2 Organizational and financial components of risk management and insurance in the field of tourism

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Features of functioning of tourist business and insurance of risks in the tourist market are defined. The content and composition of risks in the tourism industry are generalized. The content and list of the main tools of risk management in the tourism business and ensuring insurance protection of tourists are determined. The generalization of the international experience of functioning of the insurance mechanism in the tourist industry at the global and regional levels is carried out. Measures to increase the efficiency of insurance services for the tourism business and ensure the protection of citizens of Ukraine in the implementation of outbound and domestic tourism are substantiated.

Today, insurance and tourism are of great importance for the economic development of many countries. The development of the tourism industry contributes to the creation of new jobs and employment, giving the opportunity to attract additional funds to the country's economy, intensifying foreign trade. In general, insurance in tourism reflects the relationship between policyholders (travel organizations, tourists) and insurers (legal entities of any legal form) to protect the property interests of tourists in the event of insurance events during the trip. The main parties to such relations are insurers (insurance companies), insurers (tour operators and travel agencies) and tourists. Insurance in tourism should be considered as a universal means of protecting the safety and property interests of tourists when traveling, as well as relevant tourism organizations in the process of their tourism activities. The need for compulsory insurance of tourists is justified by statistical

indicators of morbidity and accidents with tourists in different countries, in different age categories.

Insurance business and tourism activities are in the service sector, and services are goods offered for sale, which consist of actions, benefits or opportunities for satisfaction. At the same time, the insurance service is both consumer and financial, while tourism is only consumer. Thus, travel insurance is a specific product even within the insurance - the provision of financial services for the insurance of transactions for the provision of other services, and this is the peculiarity of travel insurance as a service [8].

The expansion of Ukraine's foreign economic relations requires bringing domestic standards in line with international ones in all segments of the insurance market and the market of tourist services. For insurance companies, this is reflected in the development of principles that ensure the provision of quality insurance services. Tourist organizations are responsible for ensuring the safety of tourists and providing them with financial guarantors.

Insurance is the most important element of economic relations and an effective way to compensate for losses. During the stay of a tourist on a trip outside the territory of permanent residence, the following types of losses are possible:

- damage suffered by the tourist in connection with the dishonest actions of the host party. In this case, the tourist will demand compensation, and usually travel agencies that value their image, will always seek to avoid scandal and provide him with reasonable compensation. To protect the interests of travel companies, it is possible to conclude a civil liability insurance agreement;

- damage suffered by the tourist regardless of the host party: theft, accident, actions from which he was warned by the host company. In this case, you can use all types of property and personal insurance of tourists;

- damage caused by the tourist to the host company by his careless or intentional actions. Tourist liability insurance is the most effective protection [5, 10].

Insurance and risk are inseparable concepts. Risk can be defined as the deviation of the actual result from the desired one. In fact, the deviation of the

expected values cannot, be determined unambiguously, because it depends on the assessment of the entity. Usually the expected values and actual deviations from them are estimated in economic indicators. To determine the risk, the insurer usually uses the information provided by the insured, who is responsible for the accuracy of this information [11]. However, if the insurer has entered into an insurance contract without the insured providing such information, this cannot be a ground for invalidating the contract. The level of risk is reduced through various financial methods, which include insurance. With the growth of tourism, the amount of risks that arise in the field of tourism increases.

Depending on the carrier of risk in the tourism industry distinguish:

- risks that are inherent in consumers of tourist services;

- risks of the enterprises of the tourist industry.

All risks of tourists should be divided into two groups [5, 13].

1. Risks that arise before the start of a tourist trip:

- inability to make a tourist trip with full payment of the tour - a possible measure to prevent risk is «travel insurance», which may include such insurance risks as: death of a tourist or his close relative, hospitalization of a tourist or his relative, refusal of a visa, call to court, conscription, emergency in the house (apartment) of a tourist (fire, flood, robbery, etc.);

- obtaining unreliable information about future travel by tourists - in order to minimize this risk, tourists need a detailed study of future travel with the help of tourist catalogs, attractions, information and reviews in open networks;

- change of flight time - to avoid risk, you can insure regular flight delay, when the insurance company pays the costs associated with the flight delay for more than 6 hours due to technical malfunction of the aircraft or extreme weather conditions.

2. Risks that arise during the tourist trip:

- non-fulfillment of obligations under the contract for the provision of tourist services;

- problems with law enforcement agencies at the place of residence;

- loss of documents and money on vacation;

- financial losses as a result of lost luggage;

- threat to life as a result of illness or accident.

Risks of a tour operator are risks of business activity in a competitive market, which in their composition do not differ much from the risks in any other commercial activity. These risks can be divided into the following groups:

1. Risks of civil liability of the tour operator, among which the risks of civil liability for non-performance or improper performance of obligations under the contract for the sale of a tourist product are allocated to a special group. Risk situations can be such that the amount of damage to be reimbursed at the request of tourists can be very significant. To ensure guarantees of liability of tour operators to customers, the requirement of mandatory financial support of the tour operator in the amounts prescribed by law has been introduced as a condition of its admission to the market. Forms of such security are a tour operator's civil liability insurance contract and a bank guarantee.

2. Market risks include the risks of changes in market conditions under the influence of fluctuations in supply and demand in the market of tourist services. These changes can be provoked by various factors, including local and global economic crises, political events and natural disasters. These factors affect the volume and structure of demand for tourism products, as well as affect the price and other conditions of services included in travel packages. Market risks are not insured by financial instruments. To some extent, the entrepreneur can predict their impact on their business and take them into account when making decisions.

For tour operators operating in the field of international tourism, important elements of market risks are currency risk and transfer and convertibility risks. Currency risk lies in the unfavorable dynamics of the exchange rate for the tour operator, when the appreciation of the currency of the country of the provider of certain services makes it necessary to buy this currency at a higher rate, which leads to an appreciation of the tourist product. Unlike all others, it is a graded risk, ie changes in the exchange rate are unfavorable for one party to the agreement, but beneficial for the other. Currency risk can be taken into account in the company's

activities with the help of hedging instruments - concluding futures contracts to buy currency or purchase options. In large foreign exchange transactions, the use of such instruments justifies itself.

Transfer and convertibility risks are political risks that businesses are unable to withstand. The risk of transfer is that the state stops transferring payments in foreign currency abroad due to its lack in the middle of the country. The risk of convertibility arises in cases where the free exchange of domestic currency for foreign currency is terminated. These risks are related to the country's insolvency due to the persistent deficit of the foreign trade balance and the balance of transfers and payments and the reduction of foreign exchange reserves. These signs can be used to assess the level of risk and its dynamics.

3. Production risks cover the whole set of risks of the firm related to its business activities. These include property risks, liability risks and financial risks. Property risks of a travel agency include the risks to which the property of the tour operator as a legal entity falls. The risks of civil liability in this case are limited to the risks of liability for damage to third parties. Another type of risk of civil liability is the risk of liability for non-performance of contractual obligations - separated into a separate group due to their significant impact on business and the specifics of legal regulation. In this regard, the production risks of the travel company include: the risk of liability of the owner of the vehicle for damage caused to third parties during its operation; the risk of non-repayment of the loan received by the firm; risks of civil liability for other types of property and personal damage caused to third parties.

4. Financial risks of the tour operator. These are the risks of losses from business activities, which are reflected in the loss of expected income and the occurrence of unplanned expenses caused by extraordinary circumstances. Such losses may be caused by breach of obligations by the firm's counterparties, such as non-payment for work performed or services provided, or cessation of activities for reasons beyond the firm's control. As protection against risk in this case, voluntary insurance against temporary cessation of activities is offered.

5. Risks that threaten the lives and health of travel agency managers and staff. To create conditions for effective work of staff, voluntary health insurance is used, which makes it possible to significantly improve the level of medical care and is often part of the social package for employees of the company [6, 12, 14].

The characteristic features of risks in tourism include the following:

- tourist risks may be associated with damage not only for tour operators and travel agents as tourism organizers, but also for other enterprises and organizations and tourists themselves, and in addition affect the flora and fauna, cultural and historical objects. Heritage;

- the level of tourist risk should be subject to strict requirements, as in some cases it includes the risk of death and harm to the health of the tourist;

- tourist risk is formed both by financial and economic, related to the economic activity of enterprises, and natural, independent of human beings and tourism organizers sources of danger, which, among other things, may be interconnected [4].

Thus, we can conclude that tourism is an area of increased risk for all its participants. For tourists who are exposed to risks to health and life in situations of changing their usual way of life and climate, moving and flying. For travel companies that risk bankruptcy very quickly due to higher prices of services and lack of working capital resulting from reduced sales of any tours in conditions where they are actually fully funded from current turnover, and travel companies have no significant share capital or reserves [9].

Risk management by the method of insurance means the organization of the economic process in which the insurance company in case of risk pays compensation to individuals and legal entities. In addition to providing insurance protection, insurance companies can finance measures to reduce the likelihood of risks and losses [13]. Financial risk insurance increases the reliability of the tour operator, it is necessary for many reasons. One of the most important is the clear asymmetry of responsibility: Ukrainian tour operators cannot transfer the terms of the contract with foreign partners and airlines to a contract with a client or agent, as the laws of other countries do not take into account the requirements of Ukrainian law. Thus, the

Ukrainian tour operator initially assumes more responsibility than its partners. Many risk factors are the same, and tourists are encouraged to insure against such cases. In insurance cases, they are provided with assistance and covered in full or in part unforeseen expenses. An insured event is an event that has caused damage to the health or property of the insured tourist, or another event provided for in the insurance contract, upon the occurrence of which the insurance company undertakes to provide assistance and reimburse in full or in part the costs incurred. In developed countries, citizens are insured for almost all cases of life.

Due to its specifics, the tourism business is prone to the fact that at any time there may be circumstances that will cause significant financial problems for both tourists and the travel agency. Today in Ukraine insurance companies provide the following main types of tourist insurance [4, 8, 13]:

1. Personal insurance, which includes the following risks:

- the need for medical care due to an accident or acute illness. This risk involves the payment of outpatient treatment, including emergency dental care, as well as inpatient treatment and the purchase of prescription drugs;

- the need for medical and transportation costs.

2. Insurance of property belonging to tourists covers insurance of personal use (film cameras, cameras, clothing, etc.), which the insured and the insured persons carry with them, or transport on vehicles and insurance of tourist equipment. The most common insurance cases are loss of property, robbery, destruction and breakage of property as a result of a vehicle accident, any illegal actions of third parties.

Baggage insurance provides for the realization of the following risks: loss of checked baggage by the carrier (authorized person) (loss, complete damage); burglary, bandit attack, intentional damage by third parties, loss of luggage.

3. Insurance of expenses of tourists for not made trip. Insurance indemnity is paid in cases where the possibility of a trip has not been realized due to the following reasons: non-receipt or delay in obtaining an entry visa by the insured or a person who makes a joint trip with the insured; illness that prevents the trip, death or emergency hospitalization of the insured person, his wife (husband) and / or his close

relative; damage to the insured property; summons at the time of the trip to court; receiving a call to the military commissariat to perform military duties.

4. Risk insurance of tourist organizations includes financial risks, liability for claims of tourists, their relatives, third parties. The composition of financial risks includes: commercial risks (non-payment or delay in payment, penalties of the counterparty if he does not recognize the circumstances of breach of contract due to force majeure); bankruptcy of the organization; changes in customs legislation, currency regulation, passport control and other customs formalities; occurrence of force majeure circumstances (for example, fires, accidents, explosions, destruction, which caused damage to tourists); unforeseen expenses of tourist organizations caused by the tourist's refusal to fulfill contractual obligations to provide tourist services; political risks.

5. Liability insurance:

- insurance of civil liability of citizens who temporarily go abroad. The object of insurance is the property interest of the insured person, which is associated with the obligation to compensate for the damage caused to life, health, property of a legal entity or individual as a result of illegal and culpable acts under the laws of the country this damage was caused. Such insurance is beneficial for both the tourist and the travel company, because in the absence of funds from the user of the tourist product will have to cover losses on the spot the company itself, and only after the return of the tourist to Ukraine, recourse will be compensation;

- liability insurance of the tourist organization for non-fulfillment of obligations. In the field of tour operator activities today the mechanism of financial support of civil liability of the tour operator and evacuation of tourists from abroad is used. Liability insurance for tour operators is one of the most expensive and mandatory, as the insurer will be liable in the event of bankruptcy of the insurer. In the event of bankruptcy of large tour operators, the sum insured is usually not enough to cover the losses of all consumers of travel services. Many insurance companies today refuse to insure the liability of tour operators due to the opacity of the travel market;

- car owners' liability insurance. The «Green Card» is a system of international agreements of the community of insurance companies that implement compulsory civil liability insurance of motor vehicle owners. The holder of a «green card» does not purchase an additional insurance policy when entering the territory of the country party to the agreement.

