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CONTENTS

INFORMATIONAL TECHNOLOGY IN ECONOMY

Polumiienko S.K., Gorda S.E.	4
Game-Theoretical Resource Model of Balanced Technological Development.....	
Veduta E.N., Dzhakubova T.N.	10
Economic science and economic-mathematical modeling.....	
Kraskevich V.E., Selivanova A.V.	23
Innovation engineering as the instrument of decision-making support.....	

MATHEMATICAL AND INFORMATIONAL MODELS IN ECONOMY

Makarenko I.P.	28
Modeling of financial flow regulators in systemic macroeconomic environment.....	
Marko M. Y., Tsegelik H.H.	42
An approximate method for solving assignment problem.....	

ANALYSIS, EVALUATION AND FORECASTING IN ECONOMY

Stefanyshyn D.V.	50
Improving diagnostic models for forecasting the behavior of dams equipped with automated monitoring systems	
Kryazhych O.O, Kovalenko O.V.	62
Some of the special features of the tritium migration	
Kremenovska I.V.	74
Waste management: accounting problem.....	
Beketova G.M.	84
Modeling of fire suppression in the ecological system of tress and shrubs...	
ABSTRACTS	91
INFORMATION ABOUT THE AUTHORS	97

INFORMATIONAL TECHNOLOGY IN ECONOMY

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S. POLUMIENKO, S. GORDA

GAME-THEORETICAL RESOURCE MODEL OF BALANCED TECHNOLOGICAL DEVELOPMENT

***Abstract.** This article proposes a game-theoretical resource approach to the modeling of sustainable development processes. Initial system is considered as an aggregate of various resources and participants consuming and creating these resources to meet their needs or interests. The system participants are not divided by economic, environmental and social subsystems. Their strategies or technologies are aimed at deriving income from the production and consumption of resources, which in turn serves to the participant coalition interests. The strategic and cooperative coalition game built on this basis describes the development process of the system. Its optimal strategy, which is represented by the Shapley value, provides the compromise strategy of the system balanced technological development.*

***Key words:** game theory, sustainable balanced development, cooperative model, resource*

Introduction

The challenge of finding a sustainable development strategy as proposed by Agenda 21 (UN, 1992) requires, among other things, finding a compromise among all the participants of the combined social-ecological-economic system (UN, 2013).

This compromise is usually defined only in the "binary projections" of the problem thru research of social-economic, ecological-economic and other bilateral influences. However, the system is characterized by interaction of three players. And this interaction has no constructive approaches in finding the needed common compromise of the processes being practically considered. Instead, we find that the models of the mentioned subsystems are segregated; their components are estimated on the sustainability of development with different details and objectives pertaining to the original task ((Bossel, 1999, UN, 2009)).

In (Polumiienko et al., 2013), is presented a game-theoretical model of sustainable development, based on a multilevel coalition strategic game (Polumienko, 1992), the optimal situation of which provides the common strategy of sustainable development. This model is a union of submodels of the social, environmental and economic systems, but it is too bulky and counter-productive.

Nevertheless, its analysis gave another foundation for constructive finding of balanced development strategies presented below.

1. Cooperative Model of Balanced Technological Development

The vital activity of any social-ecological-economic system is based on the resources which are produced and used by its participants. At least, just this possibility for the next generations is declared by the Agenda 21 as a sustainable development.

Suppose $Res(tk)$ is a resource vector of the initial social-ecological-economic system with the components $Resm(tk)$ at the moment of time tk of the breakdown of the time interval $[t_0, T]$, $m = 1, \dots, M$. Components of the vector $Res(tk)$ are defined by a higher-level player GI, for example, by the government, which analyzes the system, works out development strategies, etc. The resource components may be described by different known indicator systems.

In contrast to conventional approaches, the system participants that are identified as lower-level players $i \in I$, are not divided by social, ecological or economic subsystems. In order to serve their needs or interests the players $i \in I$ produce and use necessary resources within their environment. Such actions of them represent their strategies $s_i \in S_i$, $i \in I$. Here S_i is the set of strategies of the player i , and these strategies are considered as having either a restorative or destructive effect on the system resources. The permissibility of the strategies is determined by the player GI, limiting or stimulating the sets of strategies S_i for all $i \in I$.

The players' strategies are designed to satisfy their interests using the received payoffs and this characterizes the system development process. The initial goal of achieving sustainable development requires identification of the participants' common interest. It may be considered as the augmentation of the common resources under the condition of their balance preservation.

The players $i \in I$ within the system are considered as infinitesimal ones. That is, they cannot influence the entire system individually. To increase this influence and receive higher income, they unite in coalitions. These coalitions $c \in C$ act as the single player with a strategy $s_c \in S_c$, where S_c is the union of the strategies s_c . So, the players may carry out strategies within different unions and receive a share of their respective payoffs.

Therefore, at the moment of time tk we have the vector $s_{it}(tk)$ of the coalition strategies s_c , $c \in C$, which will be named as a situation $s_{it}(tk) \in Sit(tk)$, where $Sit(tk)$ is the set of all the situations. That is, it is the union of all possible actions of the system participants at the moment of time tk . So, the payoff or income of the coalition depends on the situation. Since all situations can vary, determination is made by taking into account the diversity of the resources. They should be represented in transferable values for the transmission between the game participants.

Suppose $v_{l,m}$ and $p_{l,m}$ are the volume and weight (or value) of the m -th resource type $Res_{l,m}(tk)$ in the l -th region of the country. Let us also assume that the value

$$rs_{l,m}(t_k) = \text{vol}_{l,m} pr_{l,m}(t_k) / \sum_l \text{vol}_{l,m}(t_k) pr_{l,m}(t_k),$$

is the relative volume of the resource m within the region l , $0 \leq rs_{l,m}(t_k) \leq 1$. If we consider $rs_{l,m}(t_k)$ instead of the resources $Res_{l,m}(t_k)$, then that allows us to unify substantially different resources. For the sake of simplicity, we will not define the complete index of the region and will denote it as $rsm_{i,c}(t_k)$ and $rsm_{c,c}(t_k)$ – respectively as the share of resources $rsm(t_k)$ held by the player $i \in I$ and the coalition $c \in C$, of which it is a member as,

$$rs_{m,c}(t_k) = \sum_{i \in c} rs_{m,i}(t_k) .$$

In carrying out the strategies, the coalitions spend some resources and consume other resources, deducting or adding certain value to their components. These actions may include savings, production means, natural resources, etc., and could be either individual or common.

In terms of their strategies, the coalitions may be matched to types of specific economic activities, intrinsic to the system. This specific classification could be made by the player GI on the basis of different systems of indicators describing the system. We suppose that coalitions $c \in C$ and their strategies $sc \in Sc$ are in compliance with such classification and consider the initial task as the division of resources between different types of coalitions claiming identical resources.

Thus, we have to find a situation which provides the balance between the coalitions $c \in C$ within the identical, as well as different types of strategies. Within the same set of them to which corresponds single coalition, this situation is regulated by agreements between its participants and by the player GI - a market, social sphere and the natural environment. Within different types of strategies – this is done by finding a balanced situation for the resource components m . In this case, coalitions $c \in C$ are interested in increasing or retaining their share of the necessary resource. As an example, this could happen with the required air or water, and then - during the allocation of the income from the created resource.

Thus, balanced development corresponds to the balance of resources, revenues of the coalitions from the use of resources by their components m , and to the dependent on the preservation of this balance achievable increase of the cumulative resources of the system.

Balanced resource status is determined by the player GI on the basis of the analysis of the resources $rsm(t_k)$ and specific features of the region. It therefore represents a heuristic evaluation, which determines a certain initial state of the system resources, while further analysis is intended to achieve improvement of it.

Let us proceed from the initial state of the resources $rsm(t_0)$, without determining its balanced state. Balanced state may be considered, for example, as an increase of the resources on the aggregate of all the components or for each of them individually. While for negative resources, such as waste, negative values may be used.

Suppose $Arsm_{c,c}(sit(t_k))$ and $Drsm_{c,c}(sit(t_k))$ - added and spent by the coalition c values of resources for the component m , $m = 1, \dots, M$, at the moment of time t_k , and

$$\begin{aligned} \text{Ars}_c(\text{sit}(t_k)) &= \sum_{m=1}^M \text{Ars}_{m,c}(\text{sit}(t_k)), \\ \text{Drs}_c(\text{sit}(t_k)) &= \sum_{m=1}^M \text{Drs}_{m,c}(\text{sit}(t_k)), \end{aligned} \quad (1)$$

$\text{Ars}_c(\text{sit}(t_k))$ and $\text{Drs}_c(\text{sit}(t_k))$ - their final values. Then the value

$$rsc(\text{sit}(tk)) = \text{Ars}_c(\text{sit}(tk)) - \text{Drs}_c(\text{sit}(tk)) + rsc(tk-1), \quad (2)$$

reflects the result of implementation of the strategy of the coalition c in the situation $\text{sit}(tk)$, $rsc(tk-1)$ is the value of $rsc(\text{sit}(tk))$ at the moment of time $tk-1$. Considering that the coalitions are all corresponded to certain types of activities, instead of the sum $\text{Ars}_c(\text{sit}(tk))$, its individual summand $\text{Ars}_{m,c}(\text{sit}(tk))$ may be considered, and thus in (2) we will have this value and the sum of all the resources spent by the coalition. Proceeding from (2), let's determine a payoff function of the coalition c in the situation $\text{sit}(tk)$ as

$$Hc(\text{sit}(tk)) = rsc(\text{sit}(tk)) - rsc(\text{sit}(tk-1)) = \text{Ars}_{m,c}(\text{sit}(tk)) - \text{Drs}_c(\text{sit}(tk)). \quad (3)$$

For their activities, resources are also needed by the other coalitions $c \in C$, and their payoff according to (3) is the result of a certain compromise. Subject to further development, this compromise is also conditioned by the maximum possible increase of the total resources during the time interval $[t_0, T]$ –

$$H(\text{sit}(T)) = \sum_{t_k \in [t_0, T]} \sum_{c \in C} H_c(\text{sit}(t_k)).$$

As a result, we have a coalition game

$$G = \langle rsm(tk), C, \text{Sit}(tk), Hc(\text{sit}(tk)), c \in C, m = 1, \dots, M, tk \in [t_0, T] \rangle, \quad (4)$$

which describes the development of the (regional) social-ecological-/economic system.

The solution of the game will be a specific situation satisfying all the coalitions, and therefore providing the balanced set of the system development strategies.

Suppose n is the number of players, I and the coalition C are its sub-aggregate. The function v , which assigns to each coalition C the highest payoff $v(C)$ (sharing $x = (x_1, \dots, x_n)$), which is surely received by it is called a characteristic function of the game (Danilov, 2002). The aggregate $\langle I, v(C) \rangle$ is thus called a cooperative game in the form of a characteristic function if:

$$x_i \geq v_i(i) \text{ for } i \in I \text{ and } \sum_{i \in I} x_i = v(I),$$

In contrast to the strategic game (4), where the players' actions in different coalitions are analyzed, in the cooperative game the coalition players united on the certain agreements, must act as a single player against the other players, and the result of such interaction is analyzed.

Let us determine the function

$$v(c, t_k) = \max_{S_c(t_k)} \min_{S_{C_c}(t_k)} H_c(sit(t_k)) = \max_{Sit(t_k)} \min H_c(sit(t_k)). \quad (5)$$

The following aggregate

$$GR(tk) = \langle rs(tk), C, Sit(tk), v(c, tk), m = 1, \dots, M, tk \in [t_0, T] \rangle, \quad (6)$$

will be considered as a cooperative game with the characteristic function (5), which is built on the basis of the game (4).

The solution of this game is determined as the Shapley value (Aumann, Shapley, 1974). It describes what the coalition can achieve after completion of the game. We can define the sharing corresponding to this Shapley value as the required balance of resources during the system participants interaction. According to it the most effective will be the balanced strategies providing the maximum possible value of the available resources.

These strategies are versatile technologies used by the players and coalitions in the process of the creation and consumption of the resources. An increase in their volume most certainly leads to the improvement and growth of the region's potential.

Finding a reliably effective way of development is implemented through the strategies $sGI \in SGI$ (managerial technologies) of the upper-level player GI. This is accomplished thru strategies of the support or limitation of the technologies used by the system participants.

Achievement of the balance and growth of the system resources also ensures the further sustainable existence of the GI itself and the entire system managed by him. The level of satisfaction with the system state, i.e. the satisfaction of the player GI interests, can be identified, for example, by the following logical functions:

$$G(t_k) = \sum_m P_{nc}(rs_m(t_k), rs_m(t_{k-1})) \alpha_m, \sum_m \alpha_m = 1, 0 \leq \alpha_m \leq 1, m = 1, \dots, M.$$

Predicates in these amounts may be based on the values of the indicators of balanced development.

Let's name the aggregate

$$SD(tk) = \langle GR(tk), GI, SGI, G(tk), tk \in [t_0, T] \rangle, \quad (7)$$

as a game-theoretical model of balanced development.

Union of such games by regions of the country, which may be made both at the level of the players GI, and at the lower level of the game (7), will reflect the problem of its balanced development. In this case, the task of finding a balance may be assigned to a player of an even higher level which regulates the behavior of

the players GI and their coalitions for the benefit of the system by establishing legislative rules and other standards. Therefore, this player (the government) will represent the interests of the country at the international level by advocating the national interests.

Conclusion

The built model constitutes the basis for the development of balanced development algorithms; however it allows to make some conclusions even now. As of today, finding the balance is in conflict with relations determined by the market; the necessity of stable economic growth of companies, ensuring improvement of the population welfare, etc. This balance involves the fostering of a conscious limitation of the volumes of consumption, accumulation, and in a word, the fair spending and allocation of resources. The need for providing the community with resources requires substitution of the accumulation interests by the priorities of creation of diversified and durable utilities of public and individual importance. None of which is a very common practice at the moment.

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VEDUTA E.N., DZHAKUBOVA T.N.

ECONOMIC SCIENCE AND ECONOMIC-MATHEMATICAL MODELING

***Abstract.** The global crisis, which has required a rethinking of economic knowledge and corresponding economic and mathematical models (EMM), makes us to return to the origins of the economic science and EMM. Thus the exceptional urgency to exit the global crisis gains the Marx theory of reproduction which study the objective economic laws, and the EMM based on this theory which helps to build the cyber system in order to enter the path of the social progress. The article shows that the EMM, which historical goal was to understand the economic mechanisms deeper, has been developed in two main directions. The article sets out the basic principles of the dynamic model of inter-branch and inter-sectoral balance (MIIB), which can be the basis for the creation of economic cyber system.*

***Key words:** Global crisis, reproduction theory, economical cyber system, strategic planning, economic and mathematical models, EMM, model of economic balance, models of economic dynamics (growth).*

Introduction

The growing threat of the global crisis force the governments of all countries to develop anti-crisis measures. However, no country has no plan of action as an algorithm of the recovery from the global crisis.

It is proved that the cyclical economic development based on the phases of the cycle "inflation – deflation", which was launched during the First World War, contributing to the concentration and centralization of the global capital, enhances the deployment of the global crisis and hostilities [1].

These phases of the cycle are served by the monetary theory of Keynes – Friedman, who consider the Ministry of Finance and the Central Bank as the main regulators of the economic development. The adherents of institutionalism, in fact, offer to carry out the certain structural transformation of the economy, depending on the phase of cycle. The international system of national accounting and the econometric models applied for forecasting and planning of the economy are the monetary targets. Almost all modern researchers do not pay attention to the root cause of crisis – the disparity of economic development. The task of achieving the proportionality of the economy can not be solved only by monetary and institutional methods. This task is the task of the strategic planning of the economy, which provides the organization of social production for sustainable growth of quality of life.

To access such planning it is required to utilize entirely the possibilities of modern information technology (IT), which involves the development of the corresponding dynamic economic-mathematical model (EMM) on basis of which it is possible to coordinate the orders of final consumers and manufacturers, taking into account the introduction of new technologies. Implementation of such EMM will transfer the economy management to the fundamentally new level of

technology and will allow to carry out the systematic adjustment of the current global economic model.

The objective of this article is to justify the need for EMM which describes the force of objective economic laws, to build economic cyber system – the tool that can release us from the global crisis.

From the specified objectives the following tasks are derived:

– to show the need of using the Marx's theory of reproduction as the scientific basis for the development of EMM, capable to use the modern IT in strategic planning of the sustainable economic growth;

– to explore the evolution of EMM from the position of the possibilities of their practical application;

– to justify the need of the dynamic model of inter-sectoral and inter-branch balance (MIIB) as a basis for creating the economic cyber system, enhancing the effectiveness of management decisions.

1. Global crisis as a signal to rethink the basics of economic knowledge.

In the reproduction theory of Karl Marx it had been proved that the transition to a new type of production relations is primarily determined by the revolutionary changes in the instruments of labor. So, as soon as the machine appeared, a revolution in production relations took place – the capitalist mode of production as a definite system of economic relations with the corresponding material and technical base became dominant. The machine, overcoming the limited capacity of man in the area of the synchronous operating of a variety of work tools, significantly increases productivity of labor. The industrial revolution is considered to be complete with the advent of machine-made machines, i.e. machine-building plants, when capitalist industry created its corresponding material and technical base. This extended process that led to the leading role of industry in the economy, was given the name of industrialization. The further production development is associated with automation. If the managing of an ordinary machine involves the the human brain and hand, the automatic machine replaces them with the control devices and thereby the productivity overcomes the limitations, associated with the natural human capabilities.

Currently the world faced the necessity to rethink the basics of the economic knowledge in order to emerge from the global crisis. Economic theorists, admitting the need for implementation of strategic planning of the economy, limit themselves by listing the same monetary "anti-crisis" measures with proposals to restrain or to launch inflation, which means the continuation of the crisis. During the Second World War the United States significantly increased their interest in the information necessary for the strategic decision tasks. A new science – cybernetics appeared and studied the processes of information processing and attached importance to the feedback in order to create the automated control systems of different nature, including the economy. The special importance the US attached to the economic information - the system of national income accounts, inter-sectoral balance and the mathematical models which could be used in the electronic computers (computers) for the calculation of macroeconomic indicators and their relationships for the purposes of anti-cyclical regulation. Starting from the second half of the XX century, the special attention is

paid to the automation of production, the introduction of IT systems in production management processes, transmission of control and monitoring functions to the automatic machines (robots). This was due to the fact that during the 50s the role of factor of organization and management had increased dramatically. In the United States during this period the number of managers in the total working-age population increased from 40% to 51%, and in the Soviet Union only in the field of business management the number of employed amounted to 63%. In the US, since 1961, this rapid process was restrained with the help of the automated control systems (ACS), and the Soviet Union only started these developments [2].

With partial automation the dependence on the reliability of operators is reserved. The appearance of cybernetic systems (cyber systems) means a transition to the higher level of automation when cyber machines (IT), performing many functions of the direct management of the complex systems of various nature (technical, economic, biological) leave the function of cybe rsystem improving and creating function of the person who makes the decisions (DMP) to man, due to the inability to formalize the decision-making process entirely.

Under conditions of the permanent global crisis, accompanied by uncontrolled growth of administrative structures, the information flows circulating among them, document flow, and the loss of control over the object – the economy – the extremely urgent issue becomes the implementation of economic cyber systems. The ttempts to "make" the economy to get out of crisis on the basis of monetary and institutional theories failed, because these theories ignore the objective economic laws that regulate the social reproduction. Development and use of these theories and the economic and mathematical models by their adherents in order to justify the proposed anti-crisis measures do not produce the desired results. The substitution of the object of the strategic planning by document flow and, therefore, the introduction of IT for its automatization is not conducive to handle the economy. Moreover, the academic studies, limited by the abstract theoretical constructions, do not offer the specific practical measures and mechanisms, but at the same time apply for state doctrine, and can greatly move back the development and implementation of science-based anti-crisis measures.

Crisis of the modern economic theories and EMM developed on their basis, fancy for the IT introduction with the aim of document flow automatization, forced us to return to the origins of the economic science and to rethink the accumulated experience of EMM for the effective use of modern IT in the interests of social progress.

If we ignore or block this important area of research, the future will be such as it is "described" by the Davos Forum President Schwab K. [3]. According to him, the digital revolution, which starred in the middle of the 50-ies of the last century and is associated with the introduction of electronics and IT for production automation, today acquires a systemic character of rapid technological breakthroughs in areas such as artificial intelligence, robotics, etc. The revolutionary changes caused by modern IT can, according to K. Schwab, bring humanity to the following consequences:

– significant increase in productivity, when robots replace people everywhere, may cause the global changes in the labor market and strengthen the social inequalities;

- people will be able to access the huge volume of information and will be able to express their opinions on various issues, and the authorities will get new opportunities for the development of surveillance and monitoring systems;
- strong IT influence on the national and international security;
- robotization of mankind – the deprivation of human heart and soul.

Indeed, all these processes will have such a development, if the global crisis continues. Considering the growing threat to the humanity, it is important to return to the theory of reproduction. This return does not mean its dogmatic interpretation of the Soviet school position. In this theory the systematic approach to the study of the economy is carried out, which means that all of its categories perform the certain functions in ensuring the dynamics of economic system, which then changes during the transition to the next type of society. The knowledge of the reproduction theory is necessary for understanding of force of objective economic laws discovered by Marx, and their reflection in the EMM. In this connection it is relevant to recall the words of V.I. Leontiev: "If, before someone tries to give any explanation to the economic development, he wants to know what the profits, wages, capitalist enterprise are, from three volumes of "Capital" (from the source) he can get the more realistic and qualitative information than that one he could find in ten consecutive reports of the US census Bureau, a dozen textbooks on modern economy ... " [4].

The objective economic laws discovered by Marx – cost, savings, time savings, the proportionality of economic development, the growth of the organic composition of capital, the formation of prices of production and others, performing in one system, form the mechanism of functioning of the economy and its development under the influence of the scientific and technical progress. EMM and the theoretical constructions that ignore or criticize the reproduction theory, that discovered the objective economic laws, are not able to solve practical problems and pursue the narrowly selfish goals. A modern interpretation of the reproduction theory involves the construction of EMM, simulating the operation of objective economic laws in order to create the economic cyber systems serving to the cultural, scientific and technological progress of society. In this context, the study of the evolution of EMM from the point of view of the development of the fundamental ideas of the reproduction theory is very interesting for science.

2. Balance Models

Historically, the mathematical school of political economy appeared in the second half of the XIX century. Its founders are considered to be W. Jevons (England), L. Walras (France) and Pareto (Italy), who used the mathematics to create the models of economic balance. One of the first representatives of Russian school of mathematics was V. Dmitriev, whose works were regarded as the theoretical basis for the creation of MIB and SNA.

The basis of the mathematics school were the ideas of marginalism, explaining the economic processes with the use a marginal (incremental) values. The achievements of this school are:

- concept of economic optimum, meaning the best condition of the economic system in terms of its inherent objective criteria of certain restrictions;
- use of mathematical tools for the analysis of marginal values – the marginal utility and marginal costs;

- studies over terms of balance;
- analysis of dependences of demand, prices, income;
- analysis of factors determining the cost of production;
- analysis of relationship of the issues of pricing and the total proportionality of the economy.

The model of the general economic balance, developed by L. Walras in the late XIX century, was in fact the first mathematical model that described the macroeconomic system with the help of micro-economic indicators (in the model a separate equation is allocated for each item) that characterized the behavior of producers and consumers. Its contribution to EMM was in application of the technological coefficients a_{ij} characterizing the structure of the cost in the production units to describe the economy through the system of algebraic equations. This approach is still the basis of modern EMM.