6. Assistance (combined insurance) is a specific type of insurance for domestic tourists in foreign countries. Assistance is a service within the insurance contract, provided at the necessary time both in kind and in cash with the help of medical, financial and technical assistance. In foreign countries it is provided by large insurance companies.

The list of specific insurance risks in different insurers differs slightly, in addition, the insured may be offered a choice of insurance policy with a smaller or larger list of insured risks. However, the standard insurance policy does not cover the losses associated with extreme tourism. Therefore, in order to avoid ambiguities, insurance companies describe in as much detail as possible the specific insured events in which they undertake to compensate the victims.

The insurance market of foreign countries has a richer and longer history than the Ukrainian one, and insurance to protect the interests of tourists has become widespread. The generalization of the world practice of tourist insurance is undoubtedly useful and relevant for the development of the domestic segment of travel insurance.

Legislation in European countries has long required mandatory financial liability for tourism organizations. On 13 June 1990, the EU Directive № 90/314, Art. 7 which obliges the organizer or seller of travel services who has entered into a contract with a consumer of travel services, «provide satisfactory evidence of return of money paid by the consumer, as well as payment of repatriation costs in case of insolvency (bankruptcy) of the organizer and / or seller.» The main types of such provision (financial guarantees) of tour operators in the national legislation of European countries are: contractual liability insurance of tourist organizations, bank

guarantees, trust (trust) accounts, bank deposits, guarantee funds or guarantees of tourist associations on the obligations of their members [1].

Each tourist market offers an ideologically designed tourist product. Therefore, the offer of insurance protection for tourists should also be adapted to the concept of a tourist product. The concentration of competitive advantages increases as insurance companies cover the borders of specific territories. In the tourism market, their proposals for tourists are formed and implemented by global insurers, companies from allied countries, national insurers with an extensive branch network, with a limited presence in the regions of the country, with a presence in a particular region (city, town, province) [3].

The first group of companies - global, systemically important insurance companies - control a significant share of the global insurance market and are integrated into global financial markets. The competitive advantages of these companies should, first of all, be connected with their wide opportunities in risk assessment and knowledge of mentality and needs of the population of concrete territories. It can be assumed that global insurers are quite adapted to the business strategy for many areas in the world. Their experience in determining the levels of risk, knowledge of insurance needs, levels of insurance service - all these are positive qualities of the company itself and its insurance product.

These insurers have a wide network of branches, therefore, the tourist will be able to insure risks with a leading company, being in any corner of the world. The largest insurance companies in the world offer tourists a wide range of insurance programs. By choosing leaders, the tourist inadvertently reduces the difficulties associated with contingencies, as these insurance companies offer programs to people who not only travel abroad, but also travelers within national territories. Their range is represented by both classic and advanced insurance programs, the latter of which are modified for the individual needs of the tourist. Accordingly, it gives companies an undeniable competitive advantage over regional insurers.

This model of insurance protection of tourists allows you to provide high quality services and establish stronger and lasting relationships between participants

in the process, as well as improve the quality of doing business by both travel companies and insurers.

Examples of such companies are:

- Founded in 2000 by the Mondial Assistance Group (France), which specializes in tourist insurance and travel assistance. Has offices in 29 countries on 5 continents;

- Seven Corners Inc, founded in 1993, specializes in providing insurance services to tourists in North America and offers its customers comprehensive health insurance, access to a network of international hospitals, multilingual telephone service, available around the clock, constant protection for tourists ;

- Founded in 1982 as a specialized insurer for travel insurance and emergency assistance to travelers Travel Guard (UK);

- EVR (Sweden) was founded in 1920 - insurance companies specializing in tourist insurance and has branches throughout Europe;

- Europ Assistance (Italy) specializes in travel insurance. There are 38 branches worldwide;

- Intermundial (Spain), founded in 1993. The main purpose of the activity is to create and develop products for the tourism sector. The company develops special programs to meet the needs of tour operators, travel agencies, hotels, campsites, airlines, tourists and more.

At the regional (local) level, tourist insurance companies are ready to provide tourist insurance. At the same time, they have a limited presence in the regions of the country, and their proposals in terms of domestic tourism will be adapted to the specific risks inherent in this recreation area. Thus, we see that the competitive advantage for small in terms of capital and capabilities of regional insurers - an individual insurance product for a particular regional consumer. Of course, it is difficult for local insurance companies to compete with insurance market leaders in terms of insuring people traveling abroad: they provide the tourist with only minimal protection, without choosing any additional options and services.

The list of insurance services for tourism in foreign countries is diverse and can reach 8-14 insurance risks for one special travel policy. Thus, abroad the most common risks covered by travel insurance are: medical (emergency medical and inpatient care), including dental expenses; evacuation (medical evacuation, repatriation); cancellation / interruption of the trip; accident; departure delay; lost, stolen or damaged luggage, personal belongings or travel documents; legal assistance; risks associated with car rental; extreme sports; natural disasters; terrorist acts; kidnapping of a tourist.

Social health insurance in almost all countries does not provide reimbursement of medical expenses outside the country [7]. The US government is urging Americans to consult with health and insurance companies before traveling abroad to determine how best to protect themselves in the event of an insured event. For example, in the United States, the Medicare social insurance program does not cover hospitals and medical expenses outside the United States, so health insurance can only be used in the United States and Canada. Thus, there is a separation of travel and health insurance when the payment of hospital and other expenses abroad is the responsibility of the tourist. Travel insurance insures financial investments in travel. As a rule, it covers such things as the cost of lost luggage and cancellation of flights and does not cover the cost of medical care that may be needed abroad.

Regarding health insurance for tourists, it should be noted that, for example, some countries (France, Germany) make it compulsory for health insurance for tourists with a fairly high coverage limit for insurance costs (up to 30 thousand euros) [2]. Tour operator's professional liability insurance funds have been established in a number of countries. In Switzerland, the Czech Republic, and Germany, on behalf of the government, such funds form public associations. In the UK, the Association of British Travel Agencies (AVTA) accepts only reputable companies, and membership in AVTA is a kind of guarantee of the company's reliability.

In our opinion, the main problem facing the domestic tourism industry is the lack of a well-established mechanism for protecting domestic tourists abroad: there is no developed insurance system that would be recognized worldwide, and the lack of

attractiveness of the domestic insurance market for foreign participants . If you take into account the experience of many foreign countries, then with an insurance policy, a foreign tourist will not pay additional own funds, and the hotel will not take the tourist hostage, demanding payment of the debt of the tour operator. In this case, it will be enough for the hotel to rewrite the insurance policy number, and all problems will be settled by the insurance company. In the domestic version, this system is very complex and has a negative impact on the attitude of tourists to the Ukrainian tourist and insurance service. The tourist must pay the contingencies himself, and then, returning home, prove and defend his right to compensation.

In this regard, in our opinion, regarding the insurance of tourists' risks at the institutional level, it is necessary to solve several main tasks: to provide a clear mechanism for the protection of Ukrainian citizens abroad from unforeseen situations; to create in almost every country where Ukrainian tourists go, specialized services to resolve their problems or to create a specialized structure at the Ministry of Foreign Affairs with the possibility of prompt travel to a country of its representatives to resolve problems; to optimize the system of tourist insurance with the revision of insurance rates in the direction of their reduction; shift the burden of responsibility on insurance companies, tour operators and associations of tour operators.

Based on the field of insurance services, it was found that it is necessary to carefully develop measures, methods and methods of insurance in the field of tourism. Because any citizen, traveling abroad, must be insured against possible risks. In foreign practice, insurance companies provide legal and informational support. Such services are very convenient for the tourist and increase the rating of the insurer. The legal aspect means providing legal support to tourists in fixing administrative and civil violations. The information aspect provides advice on the following issues: the purpose of the trip and the region of rest; the level of the health care system in the host country; way of vacation (on the beach, sports); trip with children or alone; the most convenient routes for travel in the country of stay; information about the sights of the host country [14].

We consider it necessary to identify the main areas of improvement of insurance services in Ukraine: increasing the volume of insurance services provided; service development; application of the most advanced forms of service; introduction of new types of services and innovations; improving the quality of services provided; reduction of time spent on assistance; improving the culture of service, reliable advertising; development of computerization; creating conveniences and comfort for citizens who use the insurance service.

For the development of the domestic tourism insurance market, it is necessary to strengthen measures to promote the types of insurance for domestic tourists traveling to Ukraine, to break it down into subspecies of such trips and to establish its own amount of financial support for each of them. It is necessary to carry out a strict specification of the sphere of tourist services, which will make the industry attractive for large insurance companies, as well as to remove the responsibility from insurance companies for intentional actions of tour operators [6].

The catalyst for the expansion of the travel insurance market may be the adoption of regulations on improving the liability insurance of tour operators, improving the insurance literacy of tourists, the use of comprehensive insurance, a system of benefits and bonuses for different categories of tourists.

To increase the insurance literacy of users of domestic and outbound tourism services, insurance companies should be advised to provide advice, explain the specifics of tourist insurance, including the main parameters of the insurance agreement: insurance risks, insured events, insured events, insurance amounts, claims settlement process. Such consultations can be carried out in travel agencies, offices of insurance companies or in the form of online consultations with the subsequent conclusion of contracts that take into account the individual needs of each consumer in insurance protection.

Thus, the issues of tourist safety during the holiday are relevant for any country, regardless of its level of economic development. Manifestation of this circumstance is expressed in improving the quality of the tourist product, improving the image of the recreation area and, as a consequence, the development of tourism in

the country. In turn, insurance companies are ready to ensure the safety of tourists, offering an effective mechanism - insurance protection. The quality of the insurance product depends on the insurance offer and the actions of the insurer. First, without an understanding of the tourist's own needs and without a proper explanation of the insurance rules by the insurer, the quality of the sold insurance product will be very low. Secondly, having satisfied the needs of the tourist in insurance protection at the time of its purchase, the insurer must fulfill the obligations later (if the insured risk). Third, when purchasing insurance coverage, the tourist must master the skills of applying insurance for travel safety, and the insurer must not only explain at the time of the insurance contract, but also accompany the risk subject (tourist) during the insurance period.

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3.3 Innovations, environmental investments and incomes of the Environmental Kuznets curve: national economy of sustainable development

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Nowadays globalization causes on the one hand new development conditions, on the other hand – new threats. That is why the problem of parameters`, conditions` and mechanisms` formation of sustainable development in Ukraine in the context of deepening ecological crisis and taking into account national economy specifics needs to be solved. Accordingly, the degree of environmental risks and threats now is largely determined by the political efficiency in the field of both emissions contraction, waste generation and its management. This requires environmental policy adjustment, taking into account the need to develop and implement comprehensive strategies aimed at lower pollutant emissions while identifying impact factors of the level of environmentally friendly manufacturing. Therefore, the study objective is to determine sustainable development conditions by the criteria of pollutant emissions including impact factors modelling of the parameters` and environmental situation in Ukraine.

Most researchers believe that the correlation between income (economic growth) and environmental pollution is nonlinear and has the form of inverse parabolic curve. Simon S. Kuznets is the author of the - environmental Kuznets curve (EKC). Figure 1 shows the dynamics of the relationship between the per capita

income in Ukraine and sulfur dioxide, nitrogen dioxide, carbon oxide and dioxide emissions volumes (EKC).model.

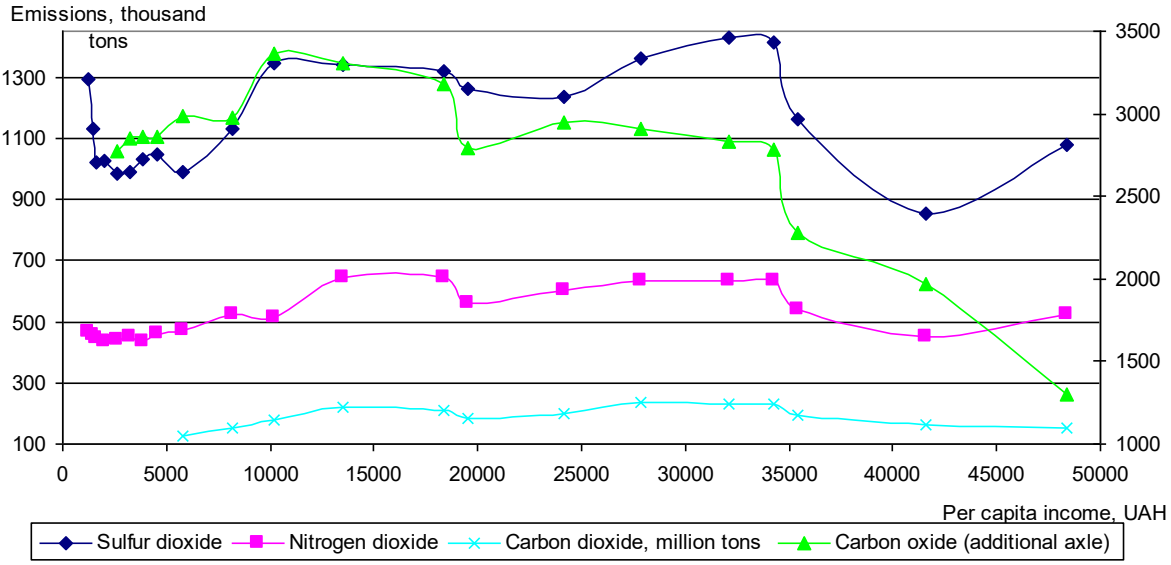

Figure 1 Dynamics of the relationship between the per capita income in Ukraine and sulfur dioxide (from 1990), nitrogen dioxide (from 1990), carbon oxide (from 2000), carbon dioxide (from 2004) emissions volumes till 2017

We have proved that these dependencies for Ukraine have been formed by the leading branches of its national economy: mining and quarrying; processing industry; supply of electricity, gas, steam and air conditioning; transport, warehousing, postal and courier services; agriculture, forestry and fisheries.

Share and dynamics of pollutant emissions and carbon dioxide emissions in these industries during 2010-2017 are defined in Table 1. As one can see, the lowest degree of emissions is in agriculture, the highest – in energy. Metallurgy occupies significant share of processing industry emissions, so special attention will be paid to its analysis.

The ratio of the average monthly nominal wage in the industries with the corresponding mean values for Ukraine have been determined the same way (Table 2). Thus, the highest wages are in mining, the lowest – in agriculture. In 2017 the employment rate in the analyzed industries was about 40% of all employed persons in Ukraine (Table 3). The largest rate was in agriculture, the smallest – in mining.

Table 1 Shares of pollutant emissions, total (pollutant emissions / carbon dioxide emissions) of point sources by fields of economic activity in total emissions in Ukraine, %

Years	Agriculture, forestry and fisheries	Transport, warehousing, postal and courier services	Mining and quarrying	Processing industry	Supply of electricity, gas, steam and air conditioning
2010	0,47 (1,7/0,4)	3,42 (4,7/3,4)	1,93 (20,6/1,5)	35,75 (32,6/35,8)	57,56 (38,8/58,0)
2011	0,42 (1,7/0,4)	2,86 (4,5/2,8)	2,25 (19,6/1,9)	43,99 (31,7/44,3)	49,54 (41,3/49,7)
2012	0,98 (1,8/0,4)	2,00 (3,8/1,2)	2,56 (20,4/2,2)	41,07 (29,4/41,3)	53,15 (43,4/53,4)
2013	0,53 (2,1/0,5)	2,23 (3,9/2,2)	2,58 (21,4/2,2)	41,26 (28,7/41,5)	52,62 (42,8/52,8)
2014	0,55 (2,4/0,5)	2,15 (3,9/2,1)	2,12 (17,5/1,8)	39,11 (30,4/39,3)	54,62 (43,8/54,7)
2015	0,84 (2,7/0,8)	1,76 (2,7/1,7)	2,12 (17,2/1,8)	41,17 (32,9/41,3)	51,78 (41,1/52,0)
2016	0,62 (2,7/0,6)	2,44 (2,0/2,4)	2,24 (15,1/2,0)	40,39 (31,7/40,6)	52,38 (46,0/52,5)
2017	0,93 (3,1/0,9)	3,51 (2,4/3,6)	3,03 (18,5/2,7)	39,40 (33,8/39,5)	51,16 (39,1/51,4)

Table 2 Ratio of the average monthly nominal wage in the industries with the corresponding mean values for Ukraine, %

Years	Agriculture, forestry and fisheries	Mining and quarrying	Transport, warehousing, postal and courier services	Processing industry	Supply of electricity, gas, steam and air conditioning
2010	63,87	158,06	118,71	102,19	135,24
2011	70,38	165,97	102,89	105,24	127,35
2012	68,27	161,30	96,63	102,35	126,27
2013	69,59	161,99	109,92	101,41	137,83
2014	71,15	156,47	108,28	102,59	140,37
2015	74,85	146,94	110,92	106,72	130,20
2016	75,55	143,97	112,10	106,95	133,47
2017	81,10	136,60	108,22	102,74	119,55

Table 3 Employment rate in the field to all employed persons in Ukraine, %

Years	Agriculture, forestry and fisheries	Mining and quarrying	Transport, warehousing, postal and courier services	Processing industry	Supply of electricity, gas, steam and air conditioning
2010	15,26	2,21	5,97	9,47	2,81
2011	16,72	2,21	6,01	9,26	2,84
2012	17,18	2,16	5,94	11,41	2,87
2013	17,53	2,10	5,99	11,15	2,79
2014	17,10	1,99	6,16	11,19	2,86
2015	17,46	1,59	6,07	11,19	2,88
2016	17,61	1,47	6,13	11,01	2,85
2017	17,71	1,36	6,14	10,99	2,76

We have also compared the share of gross value added (GDP by sector) of the analyzed industries in 2017 with the total GDP of the country (Table 4).

Table 4 Share of gross value added by types of economic activity to GDP of Ukraine, %

Years	Agriculture, forestry and fisheries	Mining and quarrying	Transport, warehousing, postal and courier services	Processing industry	Supply of electricity, gas, steam and air conditioning
2010	7,4	5,7	7,8	13,0	2,8
2011	8,1	6,3	8,0	11,8	3,1
2012	7,9	5,7	7,1	12,2	3,1
2013	8,7	5,4	7,2	11,2	2,9
2014	10,2	5,0	6,4	12,2	2,8
2015	12,1	4,8	6,8	11,9	2,7
2016	11,7	5,5	6,6	12,2	3,1
2017	12,1	5,6	6,7	12,1	2,9

The largest share of GDP was generated in the processing industry, the smallest – in the field of electricity, gas, steam and air conditioning supply. In 2017 agriculture`s, forestry and fisheries`, and the processing industry`s shares in GDP were equal.

Thus, agriculture having the lowest degree of emissions and waste generation, generates the same value added (GDP by sector) as the processing industry, which is the leader in pollution (metallurgy gives the biggest part of pollution). At the same time, the industry that accounts for the largest share of pollution – energy, generates the smallest share of GDP in the country.

The obtained results reveal that the «turning point» for Ukraine on the EKC was reached in 2013 (income –UAH 34264, average nominal income per employee – UAH 39180). Industries that reached the final «turning point» in 2013 accumulated 46.07% of pollutant emissions and 20% of the employed population of Ukraine. Among 20% of employed persons, 2.1% worked in the mining characterized by 1.61 times higher wages than the average; 11.5% – in the processing industry having the average income; 5.9% worked in the transport industry with slightly higher income than the average in Ukraine.

However, energy and agriculture, reaching the turning point in 2014 – 2016, employed the same 20% and formed almost the same amount of 53% of pollutant emissions. Among 20% of employed persons, 2.8% worked in the energy sector characterized by 1.5 times higher wages than the average; 17.1% – in agriculture, having the average income.

Thus, comparison of the obtained results shows that 20% of the working population in Ukraine being employed by industries that generate 46% of pollutant emissions ensure the «turning point» on the EKC, if national average nominal income per worker and steady growth of environmental costs for at least two years are reached.

The analysis demonstrated that the industries like mining and quarrying, agriculture, fisheries and forestry have one «turning point», others – two. We believe that these sectoral features may be related to the environmental costs. Table 5 illustrates the results of pollutant emissions` and sectoral environmental costs` growth rates analysis. Their analysis allows us to conclude that in Ukraine, not only average nominal income per employee, but sectoral environmental costs matter.

As one can see, to achieve the «turning point» in the mining, it was necessary to increase environmental costs` growth rate during two years. Having high level of wages in the industry, the result was achieved in 2013. The processing industry has similar pattern: as the required income per employee was achieved in 2013, it has two «turning points». Transport, warehousing, postal and courier services industries had two «turning points» as well; the upsurge of environmental costs also lasted for two years. In addition, as one can see, after a two-year growth of environmental costs and «turning point» reached by all industries, pollutant emissions contracted. If environmental costs dropped off, emissions rose.

In the energy sector despite high average nominal income per employee (UAH 40236 in 2011), the dynamics of sectoral environmental costs constantly increased or decreased, then during 2014-2015 they were rising and therefore, in 2016 the «turning point» was reached.

Table 5 Dynamics of chain weighted growth rate of pollutant emissions and sectoral environmental costs

Years	Growth rates, %									
	Mining and quarrying		Processing industry (metallurgy)		Supply of electricity, gas, steam and air conditioning		Transport, warehousing, postal and courier services		Agriculture, forestry and fisheries	
	Emissions	Environmental costs	Emissions	Environmental costs	Emissions	Environmental costs	Emissions	Environmental costs	Emissions	Environmental costs
2011	*142,11*	*157,11*	***150,28*** **(161,68)**	***127,04*** **(126,61)**	105,10	97,95	***102,12***	***346,67***	*109,39*	*153,02*
2012	*111,34*	*106,65*	*91,52 (92,37)*	*106,65 (119,95)*	105,17	114,88	*68,58*	*122,96*	*230,93*	*135,99*
2013	***100,47***	***89,62***	***100,16*** **(102,19)**	***97,04*** **(106,85)**	98,72	38,48	***111,07***	***41,07***	*53,37*	*271,94*
2014	63,62	127,82	73,38 (70,33)	95,78 (102,92)	***80,36***	***382,58***	74,57	59,63	***80,17***	***31,63***
2015	90,94	103,73	95,47 (95,54)	100,39 (97,25)	*86,00*	*102,10*	74,37	90,64	139,30	111,77
2016	114,39	99,44	106,33 (109,93)	125,84 (140,29)	***109,62***	***177,10***	149,98	264,21	80,81	190,87
2017	111,64	114,93	80,50 (74,19)	103,33 (94,13)	80,60	64,01	118,99	70,31	122,91	116,83

Agriculture, forestry and fisheries had positive environmental costs growth; the «turning point» was reached only in 2014 due to low wages in the industry.

Parameters of national economy`s sustainable development by pollutant emissions have been modelled in the paper. It has been proposed to apply sectoral approach and the model of the environmental Kuznets curve (EKC). Modelling has been made for the following industries: processing; mining and quarrying; agriculture, forestry and fisheries; supply of electricity, gas, steam and air conditioning; transport, warehousing, post office and courier service.

It has been proved that the sectoral EKC reflects the progress towards industries` sustainable development that form the main budget incomes and determine wages in the real sector of the economy. The EKC parameters` modelling for waste and emissions fully corresponds to the trends of sustainable economic growth and its transition to the innovative development pattern.

The study of sectoral EKC revealed close correlation between environmental investment, investment activity and skilled labour force. Sectoral environmentally friendly investments can induce significant effect without drastic changes in the production structure. It has been confirmed that stable sectoral investments in environmental protection together with sufficient income of employees, form the conditions for national economy`s sustainable development. Environmental investments allow to modernize production, surge R&D intensity and profitability of the applied technologies. This will reduce emissions and increase wages. Indeed, higher R&D intensity of production will induce the need for highly qualified personnel with wages bigger than average. The second important outcome of environmental investments will be more qualitative and competitive products, their effective market promotion.

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3.4 Impact of export-biased policy in the development of automotive industry

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In the modern world the automotive industry is the leading field of the developed countries` national economies. The volume of the produced cars, vans, tracks and buses is one of the key elements of the world economy functioning as well citizens` wellbeing. The industry determines to a wide extent technological progress` trends, being one of the key innovators accumulating EUR 84 billion investments in R&D. Automotive industry reflects technological level of the related industries and the society itself. Also automotive industry satisfies needs of every individual customer. It is an important source of funding for a state budget. The automotive industry is a leading field for South Korea as the country is highly integrated into modern mechanical engineering structure. As one of the world car-makers, the Republic of Korea participates in powerful international trade agreements. The government supports preferential environment for the development and operation of multinational companies specialized in car-making and supplement products manufacturing. The degree of the automotive industry's development indicates the level of country's development, as it creates highly added value products. Due to the scale effect the automotive industry creates additional jobs.