The task of the optimal behavior of producers and consumers was not set in this model. However, this problem was set by Walras in his exchange model in which the demand for the final product is determined by the criterion of maximizing utility, formulated W. Jevons. He found the main problem of economic science in the study of consumption, the basic law of which he considered to be the law of diminishing marginal utility. Under the concept of "utility" Jevons meant an abstract property of the object to correspond the objectives of consumers. He believed that the total value of units of goods depended on their quantity, and the utility of the last increment of the good tends to decrease with increasing amounts of goods [5]. The follower of Walras, who contributed to the development of the Lausanne school, became Pareto, who introduced the concept of optimum, named after him - "the optimum of Pareto" [6]. Pareto optimality means to attain such condition of the economic system, in which the criterion function value of any participant of the system cannot be improved without impairing the other participants in the target function values. The concept of Pareto optimality is widely used in the theories of economic balance and coordination of interests.

In fact, the creators and researchers of the models tried to describe the proportionality of the economy development using a static system of algebraic equations. It was a step forward from the point of view of understanding of the relationship of producers and consumers in their attempt to achieve proportionality. Moreover, the authors of balance models contributed significantly to the understanding of achievement of the optimum system, both in terms of behavior of individual agents, and the total system. Their introduction of the concepts of marginal utility and marginal costs proved to be useful for better understanding of marginal and average cost pricing mechanism in the reproduction theory. Analysis of the conditions of balance and optimum implemented by Walras, Jevons, and Pareto had a great influence in the 40th and especially in the 50-ies of XX century on the economists involved in EMM. The model of Leontiev, who developed the method of "Input – Output" can be considered as a development of the Walras model because it also describes the economic system by means of linear equations and uses the technologic coefficients a_{ij} characterizing the cost of production of goods in one branch in the production of goods in the other industries. At the same time Leontiev model can be seen as the first step towards the practical use of EMM, as it reflects the real economy in the existing relationship between the final, intermediate and gross domestic product.

While the Leontiev model "Input - Output" (model of inter-branch balance) was increasingly being used in the state regulation of the economy in the post-war Europe, Japan, and then in the USSR (1958), the researches in the development of mathematical balance models of intensified. A typical example of such research was the balance model of Arrow – Debreu [7]. In this model, besides the criterion functions of consumers, the target functions of manufacturers - to maximize profits – were taken into account. The balance in the model of Arrow – Debreu means the totality of the price vector, the cost – production vectors and vectors of purchasing, that are optimal for the participants at these prices, and in which the total demand for each product type, that has a non-zero price, does not exceed its total supply. It is proved that under the general assumptions, the balance in the model of Arrow – Debreu exists, although its uniqueness cannot be guaranteed. Balance of Arrow – Debreu obtains many optimal properties under very general assumptions, in particular, the balance vectors consumption and costs-production maximize a balanced sum of the criterion functions of consumers.

Some researchers thought it was possible to use this theory to simulate the planned economy [8].

In the 60s-70s many new versions of models of economic balance appeared, they had the different ways of formation of consumer income, different participants and assumptions about their behavior. The attempts to reflect them in the balance model, to take into account the existence of the collective goods, and so on, was taken. The ideas of marginalism and balance theory became popular among the representatives of neoliberalism. Today they are used in the main branches of economics – demand theory, theory of the firm, and so on. However, developing the mathematical apparatus of balance models, their supporters, in contrast to the Leontiev school, do not focus on the use of these models in the modern IT in order to improve the efficiency of administrative decisions in the economy.

3. Growth models (models of economic dynamics).

Under the models of economic growth (dynamics) the models, in which time is one of the parameters and the calculation for the next year is based on the calculations for the current year are understood.

One of the first models of economic dynamics was developed in 1937 by the American scientist John von Neumann – a model of balanced growth (expanding economy) [9]. The model suggests that the production output of this period is the cost of the next period. The concept of stationary trajectories imposed by Neumann, which is understood as the constant growth of output at its constant structure, is widely used to predict the possible trajectories of growth in output and cost estimates. The particular importance for the researchers is the stationary concept, which is used to determine the optimal trajectory, close to the main, which is understood as a stationary trajectory, which figures are growing with the constant, the maximum possible rate. For economic dynamics models it is mathematically proved that, regardless the initial condition, any optimal trajectory after some time becomes closer to the main. On the one hand, the value of the von Neumann model is in attempt to describe the economy as a dynamic system, and in the introduction of concepts of stationarity and mains, which can be used in the scenario calculations of economic development. On the other hand, the model gave the impetus to the use the mathematical programming apparatus for solving a

system of linear inequalities and for development of the mathematical apparatus used in it. In particular, a new direction appeared on its base - the theory of games. The further development of the Neumann model followed the way of its combination with the other models and complexity of the mathematical apparatus. Therefore, the Neumann model was developed by the Japanese economist M. Morishima in 1965 [10], which saw its resemblance to the Marx's schemes, introduced a number of additional conditions, and a new mode was called the "model of Marx – Neumann." Other researchers tried to connect the Neumann model with the model of Walras – Arrow – Debre.

During the 50-70-ies the most important results in mathematical economics (optimal programming, game theory, the theorem on mains, and others.) were reached mainly by the professional mathematicians. The mathematical tools developed by them could be useful for the analysis of some economic phenomena.

The important contribution to the development of mathematical programming as a tool of EMM had been made by mathematician R. Bellman (USA), who worked in the field of dynamic programming. He developed the theory and numerical methods, which was a multi-step process of finding the optimal solutions for some of the criterion function. His main method was the method of recurrence relations, the base of which was the optimality principle: if the process of control is optimum in the first step, it will be optimal for the process, remaining after the first step [11]. Dynamic programming methods are used for simulation of random processes such as inventory management, where the costs of storing of the excess inventory at the reduced demand are compared to the losses from the lack of reserves at the intensive demand. EMM of the dynamic programming of the stochastic processes are called Markov chains.

Bellman optimality principle was used in the models of economic dynamics which had have been used in the practice of the state regulation of economy in the 50-s as the instrument of prediction. These models are, first of all, the growth model (Harrod, Domar, Solow and others) and the dynamic model of Leontiev. In the growth models based on Keynesian ideas, in addition to the time factor, the relationship between capital investment and production was taken into account [6]. Then the growth models became more complex in different directions, mainly used to account the time lags between investment and production. The further development of the growth models was the use of the principle of optimality: the criterion function of the economic system or the criterion function of separate entities of system, if they have autonomy.

The development was given to two approaches to the modeling of economic dynamics, that reflected the existence of two directions in the economic research, conditioned by the existence of two economic systems – the planned economy of the USSR and the market (oligarchic) economy of the US.

The first approach (constructive) was based on the principle of control of the economic system, and contained the formulation of the extremal problem in a great number of the permissible trajectories of movement of economy. These models are often called the models of optimal economic growth or the welfare models.

The second approach is descriptive, according to which the trajectory of economic development is the condition of balance which is formed by the interaction of different entities of system. The developers of these models showed that in some cases there was the balance theorem, according to which any balance

trajectory is optimal at the certain criterion function, and vice versa, each optimal trajectory is balanced at a certain organization of the system entities interaction.

When developing the models of balance and dynamics the Soviet economists and mathematicians followed two mentioned approaches. The research center was the development of dynamic Leontiev model [12]. Researches were undertaken in the following areas: accounting of the criterion function in the model; the introduction of the variance in the technological production methods that vary with time, depreciation of funds, different time of construction and development of facilities; accounting of the lag of capital investments, and so on. In general, the researches were limited by the introduction of additional exogenous parameters and the improvement of mathematical apparatus that describes the inter-branch balance (MIB). The attempts to use the MIB in automation of routine calculations (ARC) were made [13]. However, these attempts were unsuccessful for the following reasons.

First of all, the planning process is iterative and the models as the system of linear equations were static. Secondly, in the modified Leontiev models the law of proportionality of the economy was ignored, and this law assumed the coordination of links of producers with the orders of final consumers taking into account the effect of feedback - balance prices and the law of economy of time, according to which the effective range of new technologies is calculated: the planned norms of cost were the exogenously given values.

Such use of mathematical methods in economic research had been criticized by academic economists. So, V.V. Novozhilov noted that EMM helped you to systematize the ideas about the functioning of economy, but the most obvious truths could be missed during their creation [14].

The value of the mathematical models in economy lies in the fact that they allow us to describe the economic phenomena and to obtain the valid conclusions in the language of formulas and algorithms. This explains the inclination of the Western economists to the creation and practical use of econometric models based on the models of economic balance and growth, the principle of optimization, game theory, and other old and new economic theories. But, there is another side of these models. No matter what the actual statistics these models are built on, if the precondition used in them was false, the calculation results would be biased.

4. Econometric models

Econometrics means the development of mathematical and statistical models of economics and quantitative assessment of their parameters. A significant contribution to its formation was made by the studies of the economic cyclicality made by Clément Juglar, J. Kitchin, S. Kuznetsov and N.D. Kondratyev, who discovered the "long waves" lasting for 45-60 years [15].

The the Harvard School can be considered as the founder of econometrics. It was organized in 1914-1918 to study the nature of economic cycles and to forecast the economic situation using statistical methods and mathematical analysis. The basic principle of this school was the notion that "the science meant measurement". According to this, the theory should reveal itself in the result of statistical analysis that was fundamentally different from the position of the founders of mathematics in economic theory school [16]. The short-term forecasting models had mostly extrapolation character. An example of such models was the "Harvard barometer",

developed under the leadership of W. Pearson in order to assess the "economic weather" on basis of statistical observations. "Barometer" was a set of three curves (stock market, commodity market and money market) concerning to which it was believed that they have nearly the same vibrations with some shift in time. This made it possible to predict the behavior of one curve, for example, commodity market, based on the behavior of another, such as the stock market.

In the 20's the ideas of Harvard School were widespread in Europe, where the opportunistic institutions were created and they studied the statistical data in order to predict the "economic weather." The all-USSR Market Research Institute (AUMRI) was created in 1922 in the USSR, whose main task was to study the economic situation, time series and seasonal fluctuation for the short-term forecasting of price indices and purchasing power of money. The well-known scientists of the institute were A. Conus, E. Slutsky and others. In 1926 the League of Nations established the Committee of Experts who were using the "economic barometer". Practice showed that the "Harvard barometer" predicted the "economic weather" in the period of stabilization relatively well, but not during the "storm": before crisis of 1929-1933 the Harvard University made a forecast of "prosperity" of the economy.

Due to the crisis of 1929-1933 the United States began to pay a special attention to the development of econometrics in order to study the problems of the economic cycle with the help of statistics and mathematics methods. In 1930 the International Econometric Society was created in the United States. On the first stage of its development the researches were carried out in the following areas:

- Mathematical school in economic theory, which assumed the use mathematics and statistics in theoretical studies of the economy;
- Econometrics, which method was essentially statistical and didn't investigate cause and effect relationships;
- Mathematical economics as a branch of mathematics devoted to the development of mathematical tools for EMM.

Among the first Russian developers of econometric models there was G.A. Feldman, who, being an employee of the USSR State Planning Committee, developed the first model to the predict the rate of economic growth (1928-1929 years). The basis for its construction became the Marx scheme. The model reflected the correlation of the national income rate of growth, changes in capital productivity and labor productivity, the structure of use of the national income. According to this model the Gosplan calculated the expected rate of growth of the national income.

Starting with the 30-40-ies econometrics gained the rapid development and today it is the main method of research of economic processes and forecasting.

If in the the 70-ies the economists - supporters of econometrics considered that it was necessary to use its methods for the quantitatively confirm of the theoretical constructions, then starting with the 70-ies the econometric methods are used to describe the cause-effect relations between the economic parameters. Today econometrics is actively used by monetarists to substantiate the choice of scenario of economic development, of a certain type of economic policy.

A powerful impulse to the use the econometrics was given by computers, and by these means there was the development a statistical analysis of time series, as well as the rapid development of the world market of loan capital and derivatives. Statistical models of different countries were integrated into the general system in

order to understand the international economic relations and predict the global economy. For example, the project "Link" – a global model of international trade – was created in 1968 from the Wharton Econometric Forecasting Associates (WEFA) in order to provide the US Department of State with the advisory assistance in development of effective measures in the domestic and foreign policy. The principal disadvantage of econometrics was the study of quantitative relations in the economy without determining the control parameters and feedback from the object of management. Econometrics uses essentially the extrapolation methods, and it limits its practical application in solution of economic problems. Like all other modern researches of EMM, these studies are in crisis because they are not able to offer the effective solutions of the practical problems in the economy [17]. According to N. Petrakov, when forecasting of the economy on basis of multifactor models the internal laws of functioning of the economy as a whole system fall out, leaving unanswered such important questions as, for example, whether the concept of efficiency of the economic system is limited by the indicator of rate of production growth [18].

To carry out the EMM calculations some initial economic information is required. The modern standardization of the national accounts, calculations of economic growth, international comparisons and the creation of strong research departments was organized by the international economic organizations (the World Bank and the International Monetary Fund, the UN and others) and occurs outside the system links with the information needs of the great amount of EMM.

To carry out the calculations with the help of new indicators of models (e.g., the index of inflation expectations, the country's credit rating, and so on) the developers require the additional collection of information that leads to its cascade growth and inefficient use of IT. The groundlessness of the modern economic theories and EMM that serve the cyclical development is primarily explained by the fact that they are not able to offer a way out from crisis cycle to the trajectory of sustainable economic growth. This can be done only on basis of implementation of the scientific approach in the construction of EMM, which suggests in the models the reflection of force of objective economic laws and creation on their base the cyber systems serving the optimization of management decisions in the economy.

5. A dynamic model of inter-sectoral and inter-branch balance (MIIB)

The force of the objective economic laws and the EMM experience are reflected in the dynamic optimization model of inter-branch and inter-sectoral balance (MIIB), developed by the economist-cybernetics N.I. Veduta [19]. This model can serve as a basis for creation of cyber system in order to improve the effectiveness of management decisions. In this model the following principles are realized:

- economy is regarded as the consciously optimized system based on the mixed ownership of the means of production;
- there is a single criterion of optimality, characterized as an objective tendency of society to maximize the growth of quality of life (maximization of the utility growth). Quality of life is determined not only by the non-productive consumption, but also by the content of the labor process, free time, intended to meet the social needs;

- national economy is considered as a complex hierarchical system, which proposes the hierarchical structure of public administration and the implementation of systematic approach in the question of defining the "input-output" indicators, the collection of economic information, its aggregation and disaggregation at different levels of government (economy – industry – corporation);

- social working time, as the only limiting (unreproducible) factor of social reproduction is the starting point for planning;

- force of objective economic laws and, above all, the law of value as a natural regulator of the economy through the proportional balance price deviations from the prices of producers, and the law of economy of time, which is expressed in the effective replacement of the old technology with new one in order to maximize the cost savings are reflected in a dynamic MIIB;

- MIIB as a dynamic system is an iterative process of harmonization of planned calculations, including the choice of effective technological methods of production and adjustment the criterion values depending on the production capacity;

- problem of the efficient distribution of productive investment is solved in the MIIB simultaneously with the task of optimizing of the structure and volume of the final non-production goods;

- taking into account the implementation of the model and its improvement the direction of the Public Administration reform is determined.

The principal difference between the MIIB table from those tables based on the concepts of the "System of National Accounts 2008" (2008 SNA) and the Balance of National Economy (BNE) is that MIIB is an absolutely symmetric matrix, which presents the interlinked accounts of all sectors of the economy. Correction of the initial MIIB information by recalculation of its indicators in reliable assessments allows to get rid of the balancing rests presented in other tables and hidden in the line "gross income" or "profit". Such correction allows to perform the calculations of the MIIB while retaining the balance of all accounts of industries and sectors.

Using some of forecast parameters, macro-economic proportions and the original data over the structure of the final non-production goods, the dynamic MIIB allows to specify them in the course of the optimization plan calculations.

Conclusion

Exit from the global crisis assumes an appeal to the economic science, which studies the objective economic laws. These laws were discovered in the reproduction theory by Karl Marx. The next step in the development of economic science were to be EMM, as a tool solution of practical problems. With the appearance of computers the possibility of practical use of EMM in order to improve the quality of economic management increased significantly.

The first EMM (equilibrium models and growth models) developers contributed to the use of mathematical formalism to describe the economic phenomena, which in its turn contributed to the better understanding of the force of objective economic laws.

Later the EMM was developed mainly in the direction of the complexity of the mathematical apparatus that turned the EMM into the object in mathematical research.

Another direction of EMM development is the econometric models, on basis of which the forecast calculations are conducted, they extrapolate the current trends, without giving an algorithm for solving the current economic problems.

However, the denial of the EMM and its substitution with the abstract theoretical constructions that reject all scientific research and practical experience, and, in fact, are lobbying the narrow selfish interests through the designation of certain priorities, does a great harm to the proportional development of the economy. The task of the economic science was formulated in the XIX century as "systematization of laws obtained by the theory, regularity and observations in order to control the various manifestations of the practical economic and social life of the society and the State" [20].

Today the dynamic MIIB based on the objective economic laws allows to implement the cyber systems in the management of the national (global) economy to ensure the sustainable growth in the quality of life.

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INNOVATION ENGINEERING AS THE INSTRUMENT OF DECISION- MAKING SUPPORT

***Abstract.** The proposed methods of assessment of the innovation project by way of application of innovation engineering as the information-analytical instrument. Methodology of situation modeling has been used for assessment of the innovation project technological decisions effectiveness.*

***Key words:** engineering, financial engineering, innovation project, investment activity, innovation engineering*

Introduction

One of the priority lines of economic policy in the developed nations is introduction and further support of innovations. The process of support of the innovations requires taking into consideration a great number of various factors that have an influence on the effective return of the investments or other expenses for development and introduction of the advanced technologies. Application of the information systems for supporting decision-making becomes evermore topical and the reason of it is the number of the information technologies and the opportunities for their implementation.

The process of creation of a product or a service from the existing and accessible resources is usually called engineering. Within the wide range of already existing brands of engineering there has appeared the need for the engineering of creating innovations, because only every tenth innovation project becomes recognized and is included in the manufacturing process. Application of methodology of innovation engineering gives the opportunity to avoid typical errors in the development of the innovative products. The conceptual foundation of the innovation engineering is the systemic, object-oriented and coordinated interaction of all participants of the innovation process [1].

The life cycle of an innovative product includes the following stages: development of the product, introduction of the product to the market, termination of production and sales in the market. Along with the life cycle of an innovative product for the systemic innovation, there is also the life cycle of the technical system, that is longer in comparison with the life cycle of the innovative product and covers the period from its groundbreaking idea to the removal from operation and utilization [2].

If an innovative product is a certain technical system, the following tasks have to be accomplished for realization of its life cycle:

- carrying out a functional analysis of the original innovative idea and identifying advantages of the proposed innovation over the existing means;
- identifying opportunities for the implementation on the basis of the existing and available resources;
- analysis of the needs that will be satisfied in case of implementation of the proposed innovation; determination of important and potential sales markets for the innovative product;

- determination of economic feasibility of development and production of the innovation;
- carrying out preliminary functional-cost analysis of the market concept of innovation;
- development of a pilot functional system and the system operation algorithm;
- carrying out internal system analysis;
- identifying the existing contradictions on the functional level;
- development of documentary support for the innovative idea;
- assembly, testing and trial of the product;
- preparation of the draft technical specification for the engineering design of the specimens of the innovative product.

1. Preliminary data

Engineering envisages a complete development of the project from the idea to the implementation and further monitoring. Thus, appearance of the financial engineering was facilitated by changes in the domain of banking and investment capitals. Financial engineering is a combination of design, development and implementation of the innovative financial instruments and processes, as well as a creative pursuit of the new approaches to resolving financial problems.

Financial engineering covers a wide range of issues – corporate finances, management of long- and short-term cash investments and the risks involved therewith. In general, the risk is the possibility of occurrence of a certain unfavorable event, entailing various kinds of losses (for example, a physical injury, loss of property, receiving income below the expected level, etc.). In other words, a risk is an activity associated with overcoming an uncertainty in a situation of the inevitable choice, in whose process it is possible to make a qualitative and quantitative assessment of the likelihood of achieving the anticipated result, a failure to achieve and deviation from the goal. The main features of a risk are contradictions, alternativeness and uncertainty. The alternativeness of a risk means the need to make a choice from two or more possible options of decisions, directions, actions. If there is no open options, there is no risk situation and, accordingly, there is no risk [3].

The key task of financial engineering is specialization in advancing and conducting negotiations on simplification and sale of credit lines intended for the construction of manufacturing enterprises.

Thus, in this case, financial engineering is development and monitoring of the project, starting from the intentions to build and obtain material assets, including those from foreign investors, to the completion of construction and repayment of credit already during operation of the enterprises.

Financial instruments are examples of the innovative use and combining existing financial instruments for reducing financial risk, lowering the cost of financing, using some advantages and peculiarities of accounting and tax legislation, or for the use of an ineffective market. There are external and internal factors producing influence on the rapid development of financial engineering [4]. The external factors include, in particular, volatility of prices, general globalization of industrial and financial markets, tax asymmetries, achievements of the financial theory in the sphere of new techniques and technologies, changes in the regulatory, legislation, strengthening of competition and operating costs. As to the internal

factors, it should be noted, that they include especially the need for the liquid funds, reluctance to risk on the part of managers and owners of the company, as well as divergence of their interests.

New financial instruments can be classified as follows:

1. By their designation:
 - financial instruments that lower the cost of attraction or increase efficiency of investments;
 - financial instruments that redistribute market risks;
 - financial instruments that reduce pressure of regulatory, accounting and tax constraints;
 - financial instruments designed to use segmented or ineffective markets inefficiently.
2. By types of the instruments:
 - financial instruments based on the "technology" of forwards and swaps;
 - financial instruments based on the option "technologies";
 - debt financial instruments.
3. By the operationally productive principle:
 - financial instruments based on consumer products and securities;
 - financial instruments based on financial processes;
 - financial instruments based on financial strategies and decisions.

The process of support of the innovative decision-making requires taking into consideration a great number of various factors that have an influence on the effective return of the investments or other expenses for development and introduction of advanced technologies.

2. Statement of the problem

Application of innovation engineering from the information-analytical standpoint permits to use the principles of situation modeling for gathering, processing and analysis of the input information for comprehensive assessment and prediction of the innovation projects.

Thus, in order to implement the principles of innovation engineering, the following tasks have to be achieved:

- identification of input and output data components;
- development of the algorithm for a possible postponement of reimbursement of a credit and the bank interest thereon;
 - study of the risks of the first year of the investment project implementation;
 - elaboration of the conceptual diagram of interaction of the investment process participants analysis of the opportunities for increasing the profitability of the project.

The following output data can be obtained based on the analysis of the state of the innovation project:

1. General preliminary settlement payments.
2. Basic net foreign currency earnings (FCE).
3. Assessment of the results of payments.
4. Structure of payments:
 - loan repayment;
 - banking interest ($k\%$ per annum);
 - indebtedness to the bank (ε millions of US dollars);

- insurance amount ($q\%$ and postponement of payments).
- 5. Possibility of restructuring payments.
- 6. Project profitability level.

3. Example

Absence of the meaningful state concepts is not an obstacle for establishment of the elements of sustainable development systems at various levels. Thus, according to the UN recommendations, there is a need for the initiative to develop local elements of sustainable development and their further scaling. It is for this purpose that an innovation project was developed for the construction of the system for integrated solid domestic waste processing and organization of the enterprise for the eco-friendly disposal of solid waste with further production of alternative energy and other useful products. Rapid development of industry makes it possible to apply a variety of methods for sorting out and processing solid domestic waste, namely: pre-sorting, sanitary waste landfilling, combustion, biothermal composting and pyrolysis. The objective of this project is to create an environmentally friendly, safe and commercially healthy solid waste management system, but as this project is a pilot project, technical, organizational and economic solutions used in it must ensure their effective use in the construction of waste management systems in other regions with similar reference conditions.

The project envisages commissioning of a production facility for processing 200 tons of solid domestic waste and 100 tons of organic agricultural waste and sludge waste per day. In general, the structure of solid domestic waste in the region is in line with the average statistical data on Ukraine and has the following structure: paper and cardboard – 10-35%, food waste – 20-50%, plastic materials - 4-15%, etc. The main mass of waste is organic components - from 35 to 50 percent with the essential increase of packaging paper and plastic materials in recent years. Compared to housing sector waste, the waste of non-housing sector is characterized by the increased content of unpolluted waste paper, metals and plastic materials.