High economic growth rates of South Korea, national programmes supporting export-biased growth in different economy fields (the car-making) have been the

subject of Jai S. Mah [1], J. Jung [2], Chang Ha-Joon`s [3] research. The researchers stated the intensive export production growth in South Korea, increasing country's ratio of dependence in foreign trade, especially on early stages of economic development. Andrew E. Green analyzed the environment of the automotive industry's development in the Republic of Korea, also the author noted the unmediated government`s role in the acceleration of more efficient and technological in comparison with competitors` production development [4]. Though state interference in the field's development has some advantages over private incentives, the presence of tough competition in the world market cannot guarantee long rate positive outcomes of the state export-oriented programmes implementation. Examining the present position of the Korean automotive industry Hang Koo Lee proves the leading governmental role in the green and highly technological market development. Accordingly strengthening of cooperation relations between government and car-makers in the R&D sphere allows to reduce oil consumption and increases the safety level [5].

The objective of the article is to examine peculiarities of export-biased policy in South Korea, in particular its impact on automotive industry's development, one of the most competitive industries of the Korean economy in the world market.

Participation of the South Korea's automotive industry in the international labour division became possible due to its modernization and transformation from cheap low quality production into high technological competitive global industry. Thus in 2010 the country became the fifth biggest world car exporter. In 2012 the automotive share in total national export was 13.1% (petroleum products – 10.3, semiconductors – 9.2, machinery – 8.8, petrochemical industry – 8.4%). Hence in 2012 Korean car-makers reached the highest export rates in the amount of 3,171 units (USD 71.8 billion), particularly due to the improved quality and production safety, Free trade agreement with the USA realization, spread of global management principles, foreign markets expansion by the Korean enterprises. Notwithstanding the decrease of production turnover, contracting of domestic sales, economic uncertainty growth, reduction of consumers` loyalty to local producers, strikes, initiated by

industry's trade unions in the period of 2008 – 2015, the automotive enterprises ramped up their presence in foreign markets. International production of Hyundai-Kia in 2012 increased by 15.8% owing to intensified competition with the USA, China, India, Czech Republic, Slovakia. Bigger international market share gains were put into action on the basis of new local markets` models. South Korea started its third plant in China and a new plant in Brazil. Nevertheless, a number of world broad-based economic shocks affected the industry during the leas few years. As a result, in 2019, around 3.95 million units of vehicles were manufactured in South Korea, which is down from about 4.03 million in 2018. The downward trend is a peculiar feature of development in recent years.

Sector's high competitive level is based on the state export-biased policy, focused on industry's development, i.e. technologies and productivity. Direct and transparent policy of industry's development was combined with R&D funding, facilities development, fostering accelerated enterprises` growth, mainly Hyundai Motor Company, Motors Corporation Kia, Daewoo Motor Corporation and other. Besides progressive restructuring took place amid field's business environment, favouring enterprises` strategic priorities adjustments to the national macroeconomic goals. «A big push policy» gave the industry chance to swift from assembly facilities stage to the innovative production phase. According to a long-run automotive industry development plan (part of the heavy and chemical industries industrialization plan) the government protected domestic market and assisted formation of strategic alliances with multinational businesses. Fostering of infrastructure and heavy industry's industrialization, especially the production of steel, contributed development of the automotive industry's advantages [6, p. 129]. For decades the state supported employees` training programmes, investments, imposed tax preferences, subsidies, loans, have positively affected country's export capacity and total production facilities of enterprises.

Korean exporters have the right for the corporate tax reduction by 80% for the purpose of R&D maintenance and attraction of foreign direct investments. Starting in 2005 foreign direct investments in the automotive sector were granted a remission of

corporate taxation during first 10 years in the Korean market performance and 50% R&D expenditure tax reduction. Changes in the South Korean tax legislation that came into force on January 1st, 2014 entailed corrections to attracted foreign direct investments concessional taxation, which includes high-tech and services sphere FDI. These companies are eligible for 100% exemption from corporate income tax during three-five years and 50% reduction during further two years in proportion to the foreign shareholding ratio [7].

Export-biased policy of the Korean automotive industry is also supported by the protective trade policy. Traditionally South Korea uses duties drawback system to cut down export goods` prices, for example, foreign origin raw materials used in export goods processing during two years after it being imported [8].

Financial non-tariff regulation tools include state loans, export funding, export insurance. Loans for vehicle producers are usually granted preferentially, i.e. through the Export-Import bank and commercial banks network. The Korean export insurance fund was organized to assist export, implement initiatives fixed in the Export insurance act.

Export potential promotion in the Republic of Korea is directly linked with creation and efficient operation of Free trade zones regulated by the Free trade zones law. Free trade zone is a territory out of state duty boundaries where free manufacturing, logistics and distribution are guaranteed, a wide range of supportive initiatives like duties drawback, tax preferences (VAT and corporate income tax) are granted, favourable investment environment for foreign companies and national export companies is built. Foreign cargoes are absolutely mobile inside Free trade zones. Korean goods on FTZ territories are classified as export, and levied duties are the subject to reimbursement. There is low rent for land for owned factories and standardized factories. Amid Free trade zones enterprises acquire access to the instruments simplifying doing business and oriented on all management levels social-economic activity effects` advancement. In particular, enterprises get access to one-stop services provided by administrative agents from the Ministry of Trade, Industry & Energy stationed nearby (factory construction and registration, foreign investment,

tax breaks and import/export paperwork). Municipalities give subsidies for facilities, employment, training as well as special subsidies given for investments in free trade zones` development. There is a rent-free lease of land and standardized factories for 10 years for foreign enterprises which invest in local factories where foreign ownership is at least 30% or the largest shareholder is a foreigner. For example, new investment of more than USD 1 million in advanced technology industries, industry support services and new investment of more than USD 5 million in components/material industries means 100% exemption (rent-free). In case of new investment of more than USD 5 million in manufacturing Korean government grants a 75% exemption. Tax breaks in free trade zones concern corporate and income taxes too. Manufacturing investments of more than USD 10 million entail absolute tax exemption for the first three years and 50 % tax breaks for the following 2 years.

But in the Masan Free Trade Zone advanced technology industries and industry-support services investments bring about 100% corporate and income taxes exemption for the first 5 years and 50% exemption for the following 2 years. On the local level foreign enterprises are free for 15 years from obligations to hire social minorities, i.e. senior citizens, veterans, people with disabilities, etc.

Nowadays there are some Free trade zones in the Repiblic of Korea like Masan Free Trade Zone, Gunsan Free Trade Zone, Daebul Free Trade Zone, Donghae Free Trade Zone, Yulchon Free Trade Zone, Ulsan Free Trade Zone, Gimje Free Trade Zone. The leading car-makers of South Korea (i.e. Hyundai Motors, GM Korea, Tata-Daewoo, Doosan Infracore, Tong Yang Moolsan, LS Mtron) locate their production facilities in Free trade zones. Besides, the neighbourship of some FTZ to industrial clusters, for example Gunsan Free Trade Zone to the nation’s premiere automotive parts cluster represented by Daewoo Motors, GM Korea and TATA, is certain to become the center of the local automotive industry. The Daebul Free Trade Zone has an advantageous geographical position for vehicles and automotive parts exports via international ports of Gwangyang and Mokpo.

The Ulsan FTZ is located in the center of industrial cluster which specializes in petrochemical production, shipbuilding, large-scale car-making. Highly efficient

industrial business environment for maximizing productivity and synergies was created due to close cooperation links between industrial cluster and FTZ, related industries development (steel making, machinery and logistics). 23% of total vehicle production (Hyundai Motors, Hyundai Mobis) is concentrated in the Ulsan FTZ.

The Gimje Free trade zone supports global logistics industries both with sparking development of the secondary sector, machinery, car-making, electronics, biotechnology which form FTZ`s competitive advantages by attracting foreign investment and promoting international trade's preferential terms, especially with China [9].

The Masan FTZ was launched in 1970 as a free export zone. It is considered to be the first foreign industrial complex of South Korea. The Masan FTZ was transformed into the intra-industry trade center on account of its specialization in industrial products and foreign direct investment attraction and access to industrial infrastructure (roads and ports), proximity to the aerospace, shipbuilding and auto parts enterprises.

A substantial shift in automotive industry`s development has resulted in the signing of a Free trade agreement between the Republic of Korea and the USA which came into force om March 15th, 2012 [10]. Moreover, South Korea promulgated the strategic trade development trends such as Transatlantic partnership and Transatlantic trade and investment partnership with the USA and the EU. Signing of the FTA was considered by the South Korean authorities to be the method of the American car and other industrial goods` market access. The distinctive features in the Korean-American mutual trade before the FTA signing were the soaring Korean vehicle import by the USA, the rising share of the US-produced Korean cars, the American car-makers` negative voices towards the Korean parts` reluctance to annihilate trade barriers or to soften trade instruments which discriminate the American products in the Korean market. As a result of the FTA coming into effect, was the US responsibility to abolishe passenger vehicles` 2.5% duties, i.e. with electric and hybrid motors by 2016. South Korea made a commitment to cut off passenger vehicles` duties to 4% and to remove the remaining tariff in 2016. Also South Korea

dropped its 10% duty for trucks, while the US 25% import tariff remains in place during the next seven years and will be fully phased out in 2021. Nevertheless, the Agreement allows passenger vehicles` tariffs renewal by the USA in case national car-makers are claiming and arguing the fulfillment by the South Korean part the FTA articles. The USA-South Korea FTA gives the possibility to the U.S.-based producers, including foreign-owned automakers such as BMW or Toyota, which meet U.S. federal safety standards, to export as many as 25,000 cars directly to South Korea. However, the standard means enterprises` maintenance of the non-tariff domestic content provisions. At this time of the FTA implementation the American companies satisfy the South Korean fuel economy and greenhouse gas emissions standards [11].

According to the American nonprofit consumer advocacy organization Public Citizen the outcomes of the USA – South Korea FTA was the hasty growth of the Korean passenger vehicles imports of the USA (USD 263 million) if to compare with USD 12 million average American exports to South Korea. The total imports in January, 2014 peaked USD 2 billion. In 2013 in comparison with period before the FTA`s 2011 about 125,000 more Korean-produced Hyundais and Kias were imported and sold in the United States` market. Increased sales of Fords, Chryslers and Cadillacs by 3,400 vehicles were caused by the growing Korean demand for foreign car-makers production. The result of the US-South Korea trade flows adjustment was the boost of the American trade deficit by 19% [12].

In 2018 the USA and South Korea signed a revised version of the United States-Korea Free Trade Agreement (KORUS), removing a few regulatory burdens for US automakers to export cars, extending a 25 percent US tariff on imported Korean trucks, and lifting a cap on US car exports to South Korea that don’t need to meet Korean safety standards. KORUS made the framework for both countries to sell more than USD 60 billion in cars, machinery, and other goods to each other avoiding a series of restrictions. By now South Korea is US` sixth-largest trading partner. As one can see, by 2018 the top import categories of the USA from South Korea were vehicles (USD 18 billion), machinery (USD 15 billion) and electrical machinery

(USD 14 billion). Among the top import categories of South Korea were machinery (USD 7.9 billion), electrical machinery (USD 5.7 billion), optical and medical instruments (USD 3.5 billion), and aircraft (USD 3.3 billion).

Trade relations between South Korea and European Union were also strengthened and reached a new level after The free trade agreement coming into effect on July 1st, 2011. It was the first EU trade deal with an Asian country. The Agreement`s aim is not only to boost bilateral trade and economic growth in partner-countries, but also to have a wider impact in Asian countries markets, i.e. third countries markets, willigness to doing free trade business with new partners in Asia. Countries achieved an agreement in automotive, pharmaceuticals, medical devices and electronics sectors. They made commitments to phase out and to escalate non-tariff measures. Specifically, there were some significant non-tariff barriers for the European car-makers` market access in the Republic of Korea. South Korea considered many European standards and recognized European certificates as equivalent. After entering into effect the FTA in the automotive sector considerably influenced export volumes to South Korea. 27.7% growth was achieved in 2012 (EUR 2 billion or 75 000 units in 2011 by EUR 2.5 billion or 95 000 unites in 2012). The South Korean export changed by 14.9% from EUR 3.4 billion in 2011 to EUR 3.9 billion in 2012. This corresponds to the increase from 383 000 to 402 000 cars. The EU trade balance in the sector, although still negative, has improved after the FTA execution. The entrepreneurs from the Republic of Korea have invested in automotive factories of the EU. There is a tendency for German premium cars rising sales in Korea (BMW, Mercedes, Porsche, etc.). In April 2012, the French automaker Citroen resumed sales in the Korean market after a decade-long hiatus. Italy's Fiat also has returned to Korea for the first time since 1997 [13]. Moreover, during 2010-2016 both South Korea and the EU reduced tariffs on imports in the automotive sector by around 95%.

South Korea-Australia Free trade agreement was signed on April 8th, 2014 and came into force on December 12th, 2014. This agreement supports the closest and interrelated international economic relations in the Asian-Pacific region. The FTA of

the kind significantly liberalizes the Australian trade with the fourth rank trade partner. Specifically the FTA means South Korea cuts off tariffs on a wide range of manufactured products, except energy and minerals, forest products for the next seven years. From January 15th, 2015 Australia eliminated import tariffs on the Korean automotive products, in consequence the price of the Korean imported cars dropped. On average the Australians save USD 250-1000 as 5% import tariff does not exceed the recommended retail price. Kia refused of the planned price rises in January 2015, as well as new models were supplied with additional advanced equipment. The similar strategy of Hyundai to introduce extra equipment is threaten by the currency fluctuations. This will make it harder to reduce prices in the Australian market [14].

The Free trade agreement grants some preferences to the Korean automotive industry. Primarily it concerns Korean vehicle import duties cut after the FTA implementation. The 5% cuts to import duty foster the Australian stagnating vehicle market recovery both for Hyundai and Kia from 2015. Notably The Australian Department of Foreign Affairs and Trade agreed to phase out gasoline vehicles duties which trade volumes comprise 76% in total sales. Duties on other types of vehicles will be gradually reduced during three years. The Agreement's implementation allows the comparison of trade advantages received by the Korean automotive industry with the preimplementation period. Company data showed soaring Hyundai Motor sales in the Australian market during 10 month period in 2014 to 80,700 units (6.1%) while Kia Motors' sales fell 9.9 percent [15]. Negative stock market tendencies, Hyundai Motor and Kia Motors shares fall down are estimated as short-running as The Free trade agreement taking into force means cheapening of the imported from Australia raw material (iron ore and coal).

As the fifth car-exporter in the world economy South Korea continues its aggressive foreign markets expansion policy which countervails domestic market constrains, sharp European, American, Indian car-makers competition. Rising competitiveness of the automotive sector depends on close cooperation strategic agreements with China as for low cost cars joint manufacturing. China`s

representatives outlook strengthening of trust between countries in the form of transfer of the set of equipment rights for the automotive enterprises in China. This strategy is based on the world forecasts of the leading countries automotive sector development, i.e. possible reallocation of the market forces, activity concentration in the pointed key directions. South Korea along with Japan and France can become centers of premium class vehicles production whereas Germany, Italy, USA will be transformed into luxury cars R&D research centers. The increased globalization processes require new global development strategies implementation by the Korean designers, i.e. adding to the traditional foreign market presence in the form of greenfield foreign investments, joint ventures integration to the world R&D system. The first step to the international R&D consolidation was started by Kia Motors Corporation and Japanese trade-partners The Research center and R&D center. Kia Motors Corporation has close R&D links with the Research institute in Detroit (USA) and Automotive research institute in Los-Angeles (USA). Technology research institute was founded by Hyundai Motor Group in the USA. A new R&D center opened in Frankfurt by the Hyundai Motor Group aimed to develop technologies and goods complying to the European needs. This gave a grounding to the creation and further development of the R&D net, which linked the leading automakers of the USA, Japan and EU. Thus, the formation and development of the global resources chains are reflected in the development strategies of companies and state's long-run world automotive market footprint forecasting.

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3.5 Sustainable development of agriculture as the strategic natural and economic system of Ukraine: indices, problems and perspectives

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Present sustainable development paradigm of a society covers global problems of economic, social and environmental development and formulates visions and goals for the future. The main sustainable development goal is to provide world population with food, so the most relevant and developed is sectoral problem of agribusiness' sustainable development. In our opinion, the agricultural sector is the closest to environmental and food problems, as it is a complex system of agricultural production, environment and rural population.

The concept of "agriculture" combines social and production, and environmental functions, sectoral and territorial aspects, i.e. it is a system based on

agricultural sector surrounded by rural environment with the appropriate resource base (spatial, natural and labour).

Sustainable development is a key principle that should support present day and future agri-food policy aimed at creating social and environmental, and economic territorial systems that counteract anthropogenic overburdening and preserve natural potential for agriculture, industry, craft industry and business, tourism, recreation and other areas of economic activity.

Application of the latest technologies of tillage, harvesting, introduction of new varieties of plants and breeds of animals by some agricultural enterprises have led to a gradual labour productivity growth in agriculture. But the level of labour productivity remains low relative to the world indicators, which is one of the main problems of agricultural sector`s sustainable development. This is due to worn-out production assets, outdated technologies, underdeveloped rural infrastructure. The "Sustainable Development Goals: Ukraine" national report identifies a number of tasks for agricultural development, including doubling labour productivity by 2030 (up to $ 15,000 per employee), which will contribute to the balanced gross agricultural output growth.

Development of agriculture is especially relevant today as the increase in output of agricultural products ensures socio-economic progress of society, poverty reduction, solution for the food security problem both at the regional and global levels. Favourable climatic conditions for the agriculture, fertile soils, geographic position of Ukraine, considerable agroindustrial potential open wide prospects for the sustainable economic development of the country, which can be achieved at the expense of increasing efficiency of agricultural production based on the increase of labour efficiency. One of the important issues of the economy of agriculture is production ramp-up at the expense of effective use of labour. Labour productivity in agriculture is a multicomponent system that is influenced by a number of factors and is an integral indicator of the degree of development of technology, labour organization, and a high level of labour productivity provides an improvement in the quality of life of the rural population and an increase in wages. It is a human factor,

which is associated with categories «labour» and «human capital» that serves as deciding factor in the economic growth. Despite the considerable amount of scientific research on increasing the efficiency of labour use in agriculture, the identification of reserves of labour productivity growth in the conditions of the interaction of technological and economic-organizational peculiarities of agricultural production with natural-biological laws of nature remains relevant. Issues of labour productivity are considered in works of D. Boginya, V. Vitvitskii, V. Gorkavyi, V. Diesperov, E. Libanova, P. Makarenko, T. Oleinik, M. Proka, D. Sink, S. Strumilin, and many others, however, in terms of the ever-changing political and economic environment of the agrarian sector, many problems remain unresolved.

1. The theoretical basis of labour productivity management in agriculture

The main source of social wealth in the production of material goods is labour. fte category of «labour» has been studied by many economists both in the classical economic school and in modernity. K. Marx wrote: «Labour is, first of all, a process between man and nature, a process by which man by his own activity mediates, regulates, and controls the metabolism between himself and nature» (Marks, 1960). A fairly detailed definition of the category «labour», in our opinion, is quoted in the economic dictionary by Professor S.V. Mochernyiy: labour is considered as «the process of conscious expedient activity of people, in which they modify the external nature, mediate, regulate, and control the metabolism between themselves and simultaneously change their own nature» (Mochernyiy, 1995). In the monograph edited by D.P. Boginya, the labour process is seen as a means of creating material and spiritual goods, and increasing the welfare of the population is determined by the effectiveness of the aggregate labour of representatives of material production and non- productive sphere (Boginya, 1990). In the process of labour, man creates various products: both for personal consumption, and as raw materials for the production of other products, means of labour. Thus, the more fruitful, more efficiently labour is used, the higher the productivity, the more the aggregate social product is created (Aydamirov, 2016).

Labour in the field of agriculture has a specific feature: the objects of labour are living organisms (plants and animals) under the influence of natural and climatic conditions; the operation of labour on them is limited by certain biological laws. The work of the same qualification and capital-labour ratio can lead to different results depending on the natural conditions. Thus, the results of labour in agriculture are determined both by natural (soil-climatic and biological) and economic processes. Working time is a measure of the costs of labour, the amount of the product created is the result of the labour process.

Economic category «labour productivity» determines the degree of fruitfulness, the ability of a particular labour force to produce use values, and perform useful work. Labour productivity in the economy, which can be compared with the efficiency in technology (reflects the perfection of machines, the degree of energy use), characterizes the ability of labour to produce the necessary products, this is a kind of coefficient of efficiency of labour. The essence of labour productivity lies in the ability of a particular labour to produce a certain quantity of output per unit of time. Labour productivity is the ratio of the labour results to its costs per employee per unit of working time, as calculated by the system of indicators. Mathematically, this can be described as the ratio of the volume of output or work in kind to the cost of working time per unit of output or unit of work. In accordance with this ratio, an increase in labour productivity is possible either on condition of an increase in the volume of output or work or under the condition of a reduction in the expenditure of working time. The effect is multiplied if both conditions simultaneously act, and the calculation of labour productivity takes into account both the amount of output produced and labour costs. Labour productivity is organically linked to important economic categories: the volume of production, cost, price, profitability, payment and motivation of work, technical equipment of labour, working day duration, labour organization, the efficiency of the use of productive assets.

In agriculture, a significant role is played by the natural factor: more favourable soil and climatic conditions not only ensure the cultivation of various crops and breeding of certain types of livestock but also determine the so-called

«natural labour productivity» (Aydamirov, 2016). fte growth of the capital-labour ratio of labour has a significant impact on increasing labour productivity: an increase in basic production assets raises the level of mechanization and automation of production, leads to a reduction in manual labour and an increase in the qualification level of workers. Important criteria for technical progress in agricultural production are an effective use of land and livestock, since living labour and the means of production are applied to land and livestock, and their rational use raises the importance of all factors of production. It is technological progress that increases the productivity of living labour, leads to a saving of working time and growth in agricultural production, an increase in net and gross income.

2. Modern trends and objective conditions for the development of agriculture in the agro-oriented region

One of the most important branches of the economy of the Zaporizhzhia region is agriculture, which forms the bulk of food resources and nearly three-quarters of retail commodity turnover. fte level of development of the region's agriculture determines the provision of the population of the region with food and industry – with raw materials. Zaporizhzhia region occupies a favourable economic and geographical position: it is located in the south of the East European Plain. The territory of the region is 4.5% of the territory of Ukraine, favourable for the development of the agricultural sector in the region is the presence of chernozem soils (75% of the total area of the region).

Sown areas of agricultural crops in the Zaporizhzhia region make up 6% of the sown areas of Ukraine. In 2016, in the Zaporizhzhia region, wheat was produced 6.6% of all volumes of Ukraine. Labour productivity in the agricultural sector in the region in 2016 was only 78% of the average for Ukraine. fte existing resource potential of the region's agriculture, based on high-productive agricultural lands, favourable climatic conditions, opens prospects for increasing the volume of agricultural production, increasing production efficiency on the basis of productivity growth. fte dynamics of the land and resource potential of the Zaporizhzhia region is presented in Table 1.

Analysis of the dynamics of the region's land and resource potential indicates its strengthening over the past five years: the sown area has increased, positive dynamics of gross agricultural output can be observed, and labour productivity has increased.

Table 1 The dynamics of the land and resource potential of the Zaporizhzhia region

Indicators	2012	2013	2014	2015	2016	Deviation of 2016 to 2012 (+,-)
Area of agricultural land, thousand hectares	2133,0	2242,1	2241,8	2129,5	2127,1	-5,9
including arable land	1886,0	1904,0	1882,2	1881,9	1880,9	-5,1
Sown area, thousand hectares	1589,8	1625,7	1625,2	1623,9	1630,2	40,4
Gross agricultural output, million UAH	7083,2	9523,3	9203,9	10055,7	9928,0	2844,8
Index of plough-disturbance	0,88	0,85	0,85	0,88	0,88	0
Gross output per 100 hectares of land, thousand UAH	332,1	424,7	410,6	472,2	466,7	134,6
Productivity per employee, thousand UAH	102,8	147,4	145,1	172,0	215,7	112,9

Reform of property relations and transformation of economic relations in the agrarian sphere of Ukraine led to the emergence of new forms of management based on private ownership of the means of production. On the territory of the region in 2016, there are 2790 enterprises engaged in agricultural production, which are mainly represented by farms – 73.3% (Table 2).

Over the past five years, the structure of business entities in the agricultural sector has practically not changed, and their number has slightly decreased – by 5.6%. In other words, in the agrarian sector, the processes of reforming production relations are continuing, as well as the search for the most competitive and effective organizational and legal forms of management. The transition of agricultural land to private ownership led to small-scale production and inefficient use of land. Among

agricultural enterprises, there is a significant stratification in terms of land use. The majority of operating agricultural enterprises mainly occupied an insignificant area: 48.6% of enterprises – up to 50 hectares, 19.0% – from 101 to 500 hectares, only 0.2% of enterprises had a land area of more than 10,000 hectares (Vasilyeva, 2016).