Preliminary analysis of modern technologies for processing solid domestic waste was conducted when choosing technological solutions with the use of situation modeling methods. Thus, taking into consideration technological, industrial and organizational aspects, comprehensive use of technologies of the companies GTE International Holding (Hungary) and Zorg Biogas (Switzerland) was chosen. Solid domestic waste processing complex of the GTE International company consists of three systems – sorting, gasification of organic waste and depolymerization. Waste paper, metals, glass and some other waste are packed and sold to consumers immediately after sorting. Organic waste products are gasified and produce synthesis gas that is used for generation of electric power. In its turn, the depolymerization system recycles milled and dried plastic waste and polymer film for further production of synthetic fuel (a mixture of about 30% gasoline and 70% diesel fuel.) It should be noted that equipment of the company GTE International complies with all EU requirements, including those presented to diesel fuel synthesized in the result of recycling.

Conclusion

The components of innovation engineering and financial instruments discussed herein are examples of innovative use aiming at reduction of financial risk and at lowering the cost of financing innovation projects. Thus, application of the innovation engineering methodology allows to optimize the flow of financial resources, to assess effectiveness of investment and provides opportunities for elaboration of substantiated recommendations for the effective innovative decision-making.

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MATHEMATICAL AND INFORMATIONAL MODELS IN ECONOMY

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MODELING OF FINANCIAL FLOW REGULATORS IN SYSTEMIC MACROECONOMIC ENVIRONMENT

***Abstract.** The peculiarities of macroeconomic influence on the innovation process of development in emerging market countries are explored. The emphasis is on economic mechanisms that create «instability zones» of monetary and fiscal policy instruments. The external and internal factors of their origin are determined. The monetary, financial and socio-humanitarian factors implementing the functions of redirection of financial flows are considered. The economic-mathematical approach to theoretical modeling the self-organization processes of economy is proposed.*

***Key words:** economic-mathematical modeling, national economy, innovation development, management of economic development, macroeconomic environment, financial system, interest rate, percentage reduction, disposable (available) income, socio-humanitarian factor.*

Introduction

Modeling of mechanisms of the economy self-organization, which carry out redirection of financial flows, is a new scientific direction. In the context of management impacts, macroeconomic policy instruments (fiscal, currency, and monetary) are usually considered. They do not operate in the mode of self-organization, but are in the field of legal economic institutions. However, there are powerful factors of non-normative influence on the processes of self-organization.

One of the problems of the macroeconomic policy development is the need for multicriteria optimization. At the same time, it is necessary to ensure low inflation and low interest rates for the stability of the exchange rate. Target fixation (setting the value to be achieved) of one of these indicators is a complex but solvable task. While simultaneous targeting of each of them by a single macroeconomic instrument is often unattainable as a result of the "conflict" of these indicators (the acquisition of some of them different vectors opposite to the purpose of targeting). Because reaching the goal of targeting will require simultaneous enforcement of the opposing actions from the same policy tool. Such conditions are called an "area of unstable influence" by macroeconomic instruments. Overcoming the problem of managing an economy in

such situation is possible under development a certain algorithm for the interaction of instruments (and indicators), in particular with the innovation sector of the economy.

The novelty of our approach to the consideration of the task of managing the national economy development lies in the study of self-organizing mechanisms for the regulation of financial flows.

The purpose of the article is to develop the basis of the methodology and justification of indices-indicators for the economic-mathematical modeling of financial flow switches as macroeconomic mechanisms of economy self-organization on an innovation basis.

Among them, the influence of monetary, financial, currency and socio-humanitarian factors (markets) of the systemic macroeconomic environment¹ on innovation development is considered.

Almost all studies in this area have been made by the author. However, their theoretical background has been developed before. In particular, the macroeconomic aspect of the problem was studied by A. Galchinsky [1], V. Heyets [2], S. Korablin [3]. The methodological foundations for its study were laid down by J. Keynes [4] and his followers [5], whose works defined the content of the Keynesian revolution in economic theory [6]. In terms of general macroeconomic theory and macroeconomic modeling they were investigated by J. Hicks [5], P. Samuelson [7] and G. Mankiw [8].

The role of money and interest rates before J. Keynes was considered by M. Tugan-Baranovsky [9], K. Wicksell [10] and I. Fisher [11]. Monetary theory and monetary policy were developed by M. Friedman [12]. The theory of economic growth – by R. Harrod [13], E. Domar [14], R. Solow [15]. The innovation theory – by J. Schumpeter [16] and P. Romer [17]. Issues of economic cyclicality and dynamics of financial and currency flows – by M. Tugan-Baranovsky [9], G. Calvo [18], M. Kondratiev [19]. Mathematical models of currency and financial crises – by P. Krugman [20] and M. Obstfeld [21].

The phenomenon of the macroeconomic environment (in its traditional sense) was described, first of all, by J. Keynes [4] and his followers within the framework of the Keynesian Revolution Mainstream. Mathematicalization of theoretical developments and the first systematization the results of this "Mainstream" was carried out by P. Samuelson in "Economics" [7]. The most significant publications also include the works of R. Mundell [22]. They had formulated the foundations of macroeconomics as a science.

The creator of modern monetary policy from the standpoint of the neoclassical approach was the Nobel Prize winner M. Friedman [23]. The role of the exchange rate as a macroeconomic instrument is considered in the writings of P. Krugman [20] and M. Obstfeld [21]. Their creation of equilibrium models of the economy and the models of monetary and financial crises approached science to consideration of currency exchange rate as important indicator of the systemic macroeconomic environment.

In recent decades developers of methods of economic management have received additional opportunities through the use of information technology (IT). Thanks to them they got close to creating new management standards based on the combination of IT and macroeconomics. This challenge requires changing in the

¹ The term is introduced and explained by the author in [26].

methods of achieving the objectives of governance and targeting the macroeconomic indicators.

Macroeconomic methodology developed at Harvard University of the USA [8], macroeconomic accounting standard – System of National Accounts (SNA), adopted by the US State Committee [24], international accounting standard of the balance of payments developed and improved by the IMF [25] – in aggregate they not only provide the opportunity to create and structure a new information and analytical space for the economic management at the macroeconomic level, but are themselves structural elements of this space.

Scientific support is required to introduce computer technologies in the forecasting and economic development managing processes. And it is growing the urgency of working up algorithms that create an opportunity for implementation the software tools of economic-mathematical modeling.

This task is facilitated by the fact that the macroeconomic methodology from the beginning is mathematical. Recently it is actively perfecting by IMF and World Bank experts. Thanks to them it was improved macroeconomic accounting standards of the balance of payments of the countries and was developed methods of teaching macroeconomic analysis used at MF Joint Vienna Institute and at World Bank [27].

But attempts to use such methods for constructing algorithms of economic and mathematical analysis of macroeconomic policy in developing countries have met with difficulties. They arose due to inadequate study of the peculiarities of the systemic macroeconomic environment development in these countries.

We faced the actual task of adequately describing the processes of economic dynamics (economic growth, cyclicity, etc.), especially the crisis processes in economic systems where macroeconomic stabilizers and indicators are not sufficiently developed. The difficulties are compounded by the need to take into account the influence of external factor of global macroeconomic environment of such countries.

1. External and internal holding factors of developing countries grows

Modern developing countries are surrounded by powerful economic systems with a developed macroeconomic environment characterized by very low interest rates and floating exchange rates. The exchange rates in them are stabilized for a long time mostly as a result of the self-organization of economic mechanisms rather than the use of macroeconomic policy instruments. Because of this developed systems look static, but in reality they are extremely flexible and sensitive to changes.

At a time when modern-day world leaders were developing their international environment was fundamentally different. There were no systems with extremely low interest rates around. The studies of world leaders countries development became the classics of economic science, but the regularities described in them do not work in modern conditions in the countries of second wave of development where operate other external factors of their macroeconomic environment.

New development conditions are extremely insufficiently researched. This negatively affects primarily the efficiency of managing the economy in the so-called "instability zones". The term "instability zone" was introduced by the author to determine the macroeconomic situation that arose as a result of the automatic action

of braking economic mechanisms after the use of a macroeconomic instrument (monetary or fiscal). When as a result of the reaction of the economic system there is a complex of multidirectional processes that impede the achieving goal of management and macroeconomic policy instruments fall into the "area of unstable influence". That is the economic situation of the multi-vector impact on the investment (innovation) process by interest rates, inflation (prices), exchange rate, income. Moreover, the multi-vectority dynamics of these factors hinders the achievement of the targeting goal.

For example it may be situation when the weakness of economic system sectors makes it impossible to accelerate investment processes due to high interest rates. Then excessive use of state economic instruments as accelerators of development can lead to the investments crowding out effect in these sectors and in the whole economy.

This effect, described in [28] arises from the impact of state finances on monetary and financial markets, which negatively affects interest rates, increasing them even more. Rising interest rates reduces the attractiveness of investments realized through the credit market. It negatively changes the structure and directions of financial flows, complicates the choosing of innovation priorities and, despite the attempts to accelerate investment processes by means of government programs, suppresses the economic development.

The large-scale impact of the investments crowding-out effect can threaten economic and national security as it may cause a slowdown in the rate and quality of economic growth.

To minimize the negative affects of this effect it is important to promote the development of macroeconomic mechanisms of economic self-organization. This can be achieved by changing the focus from fiscal to monetary policy. Soft monetary policy is capable of intensify the growth of economic activity which will be accompanied by an intensification of the processes of economic self-organization.

However in weak economic systems such a policy causes the problem of accelerating inflation – Fisher effect [29, p. 104]. Therefore in emerging economies the use of monetary (and currency) instruments causes a "conflict" of management tools, that is the emergence of "areas of unstable influence". The conflict is that the situation requires multi-directional, sometimes diametrically opposed actions from the monetary instrument. It extremely complicates the monetary policy application. And not optimal use of monetary instruments can cause an economic crisis.

For example the policy of reducing inflation involves the central bank's monetary constraint. But such actions will lead to an increase in interest rates, which will suppress investment processes and slow down development. The policy of stimulating investment and lower interest rates on the contrary will require the implementation of a soft monetary policy. But such a policy will stimulate inflation and crisis processes owing to overheating of the economy. That is, there will be negative consequences in both directions of the monetary instrument – and in the case of increasing, and in the case of reducing money supply.

Because of this the "enchanted circle" is formed which every time returns monetary policy to hardcore restrictions, raising interest rates and suppressing investment activity. If as a result of the struggle with the negative consequences of this "circle" a powerful crisis arises the fiscal anti-crisis policy may be the last remedy to counteract it. But in the case of its application the effect of crowding out investments will reappear. That is, everything will return to the starting position

from which the transfer of political accent to monetary instruments began. So the economic development process is slowed down again.

In developing economies there are several "enchanted circles" similar to the described. This makes it difficult and sometimes impossible the transition to optimal use of fiscal, monetary and currency management tools. It is important that such difficulties arise only in certain states of economic systems and their macroeconomic environment. Namely, in a state of weakness or lack of innovation sectors of the economy combined with the weakness of the systemic macroeconomic environment (because of what it is in the "instability zone" and its instruments – in the "area of unstable influence").

Overcoming the "instability zones" is complicated task. In some countries it is impracticable due to the fact that developing countries are surrounded by developed countries with low interest rates. As a result there is a percentage reduction which becomes an amplifier of wave-like processes of free capital inflow and outflow [30, p. 77-90, 140-170].

Therefore the greatest problem of development management optimizing in developing countries is reducing the risk of sliding the economy into a crisis due to its overheating or excessive collapse of business activity. The solution of this problem only by the efforts of the central bank and government requires continuous monitoring of indicators: employment, real disposable income, interest rates, exchange rates, etc.

It is also necessary to take into account the ambiguous influence of humanitarian factor which determines the nature of development management of each economy. Even in the presence of a professional approach by regulators, the lack of ethics and positive social capital will become a major constraint in the design and implementation of efficient algorithms for simulating the switches of financial flows. Since the creation of such switches on the basis of self-organizing mechanisms becomes impossible due to the need for constant intervention of government instruments distorting interest rates in the economy. It is the humanitarian factor that laid the foundation of European civilization contributed to the formation of science, culture, modern financial and innovation systems. For all that has provided an explosion of innovation development in Europe and then throughout the world.

Unfortunately, the influence of the humanitarian factor can not yet be formalized in macroeconomic mathematical models. Mostly because it can not be exhaustively evaluated in monetary, financial and currency formats. Only some of its aspects are evaluated (by the indicator of patenting intensity, etc.) because it is a category of ethics and faith in the Absolute not an economic exchange.

Consideration of the humanitarian factor influence on the development of countries with a weakly developed systemic macroeconomic environment is traditionally carried out in the political-economic context. Such compensation models have been called "liberal", "social", ect. "Compensation" consists in an attempt to reflect the influence of the humanitarian factor on the development of the economic system indirectly in particular through political-economic or cultural aspects.

2. Theoretical foundations of mathematical modeling of development regulators

In mathematical modeling, in addition to the described difficulties, there are also complications in the description of the macroeconomic environment in terms of creating a methodology to overcome the "instability zones". Within the framework of a positive economy it has been developed. However, in the framework of normative economy its formalization is complicated.

The simulation of macroeconomic mechanisms of financial flows redirection operating in conditions of economic self-organization is a relatively new scientific direction.

Only macroeconomic policy instruments are usually considered as the managerial influences. They operate mainly in the legal field of economic institutions which are inherent in stability. Instead of it we focus on the tools of economic self-organization which are in the field of action of economic mechanisms and are described by market categories. They reflect prices in the relevant markets (monetary, financial, currency) which characteristic feature is volatility.

The use of these instruments faces many difficulties because of their excessive volatility (fluctuation) and multi-vector impact on the objects of management. For "manual" economic management these problems are solved. However, such a management style requires a lot of special training and qualifications of performers especially in the field of macroeconomics. Moreover, even such successfully used instruments are always far from optimum in their results. This is especially evident when there is a need for multi-criteria optimization. For example, if the task is to simultaneously ensure low inflation, low interest rates and a stable exchange rate.

The theoretical basis for the creation of economic-mathematical toolkit for methods to overcome this problem is partly contained in Harrod-Domar's model of balanced development [13, 14]. In it the balanced increase of investments provides the growth to incomes and savings. It can be assumed that this increase leads to an increase in the commodity supply. In its turn it keeps inflation which enable the central bank to increase the money supply regardless (to a certain extent) of inflation. But this model does not give an answer to what volume and quality should be an investment.

Such an answer can be found in the R. Solow's model of economic growth [15] which leads to the conclusion that for balanced development is not enough investment (capital formation). There is also a need for certain number of population and the quality of investment (availability of innovations). That is, the problem of balanced development in the real sector of the economy can be solved by stimulating innovation processes.

For developing countries the situation is complicated by the fact that innovations at the level of economic self-organization are possible only with the honesty of economic agents to each other: a banker to a client, a client to a banker, entrepreneur to entrepreneur, entrepreneur and banker to a scientist and others like that. For lack of such virtues innovations take place in response to economic or national security challenges (the state of war, the defeat in it, the risk of losing sovereignty, etc.) as a catch-up race for the leader (adaptation efforts) implemented by the hard-willed means inherent in political dictatorships.

Personal and corporate mutual honesty is a prerequisite for realizing all aspects of economic self-development. It should be considered in the context of

categorical imperative of E. Kant [31, p. 5] as the economic factor of "social capital" [32] – special ethics of the "spirit of capitalism" [33]. If it is lacking the processes of economic self-organization become destructive. In such conditions the transition to active monetary policy will increase the risks of losses and economic chaos.

Therefore, the list of factors stimulating innovation development must include a characteristic of social capital in terms reflecting the degree of honesty, which requires special research.

To create software systems for the economic development managing in emerging markets countries it is necessary to be mathematically described the factors of innovation development stimulation: fiscal and financial (income, disposable income), monetary (interest), export (exchange rate), as well as socio-humanitarian (indirectly reflected by financial categories).

3. Modeling of "switches of financial flows" in the national economy

Before considering the "switches of financial flows" it is expedient to outline the theoretical and methodological basis of formal description of the macroeconomic environment in which management factors of economic development are in force.

In the macroeconomic context the national economic system consists of four institutional sectors ("households", "firms", "government" (state), "abroad"). The basis for such structuring is the: methodological standard of the System of National Accounts, grouping by the type of institutional units in the national economy macroeconomic environment [24, c. 67-97]. For each of the institutional sectors one can identify the affecting factors of macroeconomic environment. In this case it is: disposable income (Y-T), market interest rate (r), taxes (T), market exchange rate (e).

Each of these factors has its own channel of influence on a particular segment of the national economy. They characterize the functioning of subsystems of the economic system, are arguments of the corresponding functions and have the following common features:

- affect the consumption of a certain institutional sector; Because of this, they can be considered with some assumption as instruments for managing the relevant sector of the economy they are influencing;
- characterize the state of money and financial markets (interest rate and exchange rate are the price of money in the money markets, and the disposable income and the state budget revenue is a reflection of household and general government finances);
- each of them depends on the state of money markets and affects these markets.

Gross Domestic Product (GDP) is the sum of the income of all subjects of macroeconomic relations (institutional sectors) or the sum of goods and services consumed by the institutional sectors, which is equal to these receipts. In this case the basic identity of the SNA (2) and (3) is fulfilled. That is, the flows that constitute the sum of receipts in the institutional sectors of the economy (Y) are equal to the flows that compose the expenditure (consumption) of the same sectors (E):

$$\sum_{i=1}^n \sum_{j=1}^n Y_{ij} = \sum_{j=1}^n \sum_{i=1}^n E_{ji} \quad (1)$$

This follows from the balance of income and expenditure flows (2) that are accounted in national accounts:

$$C + I + G + NE = L + K + T + NI, \quad (2)$$

where:

$(C + I + G + NE)$ is the amount of expenses by the institutional sectors of the economy, as a rule in a year (aggregate demand);

$(L + K + T + IN)$ – the amount of receipts of all institutional sectors of the national economy;

C – consumption by households;

I – gross private investments;

G – consumption of public authority (government expenditures, expenditures of state and local budgets);

NE – net export, difference between export (EX) and import (IM) ($NE = EX - IM$);

L – income received by households;

K – income received by firms (financial and non-financial corporations);

T – income received by government (sector of the state administration), revenue part of the state and local budgets;

IN – income received by "abroad".

Y – in equations (1) and (3) is the aggregate income (GDP). In accordance:

$$Y = C + I + G + NE, \quad (3)$$

where:

$$Y = C(Y - T) + I(r) + G;$$

$$Y = C + I + G + NE;$$

$$C = C(Y - T);$$

$$I = I(r);$$

$$NE = NE(e);$$

$$NE - (S - I) = 0;$$

If $NE = Y - C - I - G$, and $Y - C - G$ – national savings (i.e. S), then:

$$(S - I) = NE.$$

All of the above categories belong to the SNA. In accordance with the structure of aggregate demand reflected in the right side of identity (3) the main participants in macroeconomic relations are determined aggregated into four institutional sectors of national economy. Their demand $C + I + G + NE$ is the aggregate demand.

The relationship between the functions of the exchange rate (r) and the interest rate (e) ($I = I(r)$, $NE = NE(e)$) can be presented as:

$$NE - (S - I) = 0, \text{ i.e. } NE = (S - I), \quad (4)$$

Equation (4) gives an analytical expression of the balance of payments of the national economy. Balance of payments characterizes the state of foreign economic relations. It consists of a current account NE and a financial account ($S - I$). The current account includes a trade balance (flows of goods and services) and current transfers. Equilibrium of payments balance is the equilibrium between current NE

and financial (*S-I*) accounts of payments balance. This equilibrium is determined by the economic mechanism $NE = NE(e)$ with the help of the exchange rate (e).

According to the concept of the balance of payments (the equality of the amount of purchases and the money spent on it - actually consumed money), the demand for goods and services is proportional to the demand for money. The demand for money is permissible to be considered within the general economic framework, that is not only the external but also the wider market, in the form of a unit of two functions - income (Y) and interest rates (r):

$$\Delta M^d = k\Delta(Y - T) - h\Delta r, \quad (5)$$

where:

ΔM^d – changes in demand for money;

$\Delta(Y - T)$ – changes in real disposable (available) income;

Δr – change of nominal interest rate;

k – coefficient of elasticity of demand for money at income;

h – coefficient of elasticity of demand for money at interest rate.

According to equation (5) the demand for money is in direct proportion to real income (Y) and in the inverse – to the nominal interest rate (r).

The demand-for-money elasticity coefficients reflect the ratio between its change (ΔM^d) and the changes of the real disposable income $\Delta(Y-T)$ (6) and the nominal interest rate (Δr) (7):

$$k = \frac{\Delta M^d}{\Delta Y}; \quad (6)$$

$$h = \frac{\Delta M^d}{\Delta r}. \quad (7)$$

According to (4) an indicator of imbalance in the balance of payments (crisis processes) is excessive volatility of:

– interest rate (r), which causes the connection: inflation → bank interest rate → discount rate → investment;

– exchange rate (e), which causes the connection: exchange rate (e) → net export NE (current account) → interest rate (Δr) → investments → financial account ($S - I$); And also → disposable income $\Delta(Y - T)$ → intermediate and final consumption.

Because volatility, if it exceeds the adaptive possibilities of economy, it breaks all balance of payments, trade balance, dramatically reduces investments.

The central bank's struggle with excessive volatility through restrictive measures leads to some stability but the growth of interest rates and exchange rates in this case can not be avoided. An increase of interest rate in such conditions will form a "zone of volatility" as well as interest and currency reductions. It will complicate investment and suppress the innovation processes in the economy. That is, there will be a "enchanted circle" which can be terminated only by increasing the supply of goods by resident firms. But high interest rates would prevent it from doing so as it would impede investment. Attempts to overcome these difficulties by

increasing public expenditures (on investments) will lead to an even greater increase in interest rates and to an investments crowding out effect. The solution to this problem is possible only at the expense of innovation process which due to increase of high-value goods and services supply holds back inflation in the markets of traditional goods. This will allow the central bank to liberalize monetary policy.

The positive growth rate of the monetary supply (positive first derivative, zero second derivative), corresponding to the level of liberalization that the central bank can afford without increasing the risk of inflation, will stimulate investment and business activity. It is a key indicator of the innovation processes availability.

It is clear that the absence of internal interest reduction in terms (4) and (5) can be achieved only in one case when the share of return on investments (money consumption) exceeds the share of costs for these investments. This condition is also possible only in one case when there is a monopoly on innovation¹ (in particular in the real sector of the economy). However, such excess of income over expenditure sooner or later exhausts all investment resources formed at the expense of disposable income ($Y-T$). Therefore, further increase in investments will be possible only through borrowing on the financial and money markets. At this time there will be a change in the sign of coefficient of elasticity of the demand for money at interest rate (h) from negative to positive in the expression (5).

That is, the redirection of financial flows will only take place due to the processes of economic self-organization. This theoretical conclusion provides a reliable basis for the creation of a methodology for economic-mathematical modeling of such switches.

In the case of a simple (traditional) monopoly due to the large internal interest reduction and consequently high interest rates, investments will be made at the expense of the disposable monopoly income. Then the role of $k\Delta(Y-T)$ in demand for money will increase in the expression (5). Incidents of deviation from this situation are considered in [30].

Moreover, the appearance of a positive value of the coefficient of elasticity (h) becomes a signal for the innovation process activation stimulated by the processes of economic self-organization.

The level of humanitarian factor development (the accumulation of positive social capital) can be partially measured and formalized as an indicator of the monetary sufficiency of the economy (the monetization ratio). The thresholds for this ratio are given in [30]. However, their relationship with the switches of financial flows and the influence of humanitarian factors will require further research.