Table 2 Operating entities in agriculture in the Zaporizhzhia region

Business entities	2012		2013		2014		2015		2016	
	Number	% of the total	Number	% of the total	Number	% of the total	Number	% of the total	Number	% of the total
Total	2957	100,0	2930	100,0	2912	100,0	2745	100,0	2790	100,0
Companies	463	15,7	477	16,3	493	16,9	418	15,2	458	16,4
Private companies	246	8,3	243	8,3	240	8,2	208	7,6	210	7,5
Production cooperatives	38	1,3	37	1,2	35	1,2	35	1,3	34	1,2
Farms	2088	70,6	2091	71,4	2067	71,0	2041	74,4	2046	73,3
State-owned enterprises	24	0,8	21	0,7	23	0,8	17	0,6	17	0,6
Enterprises of other forms of management	98	3,3	61	2,1	54	1,9	26	0,9	25	0,9

The level of agricultural production, the yield of agricultural crops, and the productivity of arable land are determined by the optimal scientifically grounded structure of cultivated areas. Agriculture in the agrarian- oriented region of the steppe zone of Ukraine specializes in growing grain and oilseeds. In the structure of sown areas, in the last years, it is occupied mainly by cereals, the specific weight of which varies within the limits of 58%; sunflower occupies 33% on average. For the «black fallow», which ensures the accumulation of moisture in the soil before the sowing of winter wheat in the steppe zone, it is advisable to allot 15–20% of the land, but this rate has not been maintained recently, and is about 6%, while in 2000 the area of naked fallows of the region occupied 19.5%.

The main reserve for increasing the yield and production volumes is the rational use of mineral and organic fertilizers, which contributes to the creation of a fertile soil layer, provides a balance of humus in the soil, and improves the quality of products. Over the financial difficulties for many agricultural producers, mineral

fertilizers became difficult to access, and the reduction in the output of livestock products limited the use of organic fertilizers (Table 3).

Table 3 Dynamics of the use of fertilizers for crops in the Zaporizhzhia region

Years	Mineral fertilizers (nutrients)		Organic fertilizers, t/ha
	kg/ha	% by 2012	
2012	49	100,0	0,7
2013	46	93,9	0,6
2014	48	98,0	0,4
2015	44	89,8	0,4
2016	63	128,6	0,3

Organic fertilizers are introduced in scanty doses, while at least 10 tons of organic fertilizers per 1 hectare of the sown area are needed annually to suspend dehumidification processes.

Analysis of the positive dynamics of agricultural production per capita indicates that the region's natural and resource potential allows satisfying the population's needs for basic food products through local production, but the low level of income of the region's population has led to a decrease in consumption of the most important food products (Table 4).

Table 4 Consumption of the most important food products (per capita per year, kg)

Foodstuffs	2012	2013	2014	2015	2016	Deviation of 2016 to 2012, (+,-)
Meat and meat products	54,4	54,6	54,9	51,6	51,0	-3,4
Milk and dairy products	185,1	190,1	194,6	186,4	181,9	-3,2
Eggs (pieces)	311	309	309	291	265	-46
Bread products	102,9	104,2	103,0	101,8	96,2	-6,7
Potato	112,3	101,1	110,1	104,1	107,2	-5,1
Vegetables and cucurbits crops	172,4	174,5	174,8	173,7	167,7	-4,7
Fruits, berries and grapes	50,6	52,0	47,9	46,5	46,1	-4,5
Fish and fish products	14,1	14,4	11,5	9,3	10,3	-3,8
Sugar	67,8	63,1	63,8	65,3	61,8	-6
Sunflower oil	12,3	12,5	12,5	11,7	11,6	-0,7

One of the factors of the efficiency of agricultural production is the technical potential. Specificity of agricultural production in the Zaporizhzhia region, specializing in grain production, involves the use of tractors and combine harvesters, the number of which per 1000 hectares of arable land is decreasing, which leads to an increase in the load per unit of machinery and may adversely affect the harvesting time (Table 5). The main reasons for the crisis in the material and technical base are a decrease in solvent demand for agricultural machinery, insufficient investment in agriculture, unfavourable credit conditions, and a minimum level of state support for the agro-industrial complex.

Table 5 Availability of basic types of agricultural machinery

Type of material and technical resource	2012	2013	2014	2015	2016	Deviation of 2016 to 2012, (+,-)
Tractors, units	8276	8191	8089	7901	8160	-116
per 1000 ha of arable land	6,6	6,6	6,5	4,2	4,3	-2,3
load per tractor, ha	151,6	152,6	153,8	238,1	232,6	81
Combine harvesters, units	1998	1928	1912	1930	2034	36
per 1000 ha of crop area of cereals (without corn)	2,85	2,3	2,3	2,1	2,3	-0,55
load per 1 harvester, ha	350,4	434,8	437,7	476,2	434,8	84,4

In our opinion, an increase in the load per unit of technology presupposes an organization of agricultural production, in which it is used as efficiently as possible. One of the ways to overcome these problems is to use financial leasing or partial compensation of interest rates on loans for the purchase of equipment.

3. Factors of labour productivity growth

An important task of studying the problems of labour productivity is to determine and analyse the causes of its changes, determine the factors and reserves for its growth.

The term «factor» reflects the most general definition that affects labour productivity. The authors of the monograph «Povyshenie proizvoditelnosti selskohoziaistvennogo truda» («Increase in Agricultural Labour Productivity») provide a fairly comprehensive definition of labour productivity factors. ftey include

«material and technical, organizational and socio- economic characteristics of social production, which actively influence the labour process and determine its effectiveness» (Mashenkov, 1983).

Complexity and intensity of factors on the dynamics of labour productivity are caused by social incentives, numerous forms of social and labour relations: the system of labour remuneration, economic incentives, moral encouragement, and administrative influence. ftus, in relation to the factors, the stimuli act as control levers (Gilitskiy, 1982).

K. Marx in his work «Value, Price and Profit» describes in detail the factors of growth in labour productivity and the conditions for their action: «Apart from the different natural energies and acquired working abilities of different peoples, the productive powers of labour must principally depend: 1) upon the natural conditions of labour, such as fertility of soil, availability of necessary resources; 2) upon the progressive improvement of the social powers of labour, such as are derived from production on a grand scale, concentration of capital and combination of labour, subdivision of labour, machinery, improved methods, appliance of chemical and other natural agencies, shortening of time and space by means of communication and transport, and every other contrivance by which science presses natural agencies into the service of labour, and by which the social or co-operative character of labour is developed» (Mashenkov, 1983). Gurtskaya (Gurtskaya, 1986) distinguishes three groups of factors: 1) increasing the level of production industrialization based on the achievements of scientific and technological advance; 2) improvement of technology, social organization of agricultural production and remuneration of labour; 3) increasing the culture of farming, economic fertility of soils, improving plant varieties and animal breeds, increasing their productivity, and intensive use of all natural conditions of agricultural production.

In our opinion, the grouping of factors for increasing labour productivity in agriculture requires the definition of clear criteria for attributes of belonging to a particular group of factors. ftus, the classification of

A.P. Vorontsov combines the factors into three groups, characterizing: the technical level of production, the efficiency of land use, and the efficiency of the use of labour resources (Vorontsov, 1973).

Ya. Maryahin unites the factors in the following three groups: the first group describes the technical re-equipment and the achievements of scientific and technical progress, the second – reflects the state of the organization of production and labour, the third one – personal reasons (Maryahin, 1983).

To identify factors that directly affect the level of labour productivity, it is first of all necessary to find the phenomena determining the quality and degree of using individual elements of the production process (means of production and labour), as well as phenomena characterizing the effectiveness of their interaction (Gilitskiy, 1982).

One of the important factors for the expanded reproduction in agriculture is an increase in the motivation of agricultural labour. fte wages of agricultural workers during the last several decades remain the lowest in the sphere of material production. Effective reproduction of the labour resources of the agrarian sector requires effective measures of the state to support agricultural producers, pricing regulation, resuscitation and development of the social infrastructure of the village.

Conclusion

Strategic management of labour productivity increase in market conditions requires the development and implementation of targeted programs for managing labour productivity, which provides for increasing the level of labour use, stimulating labour, and reducing production losses. We believe that when studying the factors of labour productivity growth in the region, it is necessary to use an integrated system approach that takes into account the degree of connection between them. ftis will allow most fully reflect the nature of the impact of all circumstances that cause changes in labour productivity, minimizing negative factors, and finding the most optimal ways to increase it.

Despite numerous studies in the field of agricultural sector sustainable development, it should be noted that Ukraine has a number of problems hindering

implementation of sustainable development strategies, including current geopolitical situation, high anthropogenic burden in some regions, significant environmental pollution due to outdated production technologies, weak control over implementation of sustainable development goals, lack of systematic and comprehensive approach to defining clear criteria and indicators of agricultural sector sustainability as a holistic construct, and weak institutional support.

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3.6 Financial reserve of vocational (vocational education and training) institutions

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Today education as a form of training organization, systematic knowledge and information transfer to the next generations faces radical changes all around the world. Changes in current education system have lots of facets and their nature is

reflected in different forms: learning process` sophistication, institutional forms` and organizational structure`s expansion, diversification of its financial mechanism. Ukraine is not an exception, since amid decentralization of its administrative and territorial system and the whole of society, it is important to provide these important processes with qualified personnel capable of effective implementation of the reform tasks, as well as to create conditions for economic sustainable development.

The issue of reform process and power decentralization management to ensure national sustainable development is intrinsically linked to the educational reform process, so reforms` effective mechanisms study requires particular attention and in-depth theoretical and practical research. Therefore, there is a need to study the mechanisms of education funding in general and vocational training in particular in the process of decentralization and reform of the country`s administrative and territorial structure.

According to the State Statistics Service, there is a professional and qualitative imbalance between supply and demand in the Ukrainian labour market: 75% of school graduates receive higher education, 25% - vocational. As a result, almost 44% of unemployed are university graduates, and in some big cities this figure reaches 90%. Analysis of the labour market of Ukraine regarding supply and demand balancing for labour resources of certain jobs and qualifications, also showed the disproportion. Thus, there were seven vacancies per one qualified locksmith, ten vacancies per one welder, but 6.8 vacancies per one lawyer.

Shortage of qualified workers was because of the 40% decline of the number of vocational educational institutions during the period of independence – from 1285 in 1991 to 736 in 2018. The number of trained workers has fallen by more than half: in 1991 there were 338.1 thousand graduates of vocational education institutions, in 2018 there were only 133.5 thousand graduates.

Therefore, today there is a need to solve the problems associated with these disparities. The last is the objective of vocational education reform which has been started in the country recently.

To fulfill the strategic tasks of education system reform and ensure its quality

and competitiveness, the possibility of its integration into the European and world educational environment, it is necessary to determine optimization of its financing system in general and vocational education and training in particular.

Table 1 illustrates the analysis of dynamics of education funding in Ukraine. During 2000 – 2017s vocational education and training (VET) share decreased of 6,53% to 4,88%, index`s growth rates have slowed down too. During 2013 – 2015s VET funding significantly dropped down. We consider that the mentioned trends negatively affected VET development and blue collars` training.

Table 1 Indices of education funding dynamics in Ukraine, 2000-2017s

Year	Total consolidate budget expenditure, mln UAH	Public spending on education, mln UAH	Public spending on education as a share of total consolidated budget expenditures, %	Expenditure on early childhood education as a share of spending on education, %	Expenditure on secondary education as a share of spending on education, %	Expenditure on VET as a share of spending on education, %	Expenditure on higher education as a share of spending on education, %	Expenditure on VET growth rate, %
2000	48148,60	7085,50	14,72	11,14	36,20	6,06	32,26	
2005	141989,50	26801,80	18,88	10,97	41,63	6,53	29,60	407,81
2010	377842,80	79826,00	21,13	12,83	41,16	6,40	31,32	291,80
2011	416853,60	86253,60	20,69	13,72	40,85	6,15	30,86	103,90
2012	492454,70	101560,90	20,62	14,40	41,81	5,94	28,89	113,73
2013	359044,50	75951,80	21,15	14,69	42,10	6,00	28,45	75,47
2014	364087,70	71767,90	19,71	14,94	42,32	5,80	28,54	91,45
2015	433159,80	75907,00	17,52	15,86	42,91	5,46	27,74	99,46
2016	701801,30	109155,20	15,55	15,53	42,86	4,80	28,03	126,43
2017	1056759,90	177755,70	16,82	15,87	47,45	4,66	21,76	158,09

[1]Authors` development based on the reference book «Statistical yearbook of Ukraine» (http://www:ukrstat.ua)

During 2015-2019s the system of VET financing faced some changes due to the decentralization process started in 2014. In 2015, in accordance with Article 26 of the Law of Ukraine «On the State Budget for 2015», subvention from the state budget was provided to local budgets for blue collars training. Changes that took place in 2016 were stipulated in the Budget Code and the Law of Ukraine «On the State Budget for 2016». The main result was VET funding transfer from central to the local level. The main sources of VET funding in 2016 were the State budget, regional and

Kyiv budgets, budgets of regional centers, budgets of cities of regional significance. Besides, the mechanism of contingency allowance from the State Budget (redistribution of stabilization grants) was applied. Therefore, funding of vocational schools located in cities of regional significance, namely regional centers, was covered by municipal budgets, and other vocational schools` - from the regional budgets and the budget of Kyiv (Articles 89 and 90 of the Budget Code of Ukraine). In 2016, a new subvention from the state budget to local budgets was introduced aimed at modernization and updating of VET physical infrastructure. The procedure for its distribution was approved by the Law of Ukraine «On the State Budget of Ukraine for 2016».

Table 2 analyzes the dynamics of VET expenditure funded from the state budget of Ukraine and local budgets.

Data analysis describes that in 2014 there was a significant decrease in VET financing both from state budget and local budgets. Since 2015, there has been a redistribution of financial constraints on VET financing from the state to the local level. During 2016 – 2017s VET financing process was accelerated, but since 2018 funding growth has slowed down. We believe that these indicators of financing dynamics do not fit the expected results of VET reform. Therefore, there is a need to find sources of additional funding for the local reforms.

Nowadays education is considered to be a form of investment in human capital. Since Ukraine has chosen a knowledge-based economy development model, investment in education is undoubtedly the investment in national economy, and its volume must grow dynamically.

Analysis of education funding sources has demonstrated that it is funded from budget funds, chargeable services provided by educational institutions, stock dividends, foreign exchange receipts, voluntary contributions, tangible assets supplied by enterprises, institutions, organizations, individual citizens. Correlation between budgetary and non-budgetary education financing is determined by: rates of economic development, availability of budgetary resources under the adequate national educational policy, forms of ownership of educational institution. Funding

restrictions cause the introduction of chargeable services as the form of educational institutions` funding.

Table 2 Dynamics of VET expenditure funded from the state budget of Ukraine and local budgets

years	VET expenditure plan indices` growth rates funded from the state budget (plan indices), %	VET expenditure plan indices` growth rates funded from the state budget (actual performance), %	VET expenditure plan indices` growth rates funded from local budget (plan indices), %	VET expenditure plan indices` growth rates funded from local budget (actual performance), %
2008	142,16	141,19	141,09	126,26
2009	106,75	108,30	112,90	91,28
2010	125,11	125,89	100,00	100,00
2011	25,29	25,11	507,03	553,96
2012	120,26	118,53	113,45	1474,23
2013	115,25	115,31	105,41	102,86
2014	97,65	93,15	101,67	92,36
2015	9,01	9,43	118,68	132,48
2016	103,52	104,68	100,21	100,09
2017	228,30	147,61	145,05	133,62
2018	95,25	147,32	113,54	120,21
2019	125,54	125,52	106,23	107,61

In our opinion, deposits income and domestic government loan bonds income should be additional source of funding for local education reforms.

Typical method of temporary free funds investment is deposits. Municipalities use them to receive additional funding to local budgets in the form of interest paid by banks. Thus, in 2018, local budget receipts for temporarily free funds investment in deposit accounts amounted to 1.3 billion UAH, which is 0.6% of the total revenues of local budgets` general fund of Ukraine (excluding transfers from the state budget).

Tables 3 - 6 provide analysis of public funds` of Ukraine deposit banking indices during 2018 – 2019s.

As we can see, in 2018, the above-mentioned general fund`s mechanism was used extensively in some regions of Ukraine, for instance in Vinnytsia, Dnipropetrovsk, Donetsk, Lviv, Poltava and Cherkasy regions. Zakarpattia, Ivano-Frankivsk, Luhansk and Kherson regions had the lowest level of application, while in

Kyiv it had never been used at all. Regarding the special fund, the maximum level of deposit opening was observed in Donetsk region, somewhat lower level - in Volyn, Zaporizhzhia and Kharkiv regions. Ivano-Frankivsk, Kirovograd, Luhansk, Odesa, Ternopil, Khmelnytsky and Cherkasy regions had the lowest figures. In Mykolaiv and Kherson regions and Kyiv it had never been used at all.

Table 3 Indices of local budgets` general and special funds` investments for 01.11.2018

Region	General fund			Special fund		
	Invested from the beginning of the year	Payback from the beginning of the year	Balance of deposit facilities by the date of report	Invested from the beginning of the year	Payback from the beginning of the year	Balance of deposit facilities by the date of report
Vinnytsia	1 327 911,0	940 260,0	387 651,0	316 482,2	186 565,0	129 917,3
Volyn	854 853,5	520 160,0	334 693,5	624 515,8	356 516,4	267 999,4
Dnipropetrovsk	3 832 087,9	2 646 120,0	1 185 967,9	297 648,4	97 798,0	199 850,4
Donetsk	1 479 500,0	348 000,0	1 131 500,0	2 920 000,3	320 934,8	2 599 065,5
Zhytomyr	484 239,9	180 872,5	303 367,4	455 461,9	198 651,8	256 810,1
Zakarpattia	50 788,6	11 894,3	38 894,3	112 389,3	106 835,7	5 553,6
Zaporizhzhia	377 412,8	119 412,8	258 000,0	593 087,2	185 700,0	407 387,2
Ivano-Frankivsk	42 000,0	18 000,0	24 000,0	21 495,0	4 788,0	16 707,0
Kyiv	437 989,0	92 500,0	345 489,0	168 620,9	32 162,0	136 458,9
Kirovograd	150 012,0	96 200,0	53 812,0	43 720,0	14 797,4	28 922,6
Luhansk	3 000,0	0,0	3 000,0	50 000,0	0,0	50 000,0
Lviv	1 110 000,0	312 500,0	797 500,0	445 201,8	290 295,0	154 906,8
Mykolaiv	300 000,0	0,0	300 000,0	0,0	0,0	0,0
Odesa	390 000,0	300 000,0	90 000,0	20 310,0	0,0	20 310,0
Poltava	1 026 099,4	461 420,0	564 679,4	171 809,8	31 607,2	140 202,6
Rivne	227 333,7	0,0	227 333,7	365 000,0	318 500,0	46 500,0
Sumy	733 399,6	458 314,2	275 085,4	256 369,4	208 115,9	48 253,5
Ternopil	238 460,7	158 290,0	80 170,7	32 079,3	9 140,7	22 938,7
Kharkiv	923 455,0	308 755,0	614 700,0	412 261,6	176 576,6	235 685,0
Kherson	16 200,0	1 200,0	15 000,0	0,0	0,0	0,0
Khmelnytsky	652 093,0	476 380,0	175 713,0	23 825,5	12 537,8	11 287,7
Cherkasy	1 187 473,8	913 223,8	274 250,0	44 543,9	33 675,9	10 868,1
Chernivtsi	594 625,0	343 555,0	251 070,0	256 351,0	43 412,9	212 938,1
Chernihiv	484 791,8	321 779,8	163 012,0	154 004,5	80 830,4	73 174,1
City of Kyiv	0,0	0,0	0,0	0,0	0,0	0,0
TOTAL	16 923	9 028 837,4	7 894 889,2	7 785 177,8	2 709 441,3	5 075 736,5

Table 4 Indices of local budgets` general and special funds` investments for 01.11.2019

Regions	General fund			Special fund		
	Invested from the beginning of the year	Payback from the beginning of the year	Balance of deposit facilities by the date of report	Invested from the beginning of the year	Payback from the beginning of the year	Balance of deposit facilities by the date of report
Vinnytsia	351 233,8	98 526,5	252 707,3	326 710,7	109 066,6	217 644,1
Volyn	60 950,0	27 167,0	33 783,0	237 096,5	193 169,6	43 926,9
Dnipropetrovsk	500 960,0	500 000,0	960,0	567 061,7	271 310,4	295 751,3
Donetsk	1 559 000,0	7 000,0	1 552 000,0	3 388 502,0	875 841,7	2 512 660,3
Zhytomyr	137 786,7	55 900,0	81 886,7	396 104,6	264 365,5	131 739,1
Zakarpattia	10 000,0	10 000,0	0,0	29 306,1	23 661,1	5 645,0
Zaporizhzhia	0,0	0,0	0,0	221 082,0	120 790,0	100 292,0
Ivano-Frankivsk	0,0	0,0	0,0	65 000,0	49 500,0	15 500,0
Kyiv	27 000,0	500,0	26 500,0	189 470,8	83 200,0	106 270,8
Kirovograd	0,0	0,0	0,0	33 790,0	16 350,0	17 440,0
Luhansk	0,0	0,0	0,0	50 000,0	0,0	50 000,0
Lviv	330 000,0	50 000,0	280 000,0	48 261,4	18 890,0	29 371,4
Mykolaiv	0,0	0,0	0,0	0,0	0,0	0,0
Odesa	0,0	0,0	0,0	6 000,0	0,0	6 000,0
Poltava	572 482,9	25 550,0	546 932,9	111 816,1	35 807,8	76 008,3
Rivne	0,0	0,0	0,0	27 800,0	18 700,0	9 100,0
Sumy	183 081,0	92 063,3	91 017,7	153 305,9	79 565,1	73 740,8
Ternopil	30 060,0	10,0	30 050,0	79 722,6	27 235,7	52 486,9
Kharkiv	65 784,9	16 649,8	49 135,1	439 821,1	89 947,9	349 873,3
Kherson	0,0	0,0	0,0	0,0	0,0	0,0
Khmelnytsky	101 900,0	96 932,0	4 968,0	176 748,6	110 134,4	66 614,2
Cherkasy	233 428,1	159 607,0	73 821,1	315 084,7	273 541,9	41 542,8
Chernivtsi	185 500,0	103 721,7	81 778,3	327 303,8	192 389,3	134 914,5
Chernihiv	68 027,4	35 896,8	32 130,7	193 213,7	122 128,7	71 085,1
City of Kyiv	0,0	0,0	0,0	0,0	0,0	0,0
TOTAL	4 417 194,8	1 279 524,1	3 137 670,8	7 383 202,3	2 975 595,6	4 407 606,7

In January 2019, the Government took a decision to suspend by the end of 2019 the investment of temporarily free funds of local budgets` general fund in banking accounts. The relevant changes were approved by the Resolution of the Cabinet of Ministers of Ukraine No. 53 of 23.01.2019 «On Amendments to the Procedure for Investment of Temporarily Free Local Budgets` Funds in Deposit Banking Accounts».

Table 5 Indices of local budgets` investment and fund balance for 01.11.2018

Region	Invested from the beginning of the year	Payback from the beginning of the year	Balance of deposit facilities by the date of report
Vinnytsia	1 644 393,2	1 126 825,0	517 568,2
Volyn	1 479 369,3	876 676,4	602 693,0
Dnipropetrovsk	4 129 736,3	2 743 918,0	1 385 818,3
Donetsk	4 399 500,3	668 934,8	3 730 565,5
Zhytomyr	939 701,8	379 524,3	560 177,5
Zakarpattia	163 177,9	118 730,0	44 447,9
Zaporizhzhia	970 500,0	305 112,8	665 387,2
Ivano-Frankivsk	63 495,0	22 788,0	40 707,0
Kyiv	606 609,9	124 662,0	481 947,9
Kirovograd	193 732,0	110 997,4	82 734,6
Luhansk	53 000,0	0,00	53 000,0
Lviv	1 555 201,8	602 795,0	952 406,8
Mykolaiv	300 000,0	0,00	300 000,0
Odesa	410 310,0	300 000,0	110 310,0
Poltava	1 197 909,2	493 027,2	704 882,0
Rivne	592 333,7	318 500,0	273 833,7
Sumy	989 769,0	666 430,1	323 338,9
Ternopil	270 540,1	167 430,7	103 109,4
Kharkiv	1 335 716,6	485 331,6	850 385,0
Kherson	16 200,0	1 200,0	15 000,0
Khmelnytsky	675 918,5	488 917,8	187 000,7
Cherkasy	1 232 017,7	946 899,7	285 118,1
Chernivtsi	850 976,0	386 967,9	464 008,1
Chernihiv	638 796,3	402 610,2	236 186,1
City of Kyiv	0,00	0,00	0,00
TOTAL	24 708 904,4	11 738 278,6	12 970 625,8

In certain regions, namely Donetsk, Vinnytsia and Poltava, placement of general fund`s resources contracted in January 2019. In Zaporizhia, Ivano-Frankivsk, Kirovohrad, Luhansk, Odesa, Rivne and Kherson regions, the general fund's resources were not invested in the deposit accounts. Investments in other regions had decreased significantly.