Thus, the methodology for managing the redirection of financial flows can be reduced to a simple algorithm using indices-indicators based on the coefficients of elasticity (k and h) in the demand model for money (5). Switching the vector of financial flows through the interest channel of managerial influence occurs in the presence of economic mechanisms for holding inflation and stimulating innovation process. It is the stimulation of innovation that allows the central bank to increase the money supply and reduce interest rates accordingly reducing the domestic interest reduction.

¹ To determine whether there is monopoly of innovative or traditional goods is possible only in the conditions of a free market and a high level of positive social capital. In a catch-up economy this can only be determined by the strict adherence to the requirements of the selected development priority.

Differently directed changes in the values of the three indices-indicators, namely: an increase in the percentage of interest channel in the structure of demand for money (the increase in demand through this channel of influence should exceed the increase due to the factor of disposable income (5); the reduction of interest rates; the growth of the monetization rate of economy to over 80%; lowering inflation and exchange rate – can be taken as a basis for modeling the influence of the humanitarian factor on economic development. The fact of simultaneous observation of the mentioned values of these indicators is important here. It is assumed that without mutual trust reached in the evolutionary process of society self-development the formation of innovation sector is not happening.

The interest rate is an important indicator of the state of systemic macroeconomic environment as well of the presence or absence of crisis processes in the economy. The interest rate begins to effectively influence the acceleration of economic development if the processes of money supply increasing are self-regulated by the market and if the monetization ratio of the economy exceeds 80% without increasing inflation risks. Under such conditions the interest rate at or below 5% becomes the main source of intensification of investment processes.

The author is aware that the methodological approaches discussed in this article can not claim to be complete coverage of the problem. In particular, the article does not fully considered issues of currency policy and currency reduction, transmissions, fiscal and financial policies optimization, the interaction of fiscal and monetary policies optimization. Given this and the general novelty of setting the problem, the material presented in the article may trigger a discussion in an expert environment that will be received by the author with gratitude.

Conclusions

1. Introduction of methods for managing economic development on an innovation basis, using the processes of self-organization, requires the formation of mature systemic macroeconomic environment, especially money, financial and currency markets. Particular attention is needed to the development of humanitarian factor.

2. Modern information technology, combined with macroeconomic methodology developed at Harvard University of the USA, and the worldwide expansion of macroeconomic accounting standards (SNA) provide the opportunity to create a new toolkit for the macroeconomic level of self-development of the economy.

3. Economic and mathematical modeling of the management processes of innovative economic self-development should be aimed at solving the problems of its withdrawal from the "zone of instability" where the inhibitory processes hinder the achievement of the goal of application the macroeconomic tools for managing the national economy development.

4. In the model of a developing economy managing the foreign and domestic percent and currency reductions should also be taken into account.

5. The influence of management tools takes place in the macroeconomic environment, that is in the "field" of transmission and adaptive mechanisms of the national economy. Their effectiveness depends first of all on the development of high level markets (financial, monetary, currency).

6. Compensation for the underdevelopment of macroeconomic environment in developing countries should take place through the growth of industrial potential

and commodity supply of innovation sector of the economy. And in the conditions of its insufficiency during periods of economic crises should be use the state budget and financial instruments.

7. The systemic macroeconomic environment is an important subsystem of innovation development management. Changing its basic conditions will cause the restructuring of innovation systems. Therefore, one should take into account the key factor of this environment – the demand for money as a function of: disposable income, interest rate, state influence by fiscal and monetary instruments.

8. It is necessary to take into account the contradictory nature of management efforts (their negative outcome) in the "zone of instability" in the form of effects: crowding out investment and rising interest rates for active state investment policy, rising inflation for soft monetary policy, falling business activity under tight monetary policy. As indices-indicators to control the development of this negative phenomenon are offered the coefficients of elasticity of demand for money at interest rate and at disposable income.

9. The humanitarian factor of honesty (a positive social capital) can not be properly formalized in the monetary and financial categories. We propose to carry out its mediated evaluation on the set of threshold values of three indicators: an increase in the percentage of the interest channel in the structure of demand for money, the reduction of interest rates, an increase the monetization factor of economy, lowering prices, lowering exchange rate.

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**AN APPROXIMATE METHOD FOR SOLVING ASSIGNMENT
PROBLEM**

***Abstract** This paper presents an approximate method for solving assignment problem that makes it possible to assign tasks to agents in order to gain utmost overall efficiency in completing all the tasks. An example is provided for algorithm illustration.*

***Key words:** approximate method, approximate solution, assignment problem*

Introduction

Evolution of market relations and management development in all kinds of purposeful human activities in a wide variety of branches (industries, agriculture, commerce, public amenities, health care, environment protection, etc.) set problems that require rendering grounded complex decisions. Particularly, it relates to modern development in Ukraine that requires expanding existing industries and founding new ones. That said, introducing new enterprises and creating new jobs is often connected with so called assignment problem, that is the problem of assignment vacant places in such the way that task performance efficiency is maximized. This problem also arises when founding new or expanding existing organizations.

The assignment problem is one of the fundamental problems of combinatorial optimization in the branch of optimization or operations research in applied mathematics. It consists in finding minimum (or maximum) weight among the elements of two finite sets. It can be presented as finding a control in weighed bipartite graph. On the other hand, the problem is among linear programming problems. It is a special case of transportation problem, that can be in turn represented as a minimum cost flow problem.

Assignment problem can be described via different application instances. For example, there are a number of agents and a number of tasks. Any agent can be assigned to perform any task. Performing tasks by an agent incur some cost that may vary depending on the agent assigned to perform a task. It is required to perform all tasks by assigning exactly one agent to each task and exactly one task to each agent in such a way that the total cost of the assignment is minimized.

If the numbers of agents and tasks are equal and the total cost of the assignment for all tasks is equal to the sum of the costs for performing each task, then the problem is called the linear assignment problem. This version of problem is basic and simplest one. Commonly, when speaking of the assignment problem without any additional qualification, then the linear assignment problem is meant.

There can be other versions of problem that include additional qualification, other methods for total cost calculation, or some changes in base conditions. For example, number of agents can be unequal to number of tasks; total cost definition can be non-linear, etc. In such cases, generalized assignment problem is suggested.

Different methods can be used for solving linear assignment problem, from common linear programming problem solving down to special methods for solving graph problems. Generally, special methods developed for solving this problem are much faster because they take advantage of its special structure. For instance, Hungarian algorithm has been one of the first algorithms, developed for solving linear assignment problem. Problem solving time is proportional to number of agents. Other algorithms used for solving the problem are adapted simplex algorithm and auction algorithm.

The objective of the paper is to demonstrate approximate method for solving assignment problem. In this case, we consider problem of assigning jobs to workers in order to gain utmost overall efficiency in completing the jobs. We also consider mathematical models for the most efficient candidate assignments to vacant positions subject to certain restrictions.

There are accurate methods for solving this kind of problem, but their program implementation is very difficult. That is why we consider method for approximate solving the problem.

An assignment problem has been investigated first in geometric shape by Gaspard Monge in 1784. Although, non-correctness of Monge's solution has been established in the early 20-th century. Further steps to solving assignment problem were made by König and Egerváry in the first third of 20-th century. König and Egerváry dealt this problem as finding perfect matching of maximum weight in weighed bipartite graph [4]. Their works settled the base for Hungarian method developed by Kuhn in 1950-s. In 1947, simplex method has been suggested by Dantzig for solving general linear programming problem to which assignment problem can be easily reduced. The assignment problem set by Dantzig and Fulkerson can be also considered as problem of maximum flow of minimum cost. In 1961, an algorithm for its solution has been published by Busacker and Gowan. As well as simplex algorithm, this algorithm for common problem has exponential complexity, and for assignment problem, polynomial. Theoretical analysis of the algorithms complexity shows that Kuhn and Busacker & Gowan algorithms feature similar theoretical complexity, which is less than that of Goldberg & Tarjan algorithm. Besides, O.F. Voloshyn and M. Y. Kvyk researched models, methods and algorithms that define decision making processes [1-2]. Although, defining the best algorithm requires empirical research.

1. Assignment problem and an approximate method for its solution

Consider assignment problem statement and an approximate method for its solution [3].

Assume that n workers has been allocated to perform n jobs. c_{ij} i -th worker's efficiency in performing j -th job is known. It is required to assign jobs to workers in order to gain utmost overall efficiency in completing all the jobs.

Having introduced variables x_{ij} defined according to formula

$$x_{ij} = \begin{cases} 1, & \text{if } i\text{-th job is assigned to } j\text{-th worker} \\ 0 & \text{in opposite case,} \end{cases}$$

then the problem's mathematical model is

$$L = \sum_{i=1}^n \sum_{j=1}^n c_{ij} x_{ij} \rightarrow \max \tag{1}$$

subject to the conditions

$$\sum_{i=1}^n x_{ij} = 1, j = 1, 2, \dots, n; \tag{2}$$

$$\sum_{j=1}^n x_{ij} = 1, i = 1, 2, \dots, n; \tag{3}$$

$$x_{ij} \in \{0, 1\}, i = 1, 2, \dots, n, j = 1, 2, \dots, n. \tag{4}$$

It follows from formulas (2) to (4) that one agent is allocated to one task. Agents distribution depends on their work performance c_{ij} .

Method algorithm. Let's form a matrix of elements c_{ij}

$$C = \begin{pmatrix} c_{11} & c_{12} & \dots & c_{1n} \\ c_{21} & c_{22} & \dots & c_{2n} \\ & & \dots & \\ c_{n1} & c_{n2} & \dots & c_{nn} \end{pmatrix}.$$

The algorithm includes n steps. In the first step, find maximum among c_{ij} elements. If such element is the only one c_{ik} , then $x_{ik} = 1$, and the first step is finished here. Assume that the max element is not the only in the i -th row. Assume that i -th row contains elements $c_{ik_1}, c_{ik_2}, \dots, c_{ik_m}$ equal to each other. Let us call

$$\max_{j \neq i} c_{jk_1} = c_{j_1 k_1}, \max_{j \neq i} c_{jk_2} = c_{j_2 k_2}, \dots, \max_{j \neq i} c_{jk_m} = c_{j_m k_m}. \tag{5}$$

Then

$$c_{ik} = \min \{c_{j_1 k_1}, c_{j_2 k_2}, \dots, c_{j_m k_m}\} \tag{6}$$

and $x_{ik} = 1$. The first step is finished here. The second step is carried out similar to the first one, but the i -th row and k -column of C matrix is not engaged. The elements of that row and column ($x_{ik} = 1$) are assigned zero. Approximate problem solution will be found in n steps.

2. Implementation example

Let us take a certain matrix C , which elements c_{ij} are given performance efficiencies of i -th worker in j -th job.

$$C = \begin{pmatrix} 5 & 1 & 2 & 3 & 4 \\ 4 & 7 & 5 & 7 & 3 \\ 3 & 4 & 4 & 6 & 6 \\ 5 & 3 & 2 & 4 & 5 \\ 4 & 5 & 6 & 5 & 4 \end{pmatrix}$$

Step 1. $\max c_{ij} = c_{22} = c_{24}$. It arises from (5) and (6) that $\max \{c_{12}, c_{32}, c_{42}, c_{52}\} < \max \{c_{14}, c_{34}, c_{44}, c_{54}\}$, then $c_{ik} = c_{22}$ and $x_{22} = 1$. As a result, we obtain matrix

$$C = \begin{pmatrix} 5 & 0 & 2 & 3 & 4 \\ 0 & 1 & 0 & 0 & 0 \\ 3 & 0 & 4 & 6 & 6 \\ 5 & 0 & 2 & 4 & 5 \\ 4 & 0 & 6 & 5 & 4 \end{pmatrix}.$$

Step 2. $\max c_{ij} = c_{34} = c_{35} = c_{53}$. By virtue of the fact of $\max \{c_{13}, c_{33}, c_{34}\} < \max \{c_{14}, c_{44}, c_{45}\}$ and $\max \{c_{13}, c_{33}, c_{34}\} < \max \{c_{15}, c_{45}, c_{55}\}$, then $c_{ik} = c_{53}$ and $x_{53} = 1$. As a result, we obtain matrix

$$C = \begin{pmatrix} 5 & 0 & 0 & 3 & 4 \\ 0 & 1 & 0 & 0 & 0 \\ 3 & 0 & 0 & 6 & 6 \\ 5 & 0 & 0 & 4 & 5 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix}.$$

Step 3. $\max c_{ij} = c_{34} = c_{35}$. By virtue of the fact of $\max \{c_{14}, c_{44}\} < \max \{c_{15}, c_{45}\}$, then $c_{ik} = c_{34}$ and $x_{34} = 1$. As a result, we obtain matrix

$$C = \begin{pmatrix} 5 & 0 & 0 & 0 & 4 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 5 & 0 & 0 & 0 & 5 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix}.$$

Step 4. $\max c_{ij} = c_{41} = c_{45}$. By virtue of the fact of $c_{15} < c_{11}$, then $c_{ik} = c_{45}$, and $x_{45} = 1$. A matrix is obtained

$$C = \begin{pmatrix} 5 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix}.$$

Step 5. $x_{11} = 1$ The final matrix is obtained

$$C = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 \end{pmatrix}.$$

Objective function value for this distribution $L = 5 + 7 + 6 + 5 + 6 = 29$.

Problems with following mathematical models can be solved in a similar way:

$$1. \quad L = \sum_{i=1}^m \sum_{j=1}^n c_{ij} x_{ij} \rightarrow \max$$

subject to the conditions

$$0 \leq \sum_{j=1}^n x_{ij} \leq 1, \quad i = 1, 2, \dots, m;$$

$$\sum_{i=1}^m x_{ij} = 1, \quad j = 1, 2, \dots, n;$$

$$x_{ij} \in \{0, 1\}, \quad i = 1, 2, \dots, m, \quad j = 1, 2, \dots, n$$

in case that candidates number m is greater then vacant positions number n . In other words, only the most qualified workers receive jobs.

$$2. \quad L = \sum_{i=1}^m \sum_{j=1}^n c_{ij} x_{ij} \rightarrow \max$$

subject to the conditions

$$\sum_{j=1}^n x_{ij} = 1, \quad i = 1, 2, \dots, m;$$

$$0 \leq \sum_{i=1}^m x_{ij} \leq 1, \quad j = 1, 2, \dots, n;$$

$$x_{ij} \in \{0, 1\}, \quad i = 1, 2, \dots, m, \quad j = 1, 2, \dots, n$$

in case that candidates number m is less than vacant positions number n . In other words, all workers receive jobs, since vacant positions number is greater than candidates number.

It's worth to notice that in the first model implementation, the final matrix C will have all zeros in $m-n$ rows, while in the second model implementation, the final matrix C will have all zeros in $n-m$ columns.

We also consider mathematical models for the most efficient candidate assignments to vacant positions in groups.

Here

n – number of vacant position groups;

m – number of candidates for positions;

k_j – number of vacant positions in j -th group;

c_{ij} – expert estimate of i -th candidate's for positions in j -th group.

$$x_{ij} = \begin{cases} 1, & \text{if } i\text{-th candidate is qualified for a position in } j\text{-th group;} \\ 0 & \text{in opposite case.} \end{cases}$$

Let us also introduce restrictions on candidates for vacancies and vacant position numbers in groups:

1. Assume that position candidates number equals to number of vacant positions in groups, where each group has k_j vacant positions in j -th group

$$m = \sum_{j=1}^n k_j .$$

Then, the objective function

$$L = \sum_{i=1}^m \sum_{j=1}^n c_{ij} x_{ij} \rightarrow \max$$

subject to the conditions

$$\sum_{j=1}^n x_{ij} = 1, i = 1, 2, \dots, m;$$

$$\sum_{i=1}^m x_{ij} = k_j, j = 1, 2, \dots, n;$$

$$x_{ij} \in \{0, 1\}, i = 1, 2, \dots, n, j = 1, 2, \dots, n .$$

That is, each candidate will receive positions according to expert estimates.

2. Assume that position candidates number is greater than number of vacant positions in groups, where each group has k_j vacant positions in j -th group

$$m > \sum_{j=1}^n k_j .$$

Then, the objective function

$$L = \sum_{i=1}^m \sum_{j=1}^n c_{ij} x_{ij} \rightarrow \max$$

subject to the conditions

$$0 \leq \sum_{j=1}^n x_{ij} \leq 1, i = 1, 2, \dots, m;$$

$$\sum_{i=1}^m x_{ij} = k_j, j = 1, 2, \dots, n;$$

$$x_{ij} \in \{0, 1\}, i = 1, 2, \dots, n, j = 1, 2, \dots, n .$$

Consequently, not all the candidates will receive positions.

3. Assume that position candidates number is less than number of vacant positions in groups, where each group has k_j vacant positions in j -th group

$$m < \sum_{j=1}^n k_j .$$

Then, the objective function

$$L = \sum_{i=1}^m \sum_{j=1}^n c_{ij} x_{ij} \rightarrow \max$$

subject to the conditions

$$\sum_{j=1}^n x_{ij} = 1, i = 1, 2, \dots, m;$$

$$\sum_{i=1}^m x_{ij} \leq k_j, \quad j = 1, 2, \dots, n;$$

$$x_{ij} \in \{0, 1\}, \quad i = 1, 2, \dots, m, \quad j = 1, 2, \dots, n.$$

That is, each candidate will receive a position according to expert estimate.

Conclusions

Hence, this problem solving algorithm allows us to allocate workers to jobs in order to gain utmost overall efficiency in completing all the tasks, if efficiency c_{ij} of i -th worker in performing j -th job is known. This algorithm is applicable in industries, agriculture, commerce, etc. Some additional mathematical models shown in this paper are applicable in cases when candidates number m is greater than vacant positions number n and when candidates number m is less than vacant positions number n . We have also presented mathematical models for the most efficient candidate assignments to vacant positions in groups.

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ANALYSIS, EVALUATION AND FORECASTING IN ECONOMY

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IMPROVING DIAGNOSTIC MODELS FOR FORECASTING THE BEHAVIOR OF DAMS EQUIPPED WITH AUTOMATED MONITORING SYSTEMS

***Abstract.** An approach to forecasting the behaviour of dams according to the data of instrumental observations with regard to capabilities of automated monitoring systems has been proposed. The approach is based on the use of situational and inductive models, where the situational models correspond to selective series of dynamics of observed data within limited time intervals and the inductive models which are constructed on model data derived from situational models simulate evolutions of diagnostic parameters.*

***Keywords:** automated monitoring systems, dams, dependent and independent variables, instrumental observations, inductive and situational models, long-term and real-time forecasting, monotonic and non-monotonic data series of dynamics.*

Introduction

The long experience the construction of dams shows that accidents on these structures can lead to serious negative socioeconomic and environmental consequences including those of catastrophic proportions. Therefore, the problems of reliability and safety of dams are given considerable attention. At the international level the main work in this sphere is conducted by the International Commission on Large Dams (ICOLD). One of the most important challenges which are solved by engineers to maintain reliability and safety of dams is the creation of effective systems for monitoring of dams condition. The importance of such systems for ensuring reliability and safety of dams was repeatedly emphasized in the past. In particular, Bulletin 59 ICOLD (“Dam Safety – Guidelines” [1]) says that the majority of damaged dams had no monitoring systems or those systems were imperfect.

The problem with proper functioning of systems for monitoring of dams condition is a complex one and its solution does not only lie in sphere of the introduction of up-to-date equipment of automation and computerization. It should be noted the modern automated monitoring systems (AMS) which are installed at dams are not able to directly perform the functions of ensuring reliability and

safety of the engineering facilities during operation. This is due to the fact that monitoring of dams can never be sufficient enough to include all possible influencing factors, important characteristics, parameters, elements and components, the condition of which may affect the overall condition of dams. The most modern types of instrumental control and samples of instrumentation installed at dams allow for doing monitoring of a relatively small number of factors and parameters. As a rule, monitoring is exercised to separate sections, cross-sections, etc. In addition the most advanced AMS is incapable of ensuring the proper modeling of dams' condition yet, which would allow predicting the future behavior of the waterworks. Adequately, they can only perform functions to storage of relevant data and control the state of instrumentation.

In this case, a new task arises which consists in ensuring the processes of modeling and forecasting of dams condition based on observational data under new circumstances when data may be collected in the great amount. Previously, when data were collected manually they were considered to be limited and insufficient to build adequate mathematical models. But without improving of approaches and methods for modeling and forecasting based on observational data, new capabilities of automated monitoring of dams condition are substantially minimized too. Practice shows that large amount of data does not always contribute to the quality of traditional regression models, whose accuracy can degrade. It was found that complex and well structured mathematical models based on observational data in conditions of large arrays of input data do not provide desired results [2]. In particular, the optimization principle, which lies at the basis of construction of traditional mathematical models based on observational data, requires for the systems under study to be in certain boundary limits. If there is a need to have taken into account large amount of data, this principle cannot be easy performed. As a result, challenges associated with the stability of solving optimization problems can even arise in the simplest of cases. Increased quantity of data in case of the traditional approach requires an increase in models dimension by taking into account additional factors and non-linear effects, etc. This leads to disruption the stability of complex models and they can not be used for forecasting purposes.

1. Basic principles of technical diagnostics on dams and principal challenges of regression modeling for forecasting purposes

The basic principles of technical diagnostics and monitoring of condition of technical systems, which were formulated by R.A. Collacott [3], are as follows:

- 1) Consistency and regularity (continuity) of measurements for characteristics which are selected as diagnostic parameters;
- 2) Detection of changes in behaviour of these parameters over time;
- 3) Predicting and forecasting of behaviour of the system which is under monitoring with taking into account these changes.

Automated monitoring systems allow maintaining regular and systematic measurement of diagnostic parameters and storing different data in sufficient quantities to form representative data samples for any situation and any time interval that can be considered in terms of monitoring changes in the environment and in behavior of dams. However, the experience of operating the system at the Kiev dam has showed that implementation of the two following above mentioned

principles requires revision of traditional approaches to modeling based on observational data which are accumulating in large volume due to the increased capabilities of AMS. This is because the typical diagnostic models which are used for predicting and forecasting of condition of dams which are in operation are models of regression type.

Regression models determine the dependence of the mean value of some random variable y , which is accepted as a diagnostic parameter or as a dependent (endogenous or resulting) variable, from the other random variable x or the several such variables $x_1, x_2, \dots, x_j, \dots, x_m$ which are called independent (exogenous, explanatory) variables. The choice of an adequate regression model is based on the minimization of functional which is usually written as the sum of squared deviations $e_i = y_i - \bar{y}$ of the model values $\bar{y} = f(a_0, a_1, \dots, x_j)$ of the diagnostic parameter y from observed values y_i , where $x_j, j = \overline{1, m}$, are independent parameters of the model with total number m :

$$\sum_{i=1}^n e_i^2 = \sum_{i=1}^n (y_i - \bar{y})^2 = f(a_0, a_1, \dots) \rightarrow \min, \quad (1)$$

where a_0, a_1, \dots are required coefficients of the corresponding regression model. In this case the structure of the model is considered known.

The use of regression analysis in modeling according to empirical data can be right if certain requirements (boundary limits) are fulfilled, in particular [2]:

- 1) Data of observations for a dependent variable are random values which follow normal distribution;
- 2) Independent variables $x_1, x_2, \dots, x_j, \dots, x_m$ are measured with errors which can be neglected compared to the error of dependent variable y ;
- 3) The factors $x_1, x_2, \dots, x_j, \dots, x_m$ are random variables that are not correlated to each other;
- 4) Random values $y_1, y_2, \dots, y_i, \dots, y_n$ of the resulting variable y should be obtained in the same conditions.