As for the special fund`s resources, only Donetsk region was characterized by the maximum level of investment in deposit accounts, Dnipropetrovsk and Kharkiv regions had lower figures. They were the lowest in Zakarpattia, Ivano-Frankivsk,

Kirovograd, Luhansk, Odessa and Rivne regions. Mykolaiv and Kherson regions as well as the city of Kyiv had not used the mechanism at all.

Таблиця 6 Indices of local budgets` investment and fund balance for 01.11.2019

	Invested from the beginning of the year	Interest rate		Payback from the beginning of the year	Balance of deposit facilities by the date of report
		min	max		
Vinnytsia	677 944,5	12,50	15,30	207 593,1	470 351,4
Volyn	298 046,5	11,50	16,40	220 336,6	77 709,9
Dnipropetrovsk	1 068 021,7	10,00	15,70	771 310,4	296 711,3
Donetsk	4 947 502,0	10,00	16,20	882 841,7	4 064 660,3
Zhytomyr	533 891,2	12,00	16,45	320 265,5	213 625,8
Zakarpattia	39 306,1	13,25	16,30	33 661,1	5 645,0
Zaporizhzhia	221 082,0	12,50	15,35	120 790,0	100 292,0
Ivano-Frankivsk	65 000,0	12,00	16,40	49 500,0	15 500,0
Kyiv	216 470,8	10,50	15,75	83 700,0	132 770,8
Kirovograd	33 790,0	10,00	13,75	16 350,0	17 440,0
Luhansk	50 000,0	15,50	15,50	0,00	50 000,0
Lviv	378 261,4	13,25	15,30	68 890,0	309 371,4
Mykolaiv	0,00	0,00	0,00	0,00	0,00
Odesa	6 000,0	13,25	13,25	0,00	6 000,0
Poltava	684 299,0	12,00	15,40	61 357,8	622 941,2
Rivne	27 800,0	13,25	14,25	18 700,0	9 100,0
Sumy	336 386,9	12,00	16,30	171 628,4	164 758,5
Ternopil	109 782,6	12,50	15,50	27 245,7	82 536,9
Kharkiv	505 606,1	13,25	15,60	106 597,7	399 008,4
Kherson	0,00	0,00	0,00	0,00	0,00
Khmelnytsky	278 648,6	12,50	15,35	207 066,4	71 582,2
Cherkasy	548 512,9	15,00	16,30	433 149,0	115 363,9
Chernivtsi	512 803,8	10,00	15,25	296 111,0	216 692,8
Chernihiv	261 241,2	13,50	16,50	158 025,5	103 215,7
City of Kyiv	0,00	0,00	0,00	0,00	0,00
TOTAL	11 800 397,1	10,00	16,50	4 255 119,6	7 545 277,5

Tables 5 – 6 contain the analysis of fund balance in deposit accounts by the end of the year and its cost efficiency. It has been demonstrated that cost efficiency level ranged from 10% to 16,5% in 2019.

Thus, the imposed restriction affected temporarily free funds investment (in the part of special fund`s resources) in banking deposit accounts.

As an alternative, the Government proposed to invest temporarily free funds of local budgets` general fund through buying government securities. This is governed

by part 8 of Article 16 of the Budget Code and by the Resolution of the Cabinet of Ministers of Ukraine No. 544 of 23.05. 2018 «On Approval of the Procedure for Investment of Temporarily Free Local Budgets` Funds through buying Government Securities».

It should be noted that the instrument for managing temporarily free budget funds is relatively new for local government bodies. As known, domestic government loan bonds are government securities, which confirm Ukraine's obligation to repay the nominal value of bonds to the bondholders with payment of income in accordance with the terms of the bond placement.

Government bonds` issue is a source to finance state budget deficit in the amount established under the Law on the State Budget of Ukraine for the respective year, and within the margin amount of the government debt.

The Ministry of Finance issues and places domestic government loan bonds; determines timing and number of government bonds; determines circulation and interest rate (selling price) of government bonds; provides annually in the draft Law of Ukraine on the State Budget of Ukraine for the respective year the funds needed for government bonds` servicing and retirement; acts on behalf of the Cabinet of Ministers of Ukraine as the guarantor of timely retirement and bonds` yield payment.

Bonds are sold on the basis of profitability criterion through government bond auctions or an auction rate bond. Government bonds yield is set by the market when they are issued by the Ministry of Finance.

The National Bank of Ukraine is the general agent for domestic government loan bonds` servicing and redemption. Transactions related to bonds issue are carried out by the National Bank through brokers and / or dealers who act as custodians and clients of the National Bank's depository. The bonds are recorded in electronic form at the National Bank's depository. That is, there are no bonds in paper form, their issue and maturity have exclusively electronic (non-documentary) form. Domestic government loan bonds according to the maturity are divided into short-term – up to one year; medium term – from one to five years; long term – over five years. The face value of one government bond is 1,000 UAH. Annual interest rate for medium-

term and long-term government bonds is defined as weighted average return on competitive bids through the auction after the initial public offering and subject to the decision of the Ministry of Finance, taking into account yield margins on bonds.

Short-term government bonds are sold at a price lower than their par value. Short-term government bond yield is the difference between the par value paid off to the bondholder by its redemption and the bid price.

Banks – primary dealers and the National Bank of Ukraine are the subjects of government bonds offerings. According to the terms of cooperation agreement in the government securities market, primary dealers cooperate with the Ministry of Finance, which includes providing bilateral domestic government loan bonds quotation and their buying through the primary market. Moreover, the Ministry of Finance grants dealers the exclusive right to buy domestic government loan bonds. The Ministry of Finance of Ukraine identifies banks – primary dealers, namely JSC CB PRIVATBANK, JSC Oschadbank, JSC State Export-Import Bank of Ukraine, JSB UKRGASBANK, JSC OTP Bank, JSC Alfa-Bank, JSC FUIB, PJSC KredoBank, RAIFFEISEN BANK AVAL JSC, Public joint-stock company JSB PIVDENNYY, JSC UKRSIBBANK, JSC Citibank.

Repayment of local budget funds that have been temporarily invested by buying domestic government loan bonds is made after their redemption or sale in the stock market. If necessary, the financial authority can apply for the early sale of domestic government loan bonds (before maturity). In this case domestic government loan bonds` are sold in the secondary market, where the price is determined by market supply and demand. That is why the price of domestic government loan bonds` sale may be higher or lower than the bid price.

Tables 7 and 8 analyze transactions in the domestic government loan bonds market during 2018 – 2019s.

Assessment of the bonds` yield in comparison with deposits, domestic government loan bonds` yield for 2018 was 17.79%, including the maturity date: 1 year – 17.92%, from 1 to 3 years – 16.18%, from 3 to 5 years – 15,87%.

As we can see, the size of domestic government loan bonds market increased significantly in 2019, but, in our opinion, this is not due to the activities of local governments in this market. They are not able to enter the stock market quickly as they do not have relevant experience. Higher stock market`s profitability will not prompt them to pull out the deposit mechanism in favor of the stock market.

Table 7 Key domestic government loan bonds market characteristics in 2018

Period	Invested in the domestic government loan bonds` primary market, UAH		i.e.									
			Budget funds		in particular by maturity							
					up to 1 year		from 1 to 3 years		from 3 to 5 years		Over 5 years	
	amount sum, mln. UAH	weighted average return,%	amount sum, mln.UAH.	weighted average return,%	amount sum, mln. UAH	weighted average return,%	amount sum, mln. UAH	weighted average return,%	amount sum, mln. UAH	weighted average return,%	amount sum, mln. UAH	weighted average return,%
January	8 528,35	16,11	8 528,35	16,11	7 553,87	16,16	233,20	15,70	741,27	15,80	-	-
February	8 877,46	16,34	8 877,46	16,34	8 244,01	16,38	345,63	15,79	287,82	15,79	-	-
March	7 376,42	17,12	7 376,42	17,12	6 692,43	17,22	683,99	16,11	-	-	-	-
April	2 636,40	16,87	2 636,40	16,87	1 962,86	17,17	27,17	16,15	646,37	15,97	-	-
May	1 542,16	16,94	1 542,16	16,94	1 089,72	17,27	422,44	16,14	30,00	16,00	-	-
June	4 563,37	17,29	4 563,37	17,29	4 418,01	17,33	145,36	16,13	-	-	-	-
July	4 513,57	17,48	4 513,57	17,48	3 426,54	17,81	1 087,04	16,43	-	-	-	-
August	7 953,31	17,99	7 953,31	17,99	7 923,61	18,00	19,41	16,79	10,28	16,00	-	-
Septembe	319,15	18,48	319,15	18,48	319,15	18,48	-	-	-	-	-	-
October	2 516,45	18,95	2 516,45	18,95	2 503,29	18,95	13,16	18,22	-	-	-	-
Novembe	1 308,85	18,90	1 308,85	18,90	1 303,09	18,91	5,76	18,50	-	-	-	-
Decembe	14 992,30	20,00	14 992,30	20,00	14 992,30	20,00	-	-	-	-	-	-
Total	65 127,79	17,79	65 127,79	17,79	60 428,88	17,92	2 983,16	16,18	1 715,75	15,87	-	-

Balance of local budgets in deposit accounts amounted to 12.5061 billion UAH by 01.12.2018. Therefore, the recommendations of the Ministry of Finance for the cities of regional significance and UTCs to invest local budgets` temporarily free funds by buying domestic government loan bonds are forward-looking.

Another stock market`s promising instrument is local authority stock, but its main disadvantage is that it takes a long time for the accumulation of essential

resources and therefore there is a risk that minor savings will be spent to solve minor issues rather than significant problems.

Table 8 Key domestic government loan bonds market characteristics in 2019

Period	Invested in the domestic government loan bonds` primary market, UAH		i.e.									
			Budget funds		in particular by maturity							
					up to 1 year		from 1 to 3 years		from 3 to 5 years		over 5 years	
	amount sum, mln. UAH	weighted average return,%	amount sum, mln.UAH.	weighted average return,%	amount sum, mln. UAH	weighted average return,%	amount sum, mln. UAH	weighted average return,%	amount sum, mln. UAH	weighted average return,%	amount sum, mln. UAH	weighted average return,%
January	24 402,08	18,96	24 402,08	18,96	24 066,91	18,98	335,17	17,58	-	-	-	-
February	10 349,48	19,20	10 349,48	19,20	9 605,61	19,30	743,87	17,94	-	-	-	-
March	22 731,14	18,76	22 731,14	18,76	13 741,64	19,24	8 989,50	18,02	-	-	-	-
April	33 887,94	18,60	33 887,94	18,60	22 032,89	19,16	9 190,43	18,00	2 664,62	16,00	-	-
May	12 320,95	17,94	12 320,95	17,94	8 216,16	18,35	2 537,04	17,79	1 567,75	16,00	-	-
June	17 338,13	17,00	17 338,13	17,00	5 982,35	18,23	3 542,12	17,49	-	-	7 813,66	15,84
July	45 618,86	16,67	45 618,86	16,67	9 045,86	17,49	22 763,0	17,04	-	-	13 809,93	15,53
August	7 475,67	16,04	7 475,67	16,04	2 157,63	16,21	3 962,11	16,21	-	-	1 355,93	15,30
Septembe r	20 691,27	15,12	20 691,27	15,12	2 448,93	15,78	5 366,69	15,72	-	-	12 875,66	14,75
October	7 966,17	15,09	7 966,17	15,09	2 297,96	15,08	3 548,83	14,90	2 119,38	15,42	-	-
Total for 2019	202 781,69	17,49	202 781,69	17,49	99 595,92	18,63	60 978,83	17,10	6 351,75	15,81	35 855,17	15,31

Thus, the analysis have demonstrated that in the future, when the domestic stock market reaches the appropriate level of development, it will be possible to apply studied models and methods of financial resource management using stock market instruments.

Based on the analysis of structure and sources of education in general and VET funding in particular in Ukraine, it has been proved that positive results of educational reform, decentralization and funding can only be ensured by raising additional resources for its development. It has been illustrated that additional income

of local budgets, which could be used to finance VET system, is obtained through temporarily free funds` investment in deposit accounts of banks and stock market instruments application. It is advisable to recommend to the bodies of regional government and local self-government to increase VET institutions financing through unutilized balances.

To do this, conditions for projects` and programs` target financing aimed at the development of such institutions must be formed. It should be noted that it is advisable not to finance institutions in general, but specific programs and projects that aim to improve the quality of educational services and graduates` competitiveness in labour market.

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