The modern regression analysis enables to simplify significantly the task of modeling with using of empirical data for on-line diagnostics of dams condition during their operation. This eliminates the need while modeling the causal relationships between different variables of solving more complex problems of structural and parametric identification of phenomenological models of processes and phenomena that determine behaviour of dams using systems of equations for the theory of elasticity, thermal conductivity, filtration theory, fluid mechanics, etc. with the relevant conditions of uniqueness [4]. This approach to technical diagnostics of dams on the basis of data of instrumental observations is the common one in the international practice. However, if the data of observations are heterogeneous, the construction of adequate regression models for forecasting purposes can be a serious challenge even in simple cases [5].

Searching for unknown coefficients of regression models, according to (1), is carried out so that the model in the statistical sense would better meet to empirical

data. That is, to solve the problem (1) the principle of optimization is fulfilled with taking account the compliance with the above boundary limits [2]. But in practice, if the data are heterogeneous, these restrictions can not usually be performed. In this case the increase in the number of observations can disturb the execution of limit restrictions which modeling requires.

For example, Fig. 1 shows a dynamic series of daily observations of upstream water level (UWL) which was taken as an independent variable (a), and the scattering field of values of water level in a piezometer (PWL) (b) which was considered as a dependent variable on random values of UWL. As we can see there is a strong non-monotonicity of UWL values and there is a significant heterogeneity of PWL values depending on UWL.

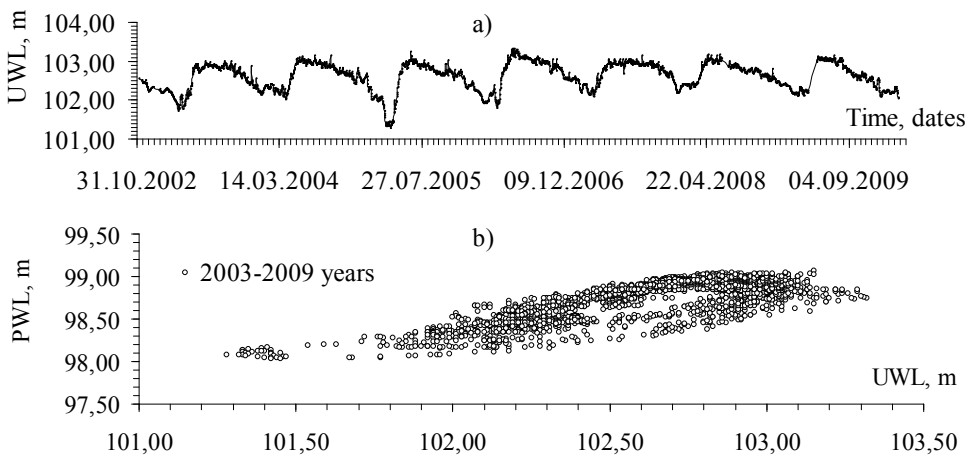


Fig. 1 – Illustration of non-monotonicity in observations of upstream water levels (UWL) (a) and heterogeneity of water levels in a piezometer (PWL) depending on UWL (b)

Increasing the structure dimension of a regression model by introducing into the model of additional independent variables cannot usually solve the problem of heterogeneity of variance. The presence of correlation between different independent variables in multivariate models (we know it as the multicollinearity problem) may become an additional challenge. And we know that under multicollinearity conditions the regression coefficients become highly unstable to small changes in the data, which violates the stability of solutions in the search for the unknown coefficients of regression models. Constructing such models like autoregressive models, distributed-lag models, etc., does not always bring success too.

2. A concept of situational regression models as the main idea of the new approach to regression modeling for forecasting purposes

In short time intervals compared to the total duration of instrumental observations it is easier to provide the monotony of observations series for variables of regression models and the homogeneity of samples of data and the independence of endogenous variables from the less significant factors [2, 4, 6]. It should be noted

the main idea of regression analysis is that a suitable regression may take place if a dependent variable y depends not only on variables $x_1, \dots, x_j, \dots, x_m$, and the variable y may depend on uncontrolled, unknown factors which form something like a forecast background [7].

It can also be assumed, if in different periods of time these forecast backgrounds are relatively homogeneous and the corresponding series of dynamics of independent variables are monotonic (Fig. 2a), adequate regression models (Fig. 2b) may be constructed. Henceforth, we will call these suitable models as situational models. The situational models can be relatively simple. These can be single-factor models [7], which show how an endogenous variable y depends on one the most important exogenous variable x .

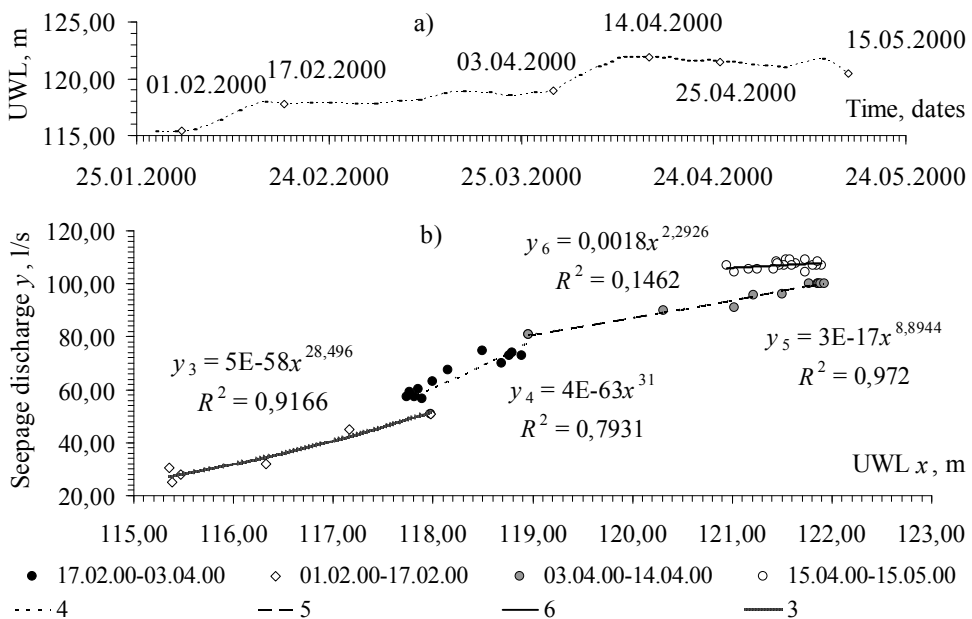


Fig. 2 – Data of observations of upstream water level (UWL) (a) and situational regression models for seepage discharge values through the dam foundation depending on UWL (b)

We suppose that upstream water level (UWL) for dams could be the principal independent variable x for situational modeling. This is the most suitable and convenient independent variable and the only independent variable which can be controlled if it is necessary.

We should emphasized that the main thing there is that situational models must adapt to particular situations (forecast backgrounds, etc.) that take place within limited time periods. It is very important they were the most adequate models to these situations.

In fact, the corresponding situational models, which are based on limited data, reflect different phase states of the dam as a dynamical system on respective time intervals. In the simulation we can get sets of adequate situational models that appropriately evolve over time (Fig. 2b). Although the transitions between the

nearest situational models which define adjacent phase states of the dam as a dynamic system can be non-monotonic [4, 7], the prediction of future condition of the dam can be based on monitoring the evolutions of these situational models. This is the main idea of such simulation to obtain situational models.

3. Inductive models and forecasting future states of dams

Inductive diagnostic models are models obtained on base of generalization of results of construction of situational diagnostic models (Fig. 3a). In the most general case, inductive models are models of “levels” (Fig. 3b). These models, which are constructed with using of results of situational modeling at separate time intervals, can spread on the entire period of observations.

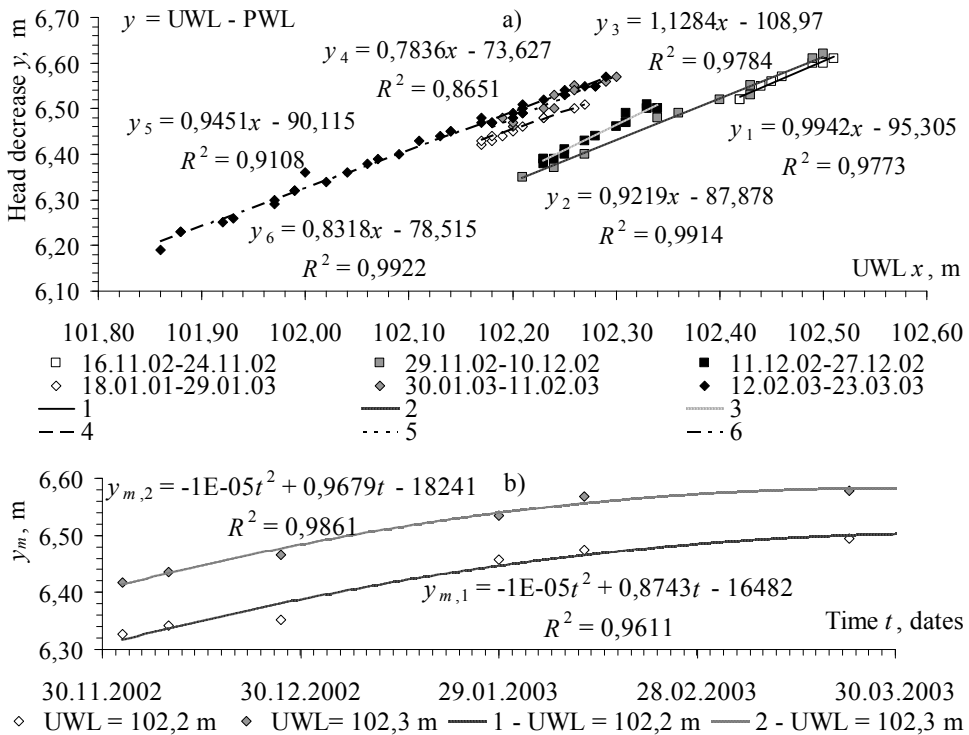


Fig. 3 – An example of a set of corresponding situational models (a) and two inductive models of “levels” (b) for dependencies of head decrease values on upstream water level (UWL) at a site of seepage between upstream and a piezometer

The structure of an inductive model is determined by particularities of behaviour of time series of simulated data obtained from corresponding situational models. In general, results of situational modeling may represent non-stationary (Fig. 3b) or stationary (quasi-steady) (See below Fig. 4a) time series of modeling data with presence or absence of trends respectively.

If trends have high coefficients of determination, inductive models can be described by these trends (Fig. 3b). Then general inductive models will consist of corresponding functions which show trends and random “balances” after the

extraction of these trends. If results of situational modeling give stationary (quasi-steady) time series (there are no trends) (Fig. 4a), inductive models can be represented as regressions (Fig. 4b). In these cases general inductive models will consist of corresponding regressions and random “balances”. If trends in dynamic series of results of situational modeling of variable y have small coefficients of determination, an inductive model of i -level for y can be presented as composition of a selected trend $T(y_i(t))$ (Fig. 5a) and a regression R for “balances” $\Delta y_i = y_i - T(y_i(t))$ which are random values of the dependent variable (Fig. 5b):

$$y_i(t) = T(y_i(t)) + R(\Delta y_i(\hat{x}_L)). \tag{2}$$

If it is necessary, we can use a new explanatory variable \hat{x}_L for modeling the regression of “balances” Δy_i . We may take into account a transport lag between the “balances” and the variable \hat{x}_L too. In more complex cases if we need to take into account autocorrelation of the “balances”, in addition some cyclical components or deterministic components of corresponding series can be considered in inductive models.

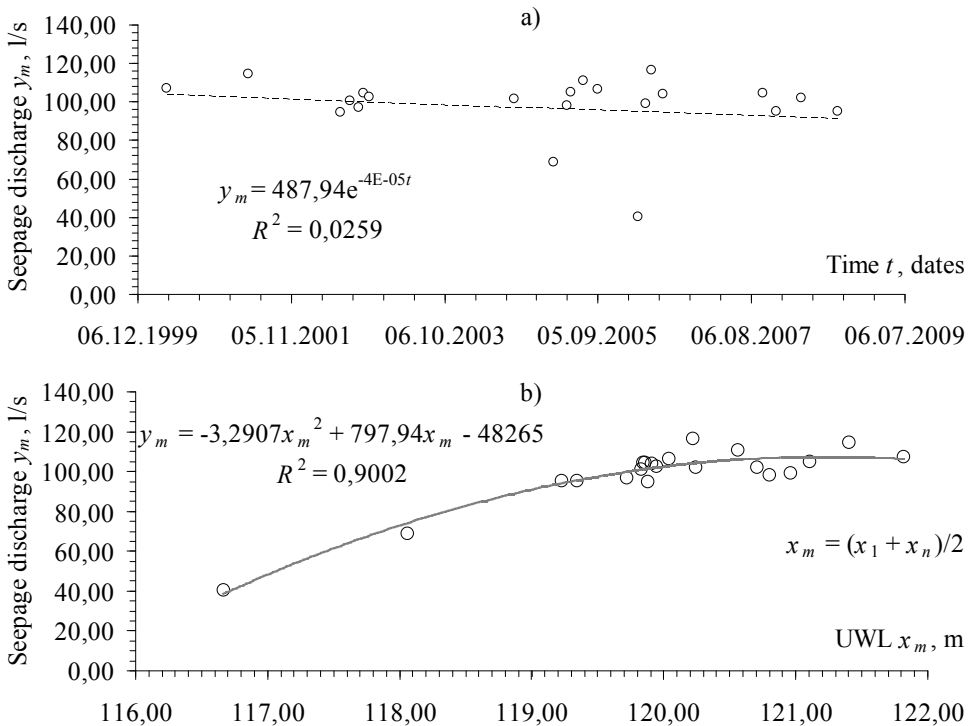


Fig. 4 – Stationary series of dynamics (a) of results situational modeling of seepage discharge values in conditions of stationary oscillations of upstream water level (UWL) and a corresponding inductive model in form of the regression (b)

Forecasting future states and behavior of dams is based on the method of extrapolation and is carried out in two main forms:

- 1) Real-time forecasts;
- 2) Long-term forecasts.

Real-time forecasts are made for the purpose of rapid assessment dams' condition in changed situations (See below Fig. 6) and performed by means of new situational models which require adjustments to previous situational models due to new data with extrapolation into region of expected values of independent variables. If new data comes, real-time forecasts may be constantly corrected. Observed values which differ significantly than situational models show can indicate changes of forecast backgrounds (Fig. 6).

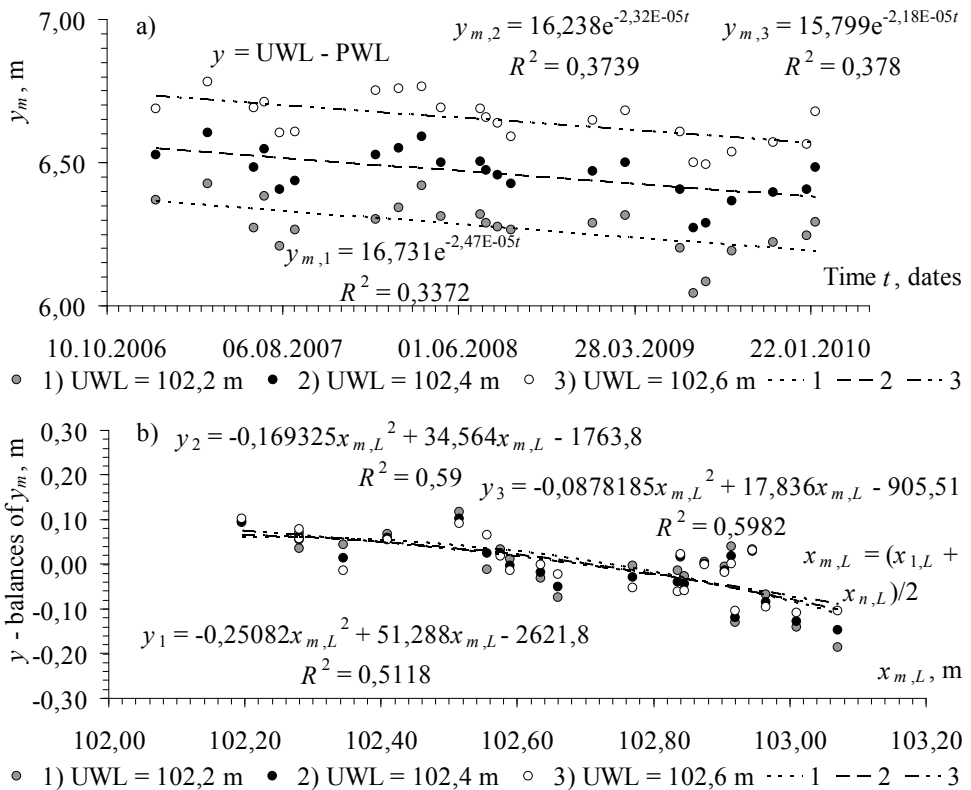


Fig. 5 – An example of non-stationary series of dynamics of results of situational modeling of head decrease values with relatively small coefficients of determination of trends

Long-term forecasts (Fig. 7) are usually based on inductive models which include trends and regressions for their balances (Fig. 5) but simple regression models (Fig. 4) may be used too. The expected results of the long-term forecasting are determination a new situational diagnostic model which corresponds to expected situation in the nearest future period (Fig. 7a) or series (variety of options) of situational diagnostic models which can correspond to several possible situations in the future period (Fig. 7b).

The accuracy of long-term forecasts which are made on the basis of inductive models can be greatly improved if the inductive models are based on results of situational modeling of past periods which are presented by homogeneous and interrelated clusters of the relevant data with taking into account behavior of independent variables and transport lags.

First, we should pay attention to behavior of upstream water level (UWL) (See below Fig. 8). In particularly, some following typical modes of behaviour of upstream water level (UWL) affecting dams can be allocated:

- 1) Slow rise of UWL;
- 2) Rapid rise of UWL;
- 3) Stationary fluctuations of UWL;
- 4) Slow lowering of UWL;
- 5) Rapid lowering of UWL.

If some transport lags exist between corresponding data of previous and next periods, forecasts can be unambiguous (Fig. 7a). Otherwise, we get several possible long-term forecasts concerning future periods (Fig. 7b).

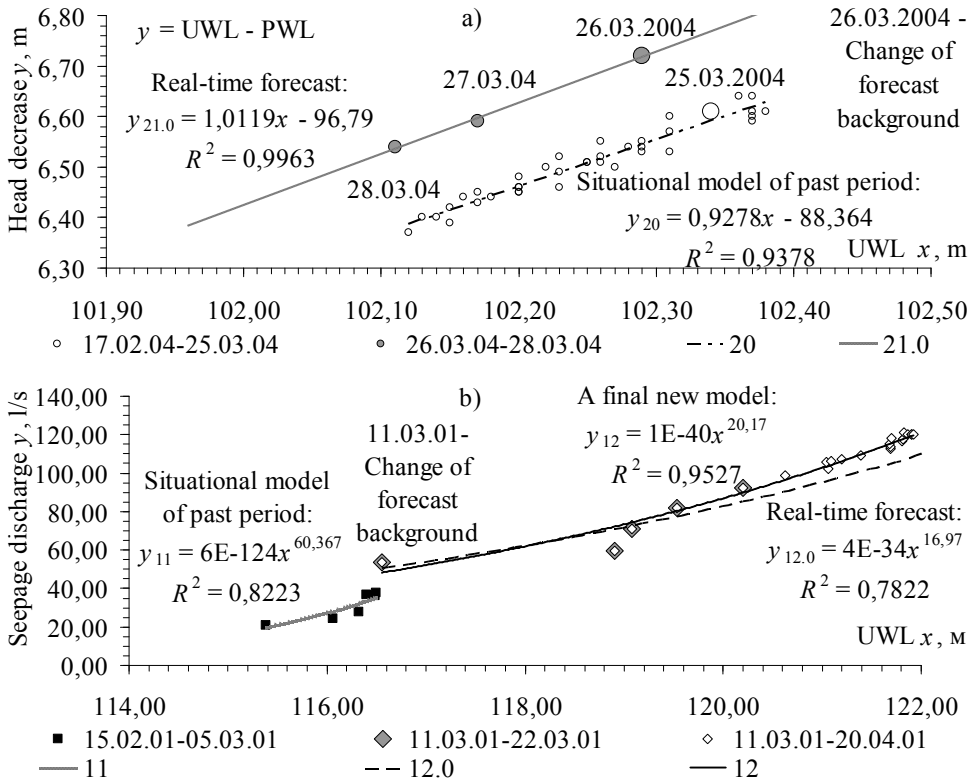


Fig. 6 – Examples of real-time forecasts: a) how head decrease values at a site of seepage between upstream and a piezometer can depend on upstream water level (UWL); b) how seepage discharge values can depend on upstream water level (UWL)

A general diagnostic model of an appropriate diagnostic parameter of a dam can be presented as a family of situational diagnostic models which are adapted to

individual time intervals or as a family of inductive diagnostic models which allow producing situational diagnostic models for periods in the future. So, forecasts are performed on the basis of situational diagnostic models and by means of monitoring for evolutions of these models in time.

It should be noticed the simple mathematical models (trends and regressions) may be used as situational and inductive diagnostic models for dams where automated monitoring systems are installed. Such models and combinations thereof are the best to adapt to new data and changes of forecast backgrounds. When choosing the diagnostic models of a dam, it is also allowed using of modified diagnostic parameters and different data processing procedures which are aimed at the construction of adequate situational diagnostic models for forecasting of dams condition to assess their reliability according to the data of instrumental observations.

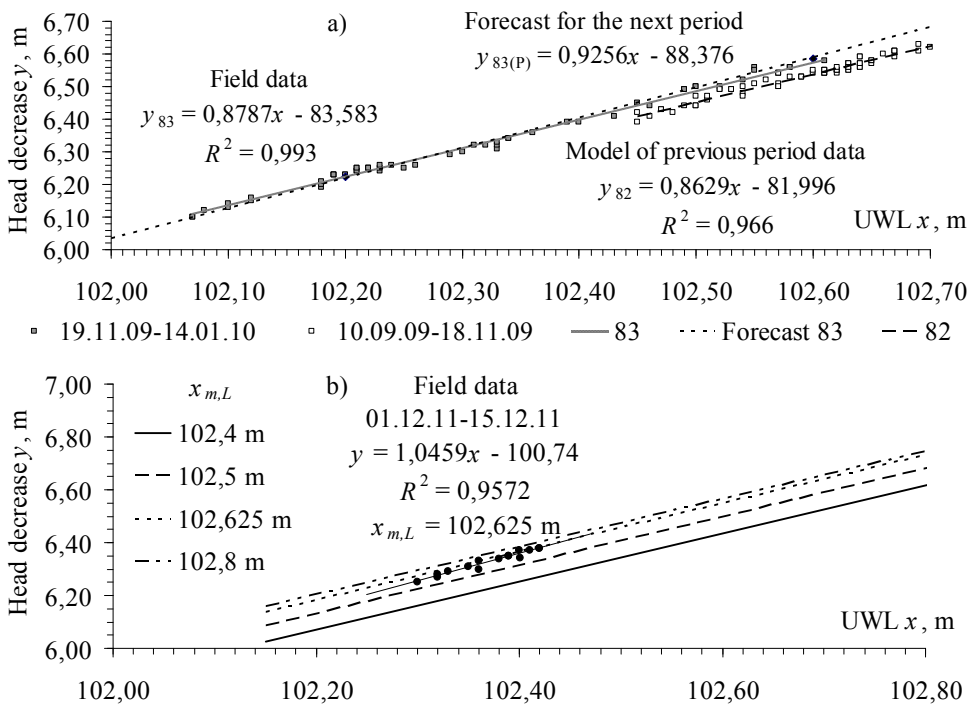


Fig. 7 – Examples of long-term forecasts how head decrease values at a site of seepage between upstream and a piezometer depend on upstream water level (UWL): a) an unambiguous forecast; b) some forecast options

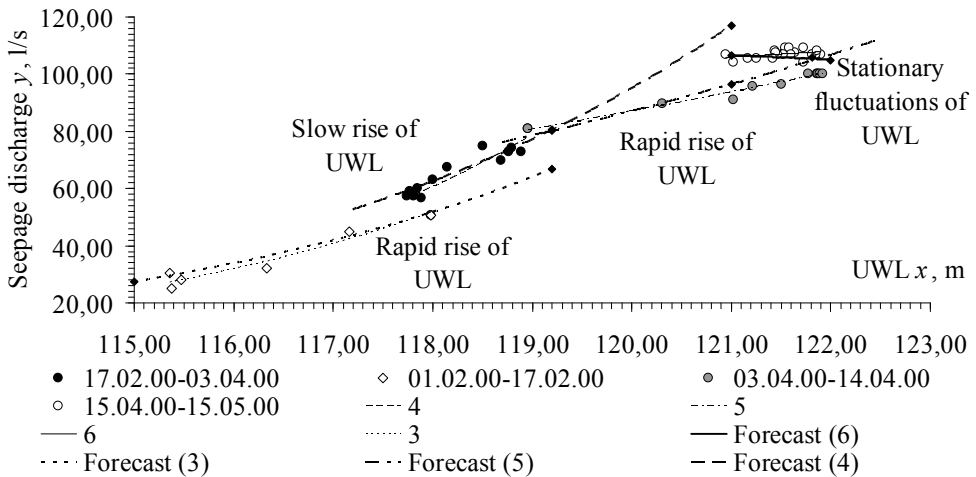


Fig. 8 – Examples of long-term retrospective forecasts how seepage discharge values depend on upstream water level (UWL)

Conclusions

1. A new approach to forecast condition and behavior of dams according to data of instrumental observations with regard to capabilities of automated monitoring systems installed on hydraulic structures has been proposed. The approach is based on the use of situational and inductive models of regression type where situational models correspond to selective series of dynamics of observed data within limited time intervals and inductive models which are constructed with model data derived from situational regression models enable to take into account evolutions of diagnostic parameters in time.

2. The simple mathematical models (trends and regressions) may be used as diagnostic models of dams if these models are easy adapted to new data and changes of corresponding forecast backgrounds. The accuracy of long-term forecasts which are made on the basis of inductive models can be greatly improved if the inductive models are based on results of situational modeling of past periods which are presented by homogeneous and interrelated clusters of the relevant data with taking into account behaviour of independent variables and transport lags.

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SOME OF THE SPECIAL FEATURES OF THE TRITIUM MIGRATION

***Abstract.** It was found that tritium is different activity as part of the free water of plants can be conditioned by the processes of plant life, taking into account the weather conditions, composition of soil on which the plant is located. The paper shows the results of the field and laboratory studies on the search of the plants, which may act as a reliable indicator for determining tritium pollution of the environment. In this study, a plant that has a tritium high volume activity in the free water is considered an indicator of the environment tritium contamination, and / or organically bound tritium as a whole or in separate plant organs on comparable terms with other plants.*

***Key words:** tritium, migration, isotope, environment.*

Introduction

The hydrogen is the most abundant element in the Universe. Taking into account the big penetration ability of tritium and possibility of easy exchange of atoms between the various isotopes of hydrogen, two main problems in the research of tritium may be named:

– The lack of the right understanding of transfer and bio-accumulation processes of tritium in natural surroundings and antropogenic environment [4, 13, 17, 18];

– The increasing need of the development of the new approaches to assessment of tritium human and nature in order to protect effectively [9, 11].

It should be noted that in Ukraine after the accident at the Chernobyl Nuclear Power Plant, work was actively carried out to investigate the migration of radionuclides in agricultural plants [24, 25, 31]. In these works the attention was alsoooven to tritium. These studies found further confirmation in works and experiments far beyond Ukraine [9, 11, 15, 34].

However, most of the studies dealt only with agricultural plants that grow on the territory that had been accurately exposed to technogenic tritium.

But due to the fact that tritium was not given proper attention for a long time. It often appears a need to determine the contamination of a specific area with technogenic tritium. The question that appears: is there a plant that can act as an indicator for the determination of tritium contamination of the environment?

The solution of this problem is relevant for monitoring of the condition of the zones that are around nuclear power plants and nuclear fusion enterprises, the repositories of radioactive materials that contain tritium. Another task is to assess the purity of recreational areas, agricultural lands and areas for grazing.

The results of the study, which are introducet below, were conducted in Ukraine in the territory of the enterprise, which until 2002 had been actively working with tritium. The work is based on the monitoring of the specific activity of tritium in birch sap, and the study of bioaccumulation of tritium in various herbaceous plants, that are common in the central part of Europe.

Partially published and unpublished results are presented in the this study.

1. Tritium - the natural isotope of hydrogen

Tritium is a beta emitter and due to radiochemical properties it easily dissolves in liquids. Tritium is also easily absorbed by the human organism with water and promotes to damaging the health. Tritium is the most poorly known radioisotope [7, 30].

The chemical form of tritium (^3H) is a rare but it is natural isotope of hydrogen (H), and it is the only natural hydrogen isotope that is radioactive. From the perspective of atmospheric existence of tritium the most important forms are such forms as tritiated hydrogen gas (HT) and tritiated water (HTO). These tritiated forms chemically behave like hydrogen gas (H_2) and water (H_2O).

In 1957, the world first faced with a serious accident of environmental contamination by tritium. It was a Kyshtym disaster, a radioactive contamination accident, which occurred at Mayak, where a plutonium production center for nuclear weapons and nuclear fuel reprocessing plant in the Soviet Union was situated [30]. The accident was classified as a disaster of Level 6 according to the International Nuclear Event Scale (INES) [19], making it the third most serious nuclear accident ever recorded, following the Fukushima Daiichi nuclear disaster and the Chernobyl disaster (both Level 7 according to the INES). Now, the Kyshtym area is usually referred to as the East-Ural Radioactive Trace (EURT) [8].

And only now, the materials about the negative effects of tritium due to this accident become available to the general public. Residents of the villages that are situated around the scene of the accident have already been massively dying of cancer for a while. The majority of researcher's blame it on the usage of water with high specific activity of tritium. Pollution of rivers in the area of the accident has led to contamination of groundwater, and as a result plants and animals. The usage of products of plant and animal origin has become harmful to human organism [30].

In 1986 when the Chernobyl disaster occurred a lot of radioactive material precipitated onto much of the surface of the western USSR and Europe [29]. This accident was classified as an of 7 event (the maximum level of classification) according to International Nuclear Event Scale [3]. After the Chernobyl accident, approximately 14^{10} Bq of tritium got in to the environment. And 30 years after the nuclear accident took place, there is a high content of tritium in water, in the juice of birch, in products of plant and animal origin outside the exclusion zone [7]. In 2016 the New Safe Confinement, a structure that intended to contain dangerous remains of the unit No. 4, was built at the Chernobyl Nuclear Power Plant. But this New Safe Confinement does not protect from tritium which has already been in the environment. Particularly, at the 1-st International Conference on Nuclear Decommissioning and Environment Recovery INUDECO'16 was stated: "The Sarcophagus will protect the 4-th block of Chernobyl's NPP from the migration of radionuclides which are in the environment, that is not protect. Migration of radionuclides has not well been studied yet. The most poorly studied is tritium " [1].

In 2011 the nuclear disaster at the Fukushima-1 Nuclear Power Plant in Fukushima occurred. Japanese nuclear engineers have estimated that to bring the NPP into a stable and safe condition and liquidate the consequences of accident they will need up to 40 years [27]. In January 2014, according to the report "Fukushima Nuclear Accident Update Log" [33], it was declared that a total of 875

TBq (2.45 g) of tritium are on the site of Fukushima Daiichi, and the amount of tritium that is contained in the contaminated water is increasing by approximately 230 TBq (0.64 g) per year [26].

The events that are taking place in the Eastern Ukraine (the anti-terrorist operation) have also gained relevance. Recently water contaminated by tritium penetrates from the war zone from coal mines in which conducted nuclear explosions in the USSR. It was also mentioned above that during the anti-terrorist operation the metallic components of various devices that contain tritium are applied. It may cause a global ecological disaster inside and outside of Ukraine [14].

Monitoring data indicate [12] that the technogenic component of tritium enters the environment in the following cases:

a) as a result of an operation of nuclear power plants, installations for nuclear fusion and emergency situations on these objects. The largest emissions of tritium accidents were recorded in Kyshtym accident, Chernobyl, Fukushima;

b) as a result of the disposal of tritium-contaminated products because of the humans of a person's technical work [7, 28]. Today it is the main source of penetration of technogenic tritium into the environment.

In January 2007, the Canadian Nuclear Safety Commission (CNSC) Tribunal directed CNSC staff to initiate research studies on tritium emissions in Canada [28]. Among there them are studies on the migration and bio-accumulation of tritium in plants. This is one of the fundamental researches in the designated sphere [22, 32].

There are many works on this subject of the French [5, 10, 16, 20], Chinese [11, 34] and Japanese [23] researchers.

But there are still many questions for the further research on the transfer of tritium in to the environment, the distribution and accumulation of radionuclides in plants [16, 21].

Since tritium irradiates the human organism from the inside, getting there with water and food, migration and bio-accumulation of tritium in the organic matter of plants is an actual topic of scientific research. As the Chernobyl and Fukushima accidents have shown, all the countries of the world are more or less affected by the consequences of such events [1].

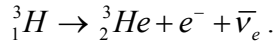
2. Tritium in the environment

Hydrogen is one of the main substances required for the support of the vital activity and functioning of living organisms. The significance of hydrogen is caused by the exclusive significance of water in processes related to living organisms. Due to isotopic exchange, heavy hydrogen isotopes are able to participate in biochemical processes and to substitute hydrogen atoms with tritium atoms easy and readily.

The accumulation and migration of tritium in the environment depends on the time of occurrence and the location of tritium, the rate of exchange of tritium in air masses, and the concentration of tritium in the stratosphere during the exchange processes. In summer, the overground concentration of tritium at a height of up to 2 km increases due to evaporation of spring and winter atmospheric precipitations, and the oversea concentration of tritium at the same height decreases due to absorption of tritium by water. The circulation of atmospheric water due to the oceanic air exchange is very fast, so, as a result of a fast isotopic exchange between

water drops and water vapors, rains transfer tritium to the lower layers of the troposphere [30].

In the process of radioactive decay of tritium, beta particles and $\bar{\nu}_e$ antineutrinos are emitted. The reaction of radioactive decay of tritium can be described as following:



The half-life period of tritium is 12.32 ± 0.02 years. The average energy of tritium beta particles is $E_\beta = 5.52 \dots 5.7 \text{ keV}$. Tritium beta particles expend the basic part of their energy on interaction with the electron shells of atoms of substances that are in the environment where the beta particles move. The isotopic composition of hydrogen and oxygen, which goes from water to plant hydrocarbons in the photosynthesis process, depends virtually completely on the isotopic composition of water. Hydrogen isotopes fractionate during processes of water evaporation and condensation. Different ratios of $^{18}\text{O}/^{16}\text{O}$ and ${}^3\text{H}/{}^2\text{H}/{}^1\text{H}$ depend directly on the average annual temperature. The water condensation temperature has a significant effect on the isotopic composition of water, that has been confirmed by the results of some studies.

The transformation of aqueous tritium (NTO) into organically bound ${}^3\text{H}$ isotope depends on the selectivity of ${}^3\text{H}$ isotope that is relative to ${}^1\text{H}$ isotope. As a result the penetration of ${}^3\text{H}$ isotope in organic compounds is reduced by approximately 20 percent. It means that the ratio of the maximum specific activity of ${}^3\text{H}$ isotope in organic fractions to the maximum specific activity of ${}^3\text{H}$ isotope in free plant water is about 0.05 within several days after a single ingress of the isotope. It is assumed that the specific activity of ${}^3\text{H}$ isotope in free water and the specific activity of organically bound ${}^3\text{H}$ isotope increase exponentially with time, in case that ${}^3\text{H}$ isotope enters the environment continuously [7]. But the studies and observations, which are mentioned below, have demonstrated the polynomial time dependence of these processes.

The studies that are performed were based on the methods developed in the seventies of the 20th century [2]. The studies for the determination the interaction of tritium with tree tissues were commenced approximately in the middle of the 20th century, and the studies for determination of the distribution of tritium in the tree annual growth rings were commenced in the eighties of the 20th century. It was detected that before the 1990s the activity of tritium in rare atmospheric precipitations was lower than the activity of tritium in tree tissues due to the accumulation of tritium in tree tissues. After nuclear tests were finished, the concentration of tritium in the atmosphere began to decrease gradually. The process of the removal of tritium from trees gets slower due to the accumulation of exchangeable tritium. These conclusions are confirmed by the results of studies mentioned below.

In the ground, tritium exists in two basic forms. Then main part of tritium is in free ground water (NTO) and corresponds to the concentration of tritium in atmospheric water. The upper 4 cm of ground layer contains up to 25 percent of all tritiated water. When the depth of the ground layer increases, the content of tritiated water decreases up to 4 percent in the 14 cm to 16 cm ground layer, and

then increases to 10 percent in the 16 cm to 18 cm ground layer. Below 16 cm, the content of tritium is 40 percent of the total content of tritium in ground [7]. After removal of free ground water, some part of tritium remains in the ground in ion-exchangeable and sorbed forms.

That is, tritium, as a hydrogen nuclide, is characterized by its high migration capability in water and, as a result, by its high activity in the exchange processes in the living organisms and by its mobility in water-plant systems.

Roots and other underground organs of plants are relatively intensively enriched with tritium. The distribution of organically-bound tritium in plant tissues and organs is nonuniform and depends on the biochemical properties of plant tissues and organs. Plants and ground bacteria are the catalysts of oxidation of gaseous tritium (NT) that is contained in the atmosphere. The rate of transformation of gaseous tritium into aqueous tritium in the ground vegetation is about 1 percent per 48 hours. Because of this, the specific activity of tritium in ground moisture increases as compared with the specific activity of tritium in free plant water [7]. But the results of studies performed within 10 years indicate that these statements are not applicable for all plants.

3. The study of the air-water-plant system

As a base statement in studying on the migration of tritium over the 15-year period, it was accepted that the specific activity of tritium ^3H in free plant water can be the same in all of organs plant only if the activity of tritium is the same in atmospheric moisture and ground moisture, otherwise there are essential differences in the specific tritium activity values, which are caused by the tritium concentration gradient in the air-water-plant system [7]. But the results of some additional measurements, which were performed with consideration of meteorological conditions during sampling and averaged through the month, provide the possibility to state that the high concentration of tritium in free plant water can be caused by the processes of vital activity of plants, with the consideration of temperature, humidity, and composition of the ground where the plants being studied that are located.

The obtained results provide the possibility to determine the total contamination of the territory with tritium and the effect of contamination of plants in the territory. The results also provide the possibility to study the process of biological accumulation of tritium in plants, specifically in *Bétula péndula*, due to water exchange. Figure 2 shows the characteristics that are illustrate the variations of the specific concentration of tritium in meltwater and birch sap that are obtained during the 13-year period of studies.

As is seen from the characteristics, if tritium continuously enters the environment, the specific activity of tritium in free water and the specific activity of organically bound tritium varies with time according to a polynomial expression instead of an exponential expression.

On the characteristic basis, there is the drastic increase of the specific activity of tritium in birch sap in 2008, when the specific activity of tritium in snow cover melt water significantly decreased. In the next years, the specific tritium activity values vary according to regularity, that is, the specific activity of tritium in birch sap increases in the following year after the increase of the specific activity of tritium in meltwater that was detected in the preceding year.

The specific activity of tritium varies according to the 5-order polynomial expressions showed below.

The specific activity of tritium in meltwater:

$$y = 0.0553x^5 + 2.2468x^4 - 33.043x^3 + 213.31x^2 - 608.23x + 956.05.$$

The approximation coefficient $RI = 0.5$.

The specific activity of tritium in birch sap:

$$y = 0.0444x^5 + 1.8959x^4 - 28.135x^3 + 163.42x^2 - 280.1x + 270.26.$$

The approximation coefficient $RI = 0.3211$.

The low values of the approximation coefficient are caused by the significant changes of the specific activity of tritium in meltwater in the range from an absolute minimum to an absolute maximum. This feature allows to make certain conclusions.

In the preceding years, the researchers in Ukraine [7] that performed studies in contaminated areas, such as the Chernobyl area and territories with radioactive waste storages, stated that elimination of tritium from plants is possible due to water exchange. The basic half-life period, which is typical for the elimination of 90 percent of aqueous tritium, virtually does not depend on climatic conditions and ranges from several hours to (10–20) days.

The characteristics in Figure 2 show that the part of tritium that was detected in meltwater in February, and which, according to the aforesaid statement, should cause the increase of concentration of tritium in birch sap in March and April, is not included in the water exchange process. The next year, the specific concentration of tritium in birch sap sometimes significantly increases, while the concentration of tritium in meltwater decreases.

These facts can be explained by following.

Firstly, in the years when the concentration of tritium in birch sap was increased, the air temperature and humidity during the study period were increased. That is, this period was characterized by more intensive birch sap circulation in favorable for vegetation conditions.

Secondly, tritium in meltwater that enter clayed ground remains in the ground. The tritium atoms participated in the atomic exchange with hydrogen atoms in some clay-containing minerals and free ground water. The temperature fluctuations decelerated (when the tritium concentration decreased) or accelerated (when the tritium concentration increased) this exchange was a normal chemical reaction in the presence of a hydrogen atom. Because of this, part of tritium in was meltwater was accumulated in the ground.

Thirdly, the aforesaid data indicate the significant increase of the concentration of tritium in the environment at the end of winter and at the beginning of spring, that is, during the periods when processes of intensive evaporation and humidification on the ground surface are intensive. The polynomial expressions for changes in the specific activity of tritium in ground water and tritium in birch sap demonstrate the cyclic decrease of the specific tritium activity, in the range from the minimum activity to the maximum activity,

at least four times within a year. According to the polynomial expressions the cycles correspond to rainy periods. For this reason, it is possible to assume that some plants that grow in the territories contaminated with tritium can accumulate tritium in the plant organs or some tissues during the plant vegetation period. The period of accumulation of tritium in plants and the period of elimination of tritium from plants depend on the temperature of the environment, air humidity, and, probably, chemical composition of the ground where the plants grow.

The question that emerges is the following:

How tritium should migrate and accumulate insomuch that the specific activity of tritium in birch sap will increase the next year?

4. The field and laboratory experiment

In order to confirm the aforesaid assumption, there was carried out a field experiment. In the period from May till October 2016, aqueous extracts from about 100 plant species were studied for determin action of the specific activity of tritium in different periods of the plant life cycles.

The study results provide the possibility to state that there are plants which accumulate tritium in the plant organic substances for some period of time. It was experimentally determined that the specific activity A of tritium in the extracts of common taraxacum (*Taraxacum officinale* Wigg.) was higher as compared to the extracts of other plants, provided that the plant samples were taken from the plants that are located at a distance of no more than 1 m from each other.

The results of one of these samples from May 28, 2016, are shown in Table 1.

Table 1. Measurements of the specific activity of tritium in plant extracts

#	Place of collection	Plant	A , Bq/l	Part of the plant
1	Zone (A)	Bétula péndula	10152.5	Green seed
2	Zone (A)	Trifolium	12673.8	Flowers
3	Zone (A)	Plantágo	11606.8	Leaf
4	Zone (A)	Taráxacum	38444.4	Stem and post-flowering flower
5	Zone (B)	Taráxacum	7967.24	Leaf

Zone (A) is a section with a radius of 300 m (sanitary zone), which is directly adjacent to one of the corps of the company working with tritium. Zone (B) is located at a distance of more than 500 m from the production building of the mentioned enterprise.

The ambient temperature during sampling was within $+ (20-26)^{\circ}\text{C}$, the relative humidity of the air fluctuate within (76-84)%.

200 measurements of aquatic extracts of taraxacum were investigated in different parts of the study area. The results allowed to assert that the specific activity of the aquatic extract of the taraxacum is always higher in comparison with the extracts of other plants that grew along with the sample of the taraxacum.

It can be noted that within the sanitary zone, the specific activity of the water extracts of *Taraxacum officinale* Wigg. has much higher indicators than analogical measurements in a relatively clean zone. It should be noted that while the aquatic extracts of other plants from these sampling points did not have similar high rates. Results of measurements of extracts of other plants accounted for (10-46)% of the indicated values.

There were made a number of measurements. These measurements confirmed the increased content of tritium in the extract of taraxacum. Subsequently, the systematization of measurements was made and the hypothesis was accepted: in different parts of taraxacum, the content of tritium is different. To test this hypothesis, several plants were selected from the Zone (A) of the previous study. *Taraxacum* from Zone (B) was taken from a distance of 150 m from the boundary of Zone (A). These plants were intact, almost the same size and weight.

From the roots, leaves, stems and flowers separately, weighing 2 grams, extracts were made and their specific activity was checked. The results are shown in Table 2.

Table 2. Measurements of specific activity of tritium A in the extract different parts of *Taraxacum officinale* Wigg.

#	Place of collection	A , kBq/l			
		Root	Leaf	Stem	Flowers
1	Zone (A)	10.90	47.29	50.60	24.44
2	Zone (A)	13.41	16.29	14.60	18.13
3	Zone (A)	14.07	18.76	14.93	28.67
4	Zone (A)	11.42	16.13	27.59	17.07
5	Zone (B)	10.27	11.98	14.51	15.78

Plants 2 and 3 grew at the same place (two plants next to each other). They were almost the same in size and weight of the plant, but for to one difference: the plant 2 was already blossoming, and 3 - still in the bud. Indicators of the root, leaf and flower pedicle had no significant differences. Plants 5 had a flower that was blossoming, but not dried yet.

Further studies of tritium in *Taraxacum officinale* Wigg. occurred in June. Weather conditions: an increase of air temperature and a decrease of moisture. In addition, the taraxacum has already ended the growing season. All available plants from the study area did not have flowers.

In the course of further measurements it was proved: with increasing heat, the specific activity of tritium in plant extracts is reduced. At the same time, the amount of latex of taraxacum decreases and the plants become rough, the flower turns into seeds, the stalk dries. Increasing air temperature and the transition of *Taraxacum officinale* Wigg. to "summer calm" the content of tritium in organic matter of plants decreases. Experiment with water that was obtained from transpiration of plants showed that the concentration of tritium in transpiration water and in the soil does not increase during transpiration period (7 days). Transpiration water was obtained by installing a glass cube with collectors over the plant. The walls of this device were deepened into the ground and sprinkled with some soil, to limit the flow of moisture and air from the outside.

After establishment a dry weather with a temperature above + 27⁰C, the specific activity of tritium in aqueous extracts of taraxacum from the all over study area has become approximately the same.

To confirm the uneven distribution of tritium in the free water of particular plant organs of *Taraxacum officinale* Wigg. there was carried out a laboratory experiment.

In a separate container with soil that is similar to the soil of the study area, were planted *Taraxacum officinale* Wigg. and random plants, that were typical for the study area. The first container – is the main one, the second container is used to confirm the results. Each container was placed in a single greenhouse.

Plants were watered trititional's water once. Further watering of the plants was only with water. The humidity in the containers was maintained at (76-86)%, air temperature was + (22-26)⁰C. Observations of the plants took place over three weeks, with recording of external changes during the growing season (emergence of a bud, blooming flower, number of new buds, growth rate).

After two weeks after the start of the experiment, when the plant threw out the first bud and started to grow rapidly (stem grew during the day up to 5 cm), samples were taken of the specific activity in extracts of particular parts of plants (at 1 gram), as well as similar samples from other plants in container – *Persicaria lapathifolia* L. (tab. 3). In the same period in the environment, to the extent not included in the sanitary zone the same (natural) taraxacum were taken for the study of the specific activity of tritium in the composition of the free water of plants (table. 3).

Table 3. The results of laboratory experiment

Part of a plant	A, Bq/l			
	Laboratory conditions		Natural conditions	
	<i>Taraxacum officinale</i> Wigg.	<i>Persicaria lapathifolia</i> L.	<i>Taraxacum officinale</i> Wigg. # 1	<i>Taraxacum officinale</i> Wigg. # 2
Flower	3849.89	1530.63	195.17	92.73
Stem	9923.06	1509.55	230.06	101.74
Leaf	6109.85	1522.98	156.03	64.84
Root	2288.04	1768.53	138.37	42.91

Figure 1 shows the comparative chart of the accumulation of tritium in particular parts of the plants.

A similar distribution of the concentration of tritium is observed in taraxacum # 1 and # 2.

Thus, considering experimental data, it can be argued that the presence of tritium in the air, in the soil and/or groundwater, *Taraxacum officinale* Wigg. will accumulate a large part of the tritium in the stem and partially in leaves and flower during the growing season.

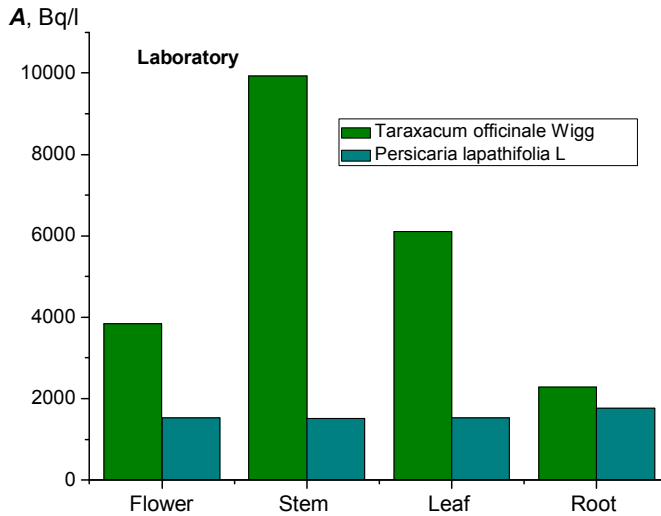


Fig. 1. Diagram of the tritium activity in particular parts of plants.

Considering the results, we can deduce the primary mechanism of tritium migration in *Taraxacum officinale* Wigg.

Conclusions

One of the main objectives of these studies was to quantify tritium migration and bioaccumulation in organic substances of plants.

This paper contains the data on the preliminary results of the studies and the data on the primary processes promoting tritium migration, which were obtained for common taraxacum plants.

The obtained results are the following:

1) If tritium enters the environment continuously, the concentration of tritium in free water and the concentration of organically bound tritium increase with time according to a polynomial expression.

2) The base statement was confirmed. The concentration of tritium in free water of plants, as assumed, is virtually the same in all plant organs only if the tritium concentration in atmospheric moisture and ground moisture is the same, otherwise there are essential differences in the specific tritium activity values due to the gradient of tritium concentration in the atmosphere-plant-ground system.

3) It was detected that the different concentrations of tritium in free plant water were caused by processes of vital activity plant of depending on air temperature and humidity.

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WASTE MANAGEMENT: ACCOUNTING PROBLEM

***Annotation.** The research is devoted to the survey of statistical data in the sphere of solid waste utilization and recycling in different regions of Ukraine. In the article cited information as to amount, volume and morphological composition of solid waste products based on information received from local authorities of cities are regional centers of Ukraine (except for the temporarily occupied areas of Donetsk and Lugansk regions and the Autonomous Republic of Crimea). Based on the analysis of the reporting approaches that have developed in different cities, shown existence of significant differences and discrepancy between some accounting indicators that influence on the state work of mass counting and amount of solid waste products, and determination of their morphological composition. Formulated proposals for unification of the approach to the implementation of the accounting of quantitative and qualitative indicators of solid waste products, which will help to more accurately to determine their volume, mass and composition to increase the efficiency of their utilization measures.*

***Keywords:** solid waste products, utilization, proving ground (landfill), accounting, processing, morphological composition of wastes.*

Introduction

Strategic planning of activities in waste management field is possible only if there are specifications for a detailed analysis of the morphological composition of solid waste products, based on which the perspectives of sorting, proper subsequent using of each type of waste products in accordance with their physical, chemical, biological, energy and other individual specifications can be determined. However, today there is a lack of the only methodological system approach to waste accounting and analysis of their morphological composition, which makes it impossible for any reasonable and well-considered actions to reform the sector of sorting, processing and utilization of waste products at the national level. Waste management issues were the subject of attention of ecology-specialists, chemists, farmers and authors of concepts and government programs of rational nature management. The analysis of scientific publications of Ukraine and foreign scientists on this topic shows that the problem of environmental safety and soil condition monitoring was mainly investigated (Zhovinsky E., Klymenko V.I., Kovda V.A., Kravtsova V.I., Kuraeva I., Stepanchuk O.V.), land usage and protection (Krzhasovsky G., Greben O.S., Danylenko A.S., Radchenko K.G., Alboshchy U.M.), separate ecological aspects of waste management (Korablyova A.I., LIalko V.I., Medvedyev V.V., Rudko G.I., Shykula M.K.). At the same time, insufficient attention was pay to legal aspects of waste management in mentioned branch, and therefore the purpose of the article is to develop proposals for the introduction of a unified system of accounting for solid waste products in all regions of Ukraine.

1. Mass and volume indicators of the amount of solid waste products

In accordance with Article 30 of the Law of Ukraine «Local Self-Government in Ukraine», the issue of gathering, transporting, utilization and disposing waste products is belongs to the executive bodies of village, settlement and municipals councils [1]. In accordance with Article 20 of the Law of Ukraine «On Waste» the compilation and keeping a register of entities for the formation, processing and utilization of waste products and list of places for removing of these wastes belongs to the powers of local state administrations [2].

Within the framework of this research, which is part of the systematic scientific research on the issues of utilization and processing of solid waste products, was collected and summarized information from all regional centers of Ukraine about the amount and volume of solid waste that generated in each place. Also, concerning to the morphological composition of waste and the directions for their further utilization, including through processing.

For the formation of the following indicators, were use official answers to information request of executive bodies of local self-government of a number of cities – regional centers of Ukraine, including: Executive Committee of the Mykolaiv State Council from 28.07.2016 № 7687/02.02.01-21/14/16, housing Department of the Executive Committee of the Kharkiv State Council Committee from 27.07.2016 № c-1-10/1529/0/180-16/08-39-6873/0/129-16, Executive Committee of Kherson City Council from 14.07.2016 № 8-7576-18/23, Executive Committee Uzhgorod City Council from 07.07.2016 № 1928/03-17, Department of Housing and Communal infrastructure of Kyiv State Administration from 22.06.2016 № 058/4/2-6168, Executive Committee Lutsk State Council from 02.07.2016 № 1.1-814236, Executive Committee Ivano-Frankivsk State Council from 30.06.2016 № 3105/01-20/14, Department of Housing and Communal Services of Khmelnytsky State Council from 24.06.2016 № c-14573-16, the Main Department of Housing and Communal Services of Kirovograd State Council from 01.07.2016 № 4535/23-05-26 (also other official sources), concerning the volume of solid waste products for 2015 year about each of the mentioned cities.

The empirical basis of research is official information received in response to requests directly from mentioned organizations.

Based on the results of analysis of statistical and other information it was determine that at the local level there is in fact absolutely unavailable the only balanced systemic centralized approach: at the very stage of calculation of the volume of waste products and its composition, there are significant differences in the approaches of reporting entities, which, in turn, prevents the development of any qualitatively new proposals and recommendation for reforming the industry and improving the legal relationship in this area.

As shown results of the researching, in some cities waste accounting is carry out in their volume, in others by their weight (mass), some are not at all.

As the first example, one should look at the approach of Chernigiv State Council to the calculation of total annual waste generation in Chernigiv city, which are located at the landfill of solid waste (Masany district) m^3/t (table 1):

Table 1. Annual volumes of waste generation in Chernigiv city

Year	Mixed type of waste	Waste of green economy	Street garbage	Building waste	Industrial waste of the fourth grade of danger	Just a year
2012	585,9 thous.m ³ /171.2thous.ton	10380m ³ / 2076t	11869,3 m ³ / 2373,86 t	126m ³ /25,2t	7446,86m ³ / 1489,3t	615,7thous. m ³ / 123,1thous.t
2013	599,5 thous.m ³ /119,9 thous.ton	6411m ³ / 1282,2t	10935 m ³ / 2187t	44m ³ /8,8t	6523,26m ³ / 1304,65t	623,4thous. m ³ / 124,7thous.t
2014	598,8 thous.m ³ /119,8 thos.ton	11481m ³ / 2296,2t	-	60m ³ /12t	5175,7m ³ / 1035,4t	615,5 thous.m ³ / 123,1thous.t
2015	600,3 thous.m ³ /120,1 thous.ton	8900m ³ / 1780t	-	85m ³ /17t	3960,35m ³ / 792,07t	613,2thous. m ³ / 122,6thous.t

The scheme of sanitary cleaning of Chernigiv City provides for solving the issues of solid household waste management in the city with the use of sorting, processing and repeat using of waste products. Among the main directions of strategic development in waste management of this sphere in Chernigiv City is planning for construction of a city waste recycling complex.

In accordance with the Program of Improving the Environmental conditions of Chernigiv City for 2016-2017 (approved by the decision of Chernigiv City Council from 31.03.2016 № 6/VII-20) in Chernigiv City is foreseen for providing of utilization of danger wastes which are formed in a sleeping area of city (fluorescent lamps, thermometers).

As for other examples, in Mykolaiv City accounting of solid waste gives in meters of cubic: thus, for 2015 was accumulate and transfer to landfills in general 905799 m³. The population of Mykolaiv is 487 thousands citizens, that is, to the arithmetical calculation per year, for one resident of Mykolaiv average is 1,86 m³ of wastes.

In Kharkiv City on two landfills were send in general 3121000 m³ of waste products, at the same time, considering the population of Kharkiv City (1,43 million citizens) volume of manufactured waste per one person per year is 2,18m³.

In Kherson City, waste accounting is carry out by mass: in 2015 to landfill was deliver 60488000 tons of waste products, considering the population (296 thousand citizens) – per one resident of city account for almost 205 kg. of waste per year.

In Uzhgorod City, the annual accounting of waste is carry out as by volume, so as by weight, and an average of 250000m³ (29377000 kg), and therefore, considering the population of city (115 thousand citizens) per one resident per year is 2,17 m³ (255 kg) of wastes.

In Kyiv City, more than 1,2 million tons of waste is produced per year (6 millions). The annual volumes of waste generated on the territory of the communal property and private sector housing in Kyiv, forming 3,9 million m³, or 780 thousand tons; on the territory of enterprises, organizations and institutions – about 2 million m³, or 400 thousand tons. That is, considering the population of Kyiv City (almost 3 million people) – up to 400 kg (2 m³) of waste per one resident.

In Lutsk City, per one resident is 2,4^m of wastes annually.

A similar situation with regard to the amount of waste per one resident of other Regional points (in the weighting – one resident Regional center «produces» more than 2 m³ of waste with weight more than 250 kg per year.

At the same time, it should pay attention that there are significant differences between the volumes of «produced» rubbish per person – from 200 to 400 kilograms per year.

2. Specific of morphological composition of waste products

The category of waste, as defined in Article 1 of the Law of Ukraine «On Waste», are wastes, which formed during the process of life and activity of a person in residential and non- residential buildings (solid, large-sized, repair, liquid, except for wastes associated with production activity of enterprises) and are not used at its place of accumulation.

Concerning to situation with morphological (qualitative) waste composition, it is absolutely complicated and confusing.

For example, the indicative morphological composition of solid waste placed on the landfill of solid wastes (Masany area) in accordance with the scheme of sanitary cleaning of Chernigiv City, approved by the decision of the executive Committee of Chernigiv City Council from 15.04.2016 № 125, Fig. 1:

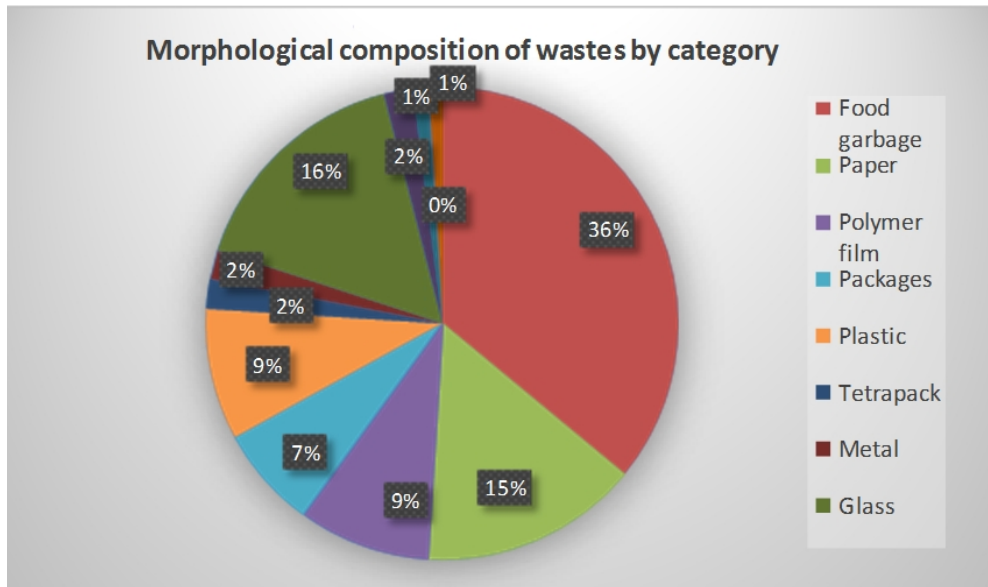


Fig. 1 –Morphological composition of waste on the example of Chernigiv City

In Vinnytsya City accounting of waste products by types of human activity, as a result of which they are form is not conducted.

Competent morphological composition of waste products in Vinnytsya City shown on Fig. 2.

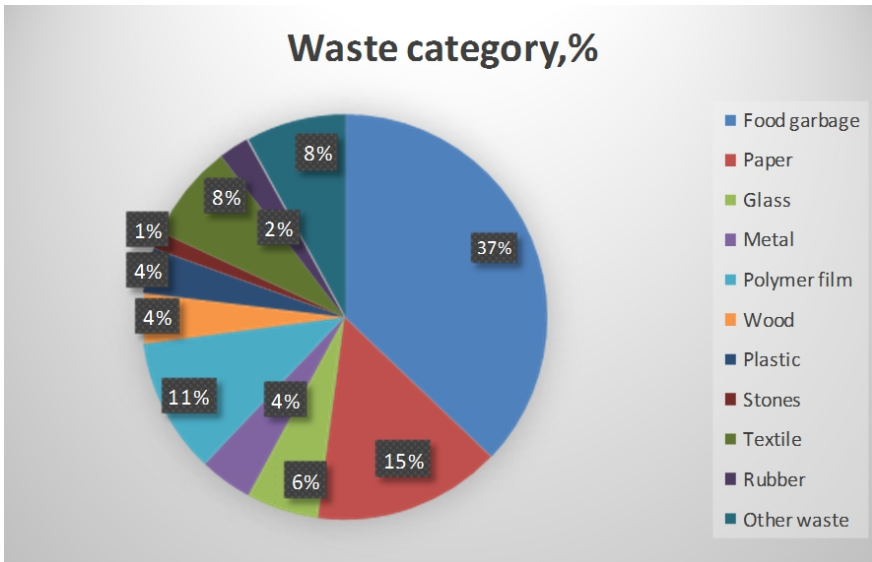


Fig. 2 – Morphological composition of waste on the example Vinnytsya City

The approximate morphological composition of solid waste in Odessa City shown on Fig. 3:

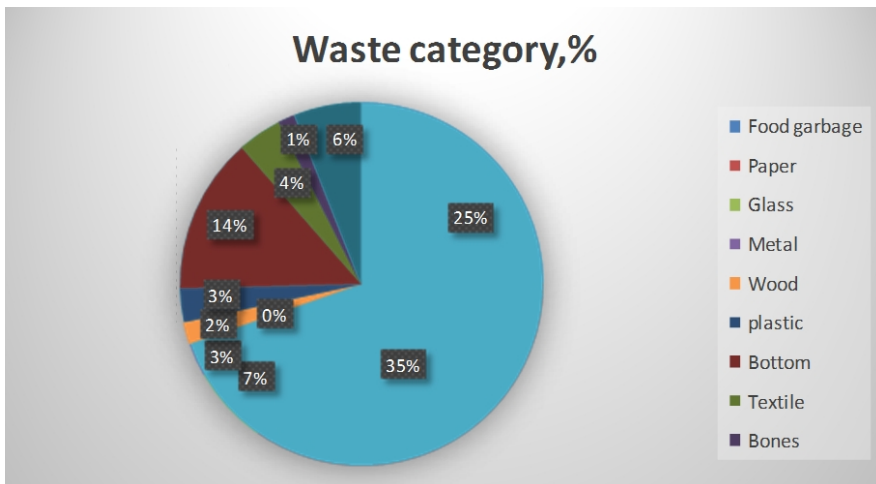


Fig. 3. – Approximate morphological composition of solid Waste in Odessa City

Detail of solid wastes by periods, districts, composition and types of human activities in Odessa is not carry out.

According to researches of the morphological composition of solid waste, which are formed in Kharkiv city (Fig. 4), on average, contain (as a percentage of the mass) – in residential buildings.

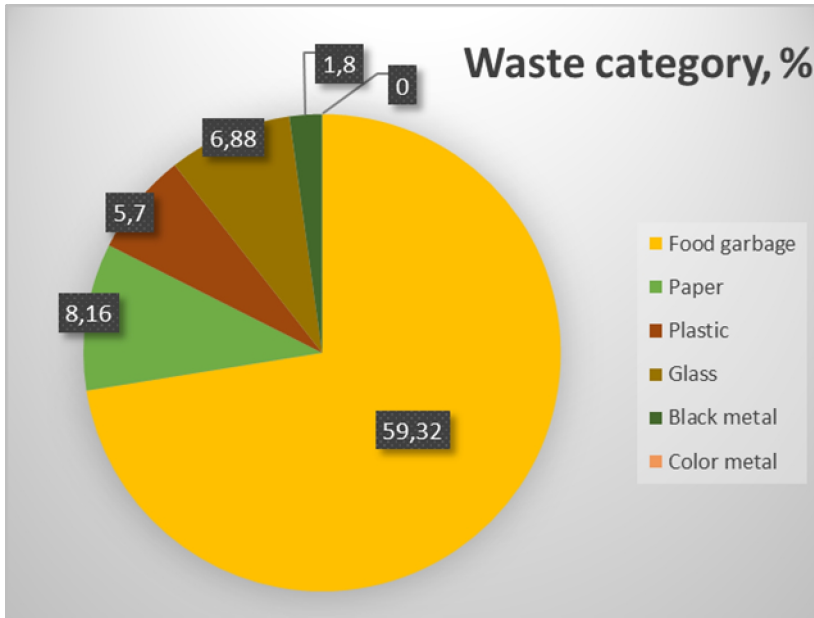


Fig. 4. – Morphological composition of wastes on Kharkiv City example

Also, we can see morphological composition of landfill waste of Ternopil (1 ton or 4 m³), as shown on Fig. 5:

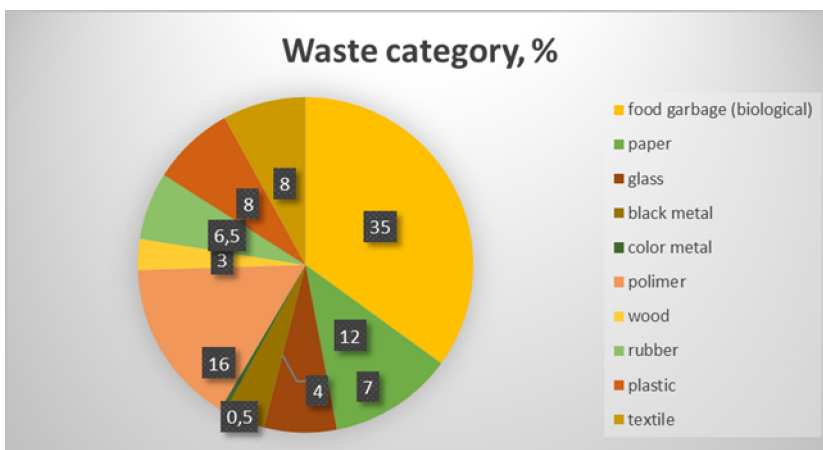


Fig. 5. – Morphological composition of Ternopil landfill

According to these indicators, morphological composition of waste in Uzhgorod significantly different: the largest part is not food (garbage) waste (as in most other regions), but streaks, stones and construction rubbish. As for the last one, building waste (construction rubbish) using at the landfill for spillage of garbage layers to prevent fire. For every 2-3-m of compressed garbage, the earth or construction waste is plummeted by 0,5 m – in the case of fire appearing, the fire spreads only to the upper layer and does not spread to the depth.

In many other cities, where there is no separate collection of waste, it is impossible (there is no possibility) to provide even an approximate detail of them, according to the morphological composition.

In the case of food waste, their composition in the total volume (mass) is follow:

- Mykolaiv city - 55,54%,
- Kharkiv city – 59,32%,
- Uzhgorod city – 10%,
- Lutsk city – 25%,
- Khmelnytsky city – 40%,
- Kropyvnytsky city – 64,4%,
- Odesa city – 25%,
- Chernigiv city – 36%,
- Ternopil city – 35%.

Approximately the same differences there are in other cities, where the waste volume oscillate from 10% almost to 60%.

It can't be consider, in some cities of Ukraine the structure of nutrition (consumption of food products) of residents is different from consumption in other cities, for explaining of these differences in traditions of food consumptions and production of food residues. Obviously, these discrepancies arise because of incorrect displacement and arbitrary «mixing» of the mechanisms and calculation principles when incompatible combinations of mass and volume as reporting criteria are applied at different stages of accounting.

The same situation with construction waste: in Khmelnytsky, the volume of construction waste (garbage) – is 8%, in Uzhgorod city together with stones and street garbage, this category reaches 40%, in Kropyvnytsky city – 6,2%, in Ternopil – 6,5%.

For other components of waste: for example, in Chernigiv city, the declared amount of waste glass is 16%, while in other cities it does not exceed 5-6%.

In Kherson, Ivano-Frankivsk, Cherkassy and Kyiv cities (and more than half of regional centers), accounting of morphological composition of waste products is not carryout at all. For example, in Poltava city general annual volume of wastes for 2015 is 604 721 m³, of these, the wastes of enterprises, institutions and organizations of all forms of property amounted to 186621, 02m³, the population (department housing, housing stock №2, private housing sector) is 418100 m³ (letter of Department of Housing and Communal Services of the Executive Committee of The State Poltava Council from 24.06.2016 № 010501/09/35-zi).

Separate waste collection is not conduct in the city; therefore, it is not possible to provide detailed information on morphological composition. Disposal of waste products, their final placement is carry out at the Poltava city dump, located in Makukhivka village of Poltava district, Poltava Region.

3. The problem of waste accumulation and classification

Any landfill (besides the fact infiltrate leaks into the soil and contaminate water resources and atmospheric air is spoiled by rotting), it is also the source of methane gas that gives rise to the surface and cause fire. Waste sorting, their processing and the practice of using as an alternative source of electric or thermal energy are used only in some cities, while in other settlement this issue is only at the stage of discussion. Specifically, in Vinnytsya from 2015 started the project of minimization and separate collection of waste, which realize by «ECOVIN» communal unitary enterprise. The project is competent on reducing environmental pollution and minimization of waste amount, saving natural resources, reducing the load on the existing landfill of waste products and more efficient exploitative of waste sorting station. Wastes in Vinnytsya are divide into two fractions: «dry» and «wet» for which installed separate containers. To the «dry» are PET-bottles, paper, glass and metal, to «wet» - food garbage, dirty packages, waste of green economy. During the last ten years, CUE «EKOVIN» tares care about this landfill.

City landfill of wastes is located on territory of Stadnytska village council outside of a settlement, exploitations from 1982. Nowadays, nobody can remember about ecological tragedy, which threatened in 2000s on the landfill, as it happened on territory some other settlements, which located near the waste landfills. But in Vinnytsya than began the first attempts to develop their own projects, German colleagues came to the aid, and thanks to determination they managed to achieve significant positive changes.

So, square of landfill is 16,0128 hectares, the total amount of accumulated wastes for the entire period of operation – 16,2 million m³. Wastes are stored only within the determined landfill on specified work cards. Also, for reducing load on waste landfill installed waste sorting station. Resource valuable waste products, which classified, using for further processing. According to rough estimates, due to the introduction of waste sorting, landfill load discharged to 10% (primarily due to the removal of plastic containers and some other resource-wasting waste). In plans – increasing this indicator to 30%, what is average in Europe.

Considering that the huge amount of wastes accumulated on landfill, this place is using for extraction of methane, which is the main component of natural gas. On landfills, methane is formed as a result of organic traces rotting without access to air, when the wastes decomposes in naturally way under soil layers.

From methane at the Stadnytsky landfill, than they produce electrical energy. And, biogas, according to experts valuations, will suffice for at least the next 15 years. On waste landfill territory, there are installed more than 10 mobile pores (wells), each of which can reach up to 20 meters. This, above all, contributes for degassing of landfill and reduces the risks of explosive mixtures formation and fire occurrences.

Subsequently, methane is supplied to the block-modular thermal power station, where use on a special installation for generation both energy: electric and thermal. The daily capacity (plant operates 24h) is about 24 MVt of electricity and 43,2 MVt of thermal energy, this amount is enough to meet the needs of the entire neighborhood of city. According to Vinnytsyaoblenergo convinces, such amount of generated electricity allows to compensate for its shortage in «rush hours» periods and to ensure consumer's needs, accordingly. Unfortunately, in many other regions such projects are absent. In addition to «official» landfills, in Ukraine there are

more than 30 thousands of illegal - spontaneous wastes' landfills. Accumulation of wastes brings huge geoeconomical, economic and social damages, - according to G. Krasovsky and O.S. Grebin affirmations, - the task of mapping, monitoring of storage sites for various types of waste – one of the most urgent in the environmental protection sphere. For solving this problem, researches are suggests using modern geoinformation technologies and remote sounding of Earth. In particular, using the means of constructing a multi-criteria system based on software of ArcGIS will allow not only solving the problem of dealing with existing spontaneous landfills, but also brings possibility for planning placements, volumes and priority types of waste depending on the quantitative population size and the type of activity of region for organization of management by established landfills [3, pages 44 – 45]. Such proposal, of course, deserves for attention, but, even the practical application of such program means does not eliminate the cause of excessive accumulation of waste, which is due, first of all, to imperfect approaches to their accounting at the stage transporting to utilization places.

All places for waste utilization – landfills, complexes, foundation pits, structures, subsoil areas (those are functioning, closed, and preserved) should be included to the list of waste utilization. The register of waste disposal sites, as defined in p.4 of Cabinet of Ministers of Ukraine Resolution from 03.08.1998 № 1216 «On the approval of the register of all waste disposal sites», this is a system of data obtained as a result of registration and description of all facilities and specially designed places where removal operations are carry out.

The Law of Ukraine «On waste» determine that state classificatory of wastes – is a systematic list of codes intended for using in national statistics in order to provide comprehensive and substantiated information about formation, accumulation, treatment (recycling), rendering and waste utilization. Paragraph 2 of Article 33 of mentioned Law also prevision a special passport is drawn up for each place or object of storage or disposal wastes, which specifies the name and waste code (according to the state classification of waste), their quantitative and qualitative composition, origin, as well as technical characteristics of places or objects of storage or elimination and information about control methods and safe operation of these places or objects.

However, the practice shows that in some regions of Ukraine, there are many problems with certification of waste elimination places; first of all, because existing waste elimination places (landfills) have exhausted their technological capabilities, their exploitation periods are over. This requires the solution of the question of determining of new locations of such facilities, or, in the case of impossibility, – to continue the term of exploitation of existing ones. For example, Cherkassy region, the term of exploitation of landfill is over, so as rubbish dumping in Barvinok village of Zakarpatska region, already in the summer of 2017, has filled so much that it will be impossible to export the waste somewhere. Seven years ago this landfill was supposed to be closed, but it still functions – at the last limit of those technological possibilities that have remained. Issues related to the placement of new waste landfills for disposal in Cherkassy, and ideally for the construction of waste recycling plant, were particularly discussed only shortly after the tragedy in Grybovychi, but during few months this activity decreased.

Conclusions

Analyze the above discrepancies in approaches of local self – government bodies to the formation of reporting and accounting of amount of solid waste products determine the existence of number negative factors that impede the effective resolution of waste management issues, including the involvement of investors. Among such factors are corruption offenses and misuse of funds from local budgets spent on waste utilization.

However, in order to implement each of the options for solving the problem, the obligatory guarantee of success is the introduction of universal sorting, that is, the separate collection of different waste categories at the stage when garbage is collect at home, and then placed in containers – this issue became relevant in Ukraine more than 10 years ago. Unfortunately, at present, only private enterprises carry out of this problem, which buy some types of waste products from the population for further processing, while municipal communal services do not even ensure of normal installation of containers for the most widespread waste (glass, paper, plastic).

Deserves special attention experience of organizing work in Vinnytsya region (Stadnytsya), which should be use in other large cities and region of Ukraine, as the installation of facilities for degassing landfills will allow extracting methane continuously and using it in the fuel and energy complex.

Besides that, it is consider necessary to introduce a single integrated centralized reporting system for accounting of solid wastes, an integral detail analysis of their morphological composition, introduction of common accounting standards. Such unified system should be based on the obligation to calculate the mass, volume and morphological composition' parameters, which, accordingly, is possible provide in condition of waste sorting adjusting. However, future compliance with these requirements will significantly improve the reporting process (eliminating existing imbalances in indicators) and control of execution determine standards and waste management rules.

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MODELING OF FIRE SUPPRESSION IN THE ECOLOGICAL SYSTEM OF TREES AND SHRUBS

***Annotation.** This work presents an approach to mathematical modeling of directional suppression of fires in the ecosystem of trees and shrubs. It is taken into account that for effective extinguishing of fire in the natural ecosystem is necessary to ensure a uniform and strong impact of dispersed flow over the entire area of the hearth burning. The presented model can be used as a baseline when planning measures of prevention, localization and liquidation of fires in natural ecosystems near industrial centers. This approach will prevent the development of fire and environmental pollution by combustion products.*

***Key words:** ecosystem, forest, fire, flow, model, process.*

Introduction

All over the world from fires in natural ecosystems at least 50% of the annual growth of trees burns on average. After a fire not earlier than 30 - 60 years is growing less valuable forest, swamps are formed, fauna dies – the whole region, where there was a forest fire irreparable environmental damage is caused. With the industrial and cultural development of forests in the countries by lumber companies, tourists, and vacationers, a number of forest fires, their speed of development, the scale, losses and environmental damage from these fires increase.

This topic is particularly relevant for the territory of the Luhansk region. In the region, there are small forest plantations of anthropogenic origin. In the agricultural part of the Luhansk region is deciduous trees and shrubs. In the industrial part of the Luhansk region is pine plantations.

The territory of Luhansk region is characterized by arid climate in summer, the typical temperature spikes to 40°C. Near industrial centers, it is observed increase in air temperature connected with the work of vehicles and industrial enterprises.

According to statistics, forest and Prairie fires in summer are registered by employees of the State service of emergencies of Ukraine in Luhansk area 10-12 times a day. As a rule, this is fire forest litter, dry grass in the steppe and along the roads.

However, the most significant environmental and economic damage are forest fires around Severodonetsk, in the Kreminskyi forests, in forest plantations of Lisichansk. These are the cities, where the enterprises of chemical and coal mining are situated. Green spaces are a barrier to trap harmful substances released by enterprises. Naturally, when it is a forest fire all of these substances are released into the air from combustion products, causing huge damage to people and the environment.

Purpose of the work: to present one of approaches to modeling the process of extinguishing fires in the ecological systems of trees and shrubs that have been planted by man around industrial cities.

Tasks of the work:

- a) to consider the features of the spread of fire in the ecosystem of trees and shrubs;
- b) to represent a model of flame spread among the trees;
- c) to create a model of the process of fire extinguishing with the physical and chemical properties of the environment.

Questions of ecological safety of technogenic loaded areas and approaches for the localization and liquidation of fires in the natural environment is considered to Dovhyi S.O. [1], Trofymchuk A. N. [2-3], Yakovlev E. A. [3], Zakhmatov V. D. [4], Snytyuk V. E. [5] and others [6].

1. Features of the spread of fires in the ecological system of trees and shrubs

Planting trees and shrubs, which is forest, forest plantation, forest zone, park, square, is a special ecosystem. This ecosystem consists of several tiers and is a community of closely related elements of animate and inanimate nature (biota). The forest biota includes vegetation, animals, and microorganisms. Fire of the ecological system of trees and shrubs affects all components of animate and inanimate nature, because it is a complex of combustion system, consisting of a combination of burning wood - trunks, branches, stumps, foliage on trees and on the ground with the participation of oxygen and other chemical elements that are found on the leaves, wood, and soil.

Wood is inhomogeneous and anisotropic combustible material, flammable ability of which is strongly depends on the structure and therefore unequal in different directions. Wood is a complex mixture of natural polymers of high relative molecular mass: cellulose 50%, helicella 25%, lignin 25% and moisture up to 85%. The mass fraction of these components and moisture varies depending on tree species, time of year and weather.

Due to the fibrous structure of wood, its thermal conductivity in the direction parallel to the fibers is approximately two times more thermal conductivity in the direction perpendicular to the fibers. The difference in the gas permeability reaches much larger values, respectively, to 1000:1. Combustible volatile products are pairs of sublimation wood, (are the gas phase of the combustion process and are formed directly under the surface not covered by the fire of the part wood) are easier evaporated through the channels along the fibers than through the thin top layer of wood.

The evaporation process may have a different intensity and occurs mainly during heating to the temperature interval 200-250°C, after which most of the volatile products from a surface layer of wood has already evaporated and it starts charring the layer. Prolonged gradual heating process of sublimation ends at low temperatures up to 120°C and starts charring. At temperatures above 300°C, it begins the more intensive cracking of the surface layer of the wood, the result is heating and the process of sublimation of the deeper layers of wood begins. Already at a temperature $T=300^{\circ}\text{C}$ there is a process of rapid physical degradation with the appearance of weak cracks perpendicular to the fiber direction, which allows fuel pairs that were formed at the bottom warms layers of wood to go on set of cracks through the charred layer and burn on this layer and even in the layer. With increasing depth and intensity of combustion of the carbonaceous layer, the cracks will grow in length, width and depth, the surface of the burning material will

be splitting and cracking. Thus is formed a powerful condensed area with large reserves of heat, available even after a long time of the downed flame to restore the combustion process.

Flammability of wood depends on acting on her heat flow. The linear burning rate of wood is 0.6 mm/min. The burning rate is not constant, and changes considerably depending on the heat flow formula,

$$\omega_n = 2,2 \times 10^{-2}I, \quad (1)$$

where I is expressed in KW/m². During fires of the piles of wood and fallen forest, the local temperature in some points can reach 1100°C; the corresponding radiation of a black body is 200 KW/m², which may cause an increase in the rate of burning of wood to 4.4 mm/min. The burning speed depends on the thickness of the burning fragment of a tree – a trunk, a branch. A relatively thin layer under the burning surface of combustible material is exposed to thermal effects. Large burning rate will be observed for thin samples, provided that the heat sink from the back side of a burning fragment of wood will not be high enough. Thick fragments of branches of the trunks are hard to flame and slower to burn due to intense heat sink into the wood, especially if the barrel at least partially retained moisture and didn't dry. Thick wooden pieces can't burn in isolated conditions from the air flow - if the flame covers them from all sides, on the contrary, in this case, thin wood chips and branches are easily ignited and burn quickly because the intensity of the heat sink will be minimal. Therefore, in the initial stage of combustion is more difficult to extinguish thin branches, especially their plexus and a handful of wood chips, shavings, respectively, when reaching a good flare-UPS that is, formation of the developed warm layer it is harder to extinguish thick logs because of the large supply of heat accumulated in the thickness of the charred layer.

The most difficult cases for suppression are: the trunks of the trees with a rough surface with hollows and provigilonline stumps, the tangle of thick branches, trunks, modeled by the stack cell crossing rows of logs. The accumulation of the heat inside the stack and mutual transverse thermal radiation of burning surfaces greatly accelerates the buildup and the process of burning of thick timbers and logs. Therefore, stacks are used in experiments as a means of generating sustainable and self-renewable sources of fires, the burning rate of which is regulated by a number of parameters - thickness logs B, the number of rows in the stack N, the distance (of timbers) of logs from each other in each row S, the length of the logs L.

2. Model of flame spread among the trees

The mechanism of flame spread among plantings of trees includes radiative heat transfer before the flame front. The advancing flame front takes with the expression (2) the speed of flame propagation will be inversely proportional to the average density of the hearth:

$$V = \frac{q}{\rho_{\Delta}h} = \frac{\varepsilon\delta(T_F^4 - T_0^4)}{\rho_{\Delta}h} \quad (2)$$

However, this formula does not take into account all the important factors, such as humidity. The formula is correct enough, if some elements of combustible material is considered as thin. Another case examines a replacement density of the lesion within effective density, which takes into account the fact that until the arrival of the flame front, only the surface layers of each element are subjected to heat, and the practice shows that only localized areas of these layers heat up. In the ecosystem of trees and bushes, the fire spreads most quickly through the shrub, branches creeping along the ground or through the edge of the trees, where the average density is low and the elements of a solid combustible material is thin. Considerable speed of fire spread is possible in the drought conditions with low humidity. Such conditions are typical for pine forests that grow around Severodonetsk town, Luhanskaya region.

For the existence of stable combustion of the solid material the following conditions must be performed:

- combustible material in the combustion zone must be sufficiently porous (cracked) to ensure penetration of the oxidant (oxygen) to the mass of combustible material;

- the material in the process of thermal decomposition should give a solid carbonaceous residue, which ensures the fulfilment of the first condition;

- the combustion process needs to penetrate into the depth of the material, this creates a condensed combustion zone that is a high temperature surface layer, in which self-heating processes are brightly manifested that causes a wave of smoldering slow burning, slowly spreading inside the combustible material to the inner layers by contact heat transfer.

As a result of such processes inside a condensed zone – the high temperature surface layer of a solid material a self-combustion reaction is formed, a stock removal is accumulated, which provides the ignition even after multiple external re-appearance of downed flame and isolation from the oxygen for a long time up to several hours.

The process of burning charred surface provides the flow of heat necessary for the process of thermal decomposition of the underlying layer of combustible material. For successful dissemination of this process it is required sequential removal of non-combustible high temperature of the solid residue and gaseous products of combustion – the smoke from the active burning zones that will expose a fresh carbon layer, which immediately ignites on contact with the oxygen. The presence of intensive surface oxidation process inside the cracks of the porous material in zones of cracking and pyrolysis is the condition for a sustained process of combustion of a solid material.

3. Modeling of the process of fire extinguishing taking into account the physico-chemical properties of the environment

For the process of combustion of is typical a strong dependence of the rate of the chemical reaction on the physico-chemical properties, aggregate state, temperatures of combustible substances and oxidizer, and the ignition conditions. All of these factors have well-defined critical value, when reaching at least one of them, the process of burning stops. For the combustion reaction it's typical critical modes and abrupt changes in burning rate at relatively small changes of combustion system parameters. Termination of a continuous process of interaction between

counter flows of fuel, oxidizer and heat flux in the charred K-zone – the destruction of this zone happened for a small period throughout the whole combustion system is a condition for effective extinguishing. At this undeveloped stage of combustion – ignition of solid material after the cessation of exothermic chemical reactions, there are processes of self-destruction plasma and condensed (K) combustion zones and dispersion of combustion products by means of intensive heat and mass transfer with the environment.

Until the formation of a stable charred zone with significant reserves of heat, the hearth recently ignited solid material easy to put out. This requires to reduce by 15-20% the heat flux to the surface of the solid combustible material, where a charred zone is formed. The transition from ignition to stationary combustion is characterized by a large heat absorption for the formation of surface, high temperature K-zone layer and then a rapid increase of the reaction rate with relatively small further changes in temperature and the heat content of the burning material.

For the most effective extinguishing of the hot solid materials one can create intense gas-dispersed flow directed mainly into the surface layer of hot material and providing an even saturation of this layer with finely atomized fire extinguishing agent.

Let's consider the advantages of directional quenching in comparison with traditionally used ways of applying extinguishing agent to the whole fire burning. For this, let's imagine numerical evidence of the benefits of the directional fire exposure on certain zone of hearth burning, which is the foundation of this burning process. In the case of type A fires, such zone is condensing (if-zone), that is porous, cracked, charred, molten layer of the solid combustible material. In any stage of development of the class A fires the destruction of the if-zone combined with cooling, inhibition or exception of material of this zone - the high temperature combustible particles from the oxygen is the only possible way of final extinguishing of class A fires. The destruction of all other zones - diffusion (D), plasma or smoke will not lead to the final extinguishing. If-zone can restore other zones and the process of combustion even during a long period of time after extinguishing all of the burning area at a constant distance from the installation of the extinguishing composition to the far border of the fire. In this case, the consumption of extinguishing agent must exceed a certain critical value:

$$F_0 v_0 > (F_0 v_0)_{kp} \quad (3)$$

where

F – required value of the contact surface area of the aggregate particles of the powdered fire-extinguishing composition with the burning of solid and combustible particles and their flammable vapors.

v_0 is the initial horizontal speed of the front of the solid phase (particles of the extinguishing composition).

Based on the flow of extinguishing agent the dependence of the magnitude of the surface area of the particles of the F_0 fire extinguishing composition from the speed of fire-extinguishing flow V can be obtained:

$$(F_0 v_0) = \frac{F_x}{D_0} (4|v_z|x_0 + u_x D_c) \ell \frac{\gamma(L-x)}{u_x} \quad (4)$$

In the expression (4) designation F_x , u_x , D_c , V_z , X_0 , U_0 are the particle parameters of the fire extinguishing composition. Accordingly: the critical value of the area of the sum contact surface of the particles of the extinguishing agent with the zones hearth of fire; the current speed of the fire extinguishing stream at a distance X from the installation of the extinguishing substances; the averaging diffusion coefficient of the particles of the extinguishing composition at the moment of contact with the combustible material; the average absolute value of the vertical component of particle velocity; the range of penetration of particles of the fire extinguishing mixture in the combustion zone.

Also:

v_i – the initial (muzzle) velocity of the front fire-extinguishing thread;

u_x – vertical component of velocity of the gaseous products of combustion (smoke);

L – the distance from the far border hearth of the fire to the position of installation of the extinguishing composition;

γ – the time of radicals of a combustible substance generating.

For the implementation of the extinguish fire in the ecosystem of trees and shrubs it is necessary to ensure a uniform and strong impact of dispersed flow over the whole area of the hearth burning – that is, to provide that $X > L$. In this case, the following form gives the formula (4):

$$F_0 v_0 > F_{kp} \frac{4|v_z|x_0 + u_x D_c}{D_c} expO = \frac{F_x}{D_c} (4|v_z| + u_x D_c) \quad (5)$$

Subsequently, this model can be slightly simplified by expressing the mass of the fire extinguishing composition through the total surface area of its particles. This will allow to describe the surface of the hearth fire fighting through a potential of the spraying fire-extinguishing compositions.

However, presented model (5) gives a complete picture of the impact of extinguishing composition on the hearth burning and allows to design a stream of particles for aimed firefighting ignition in the ecosystem of trees and shrubs.

Conclusion

The fight against forest fires has long passed beyond the regional issues and turned into an acute political-economic problem for the state. On average, no more than 1-2% of the sprayed mass of extinguishing agent falls on the charred surface of the trees and cools the high-temperature layer, which is the foundation of a forest fire and a source of repeated firings. That is why the task of creating a focused dispersion stream to dense cover the largest possible area of fire is primary in the implementation of technologies for fire-fighting.

This work presents one of solutions of this problem. The presented model allows providing a uniform and strong impact of dispersed flow over the entire area of the hearth burning and can be used as a baseline when planning measures for prevention, localization and liquidation of fires in natural ecosystems near

industrial centers. This approach will prevent the development of fire and environmental pollution by combustion products.

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ABSTRACTS

ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ В ЕКОНОМІЦІ INFORMATIONAL TECHNOLOGY IN ECONOMY

УДК 519.8

Теоретико-ігрова ресурсна модель збалансованого технологічного розвитку / Полумієнко С.К., Горда С.Є. // Математичне моделювання в економіці. – 2017. – № 3-4. – С. 4-9.

У статті пропонується теоретико-ігровий ресурсний підхід до моделювання процесів сталого розвитку. Вихідна система розглядається як сукупність різних ресурсів і учасників, які споживають і створюють ці ресурси для задоволення їх потреб або інтересів. Учасники системи не діляться на економічні, екологічні та соціальні підсистеми. Їх стратегії або технології спрямовані на отримання доходу від виробництва і споживання ресурсів, що, в свою чергу, спрямовані на коаліційні інтереси учасників. Стратегічна і кооперативна коаліційна гра, побудована на цій основі, описує процес розвитку системи. Її оптимальна стратегія, представлена вектором Шеплі, забезпечує компромісну стратегію збалансованого технологічного розвитку системи.

УДК 519.8

Теоретико-ігровая ресурсная модель сбалансированного технологического развития / Полумиенко С.К., Горда С.Е. // Математическое моделирование в экономике. – 2017. – № 3-4. – С. 4-9.

В статье предлагается теоретико-игровой ресурсный подход к моделированию процессов устойчивого развития. Исходная система рассматривается как совокупность различных ресурсов и участников, потребляющих и создающих эти ресурсы для удовлетворения их потребностей или интересов. Участники системы не делятся на экономические, экологические и социальные подсистемы. Их стратегии или технологии направлены на получение дохода от производства и потребления ресурсов, что, в свою очередь, направлены на коалиционные интересы участников. Стратегическая и кооперативная коалиционная игра, построенная на этой основе, описывает процесс развития системы. Ее оптимальная стратегия, представленная вектором Шепли, обеспечивает компромиссную стратегию сбалансированного технологического развития системы.

УДК 338.262

Економічна наука і економіко-математичне моделювання / Ведута О.М., Джакубова Т. М. // Математичне моделювання в економіці. – 2017. – № 3-4. – С. 10-22.

Глобальна криза, що вимагає переосмислення економічних знань і нових економіко-математичних моделей (ЕММ), на яких ці знання базуються, змушує повернутися до витоків економічної науки і ЕММ. Тому виняткову актуальність для виходу з

глобальної кризи набуває теорія відтворення К. Маркса, яка вивчає об'єктивні економічні закони, та ЕММ, яка базується на цій теорії, для побудови кіберсистеми, що допомагає вийти на траєкторію суспільного прогресу. У статті показано, що ЕММ, які історично виникли для більш глибокого розуміння економічних механізмів, отримали розвиток у двох основних напрямках. Розробники першого напрямку пішли шляхом ускладнення використовуваного математичного апарату і збільшення кількості параметрів, задаються екзогенно, в описі економічних систем аналізу і прогнозування, заснованого на екстраполяції. Починаючи з 50-х років минулого століття прискорено розвивається саме цей напрямок, який, на думку багатьох дослідників, потрапив у глибоку кризу через неможливість використання ЕММ і економічних теорій, на яких вони базуються, для розробки антикризових заходів. Розробники іншого напрямку розвивають ЕММ шляхом все більш повного відображення в моделі дії об'єктивних економічних законів для конструювання економічної кіберсистеми, що припускає використання сучасних інформаційних технологій як інструменту підвищення ефективності управління. По суті, використання кіберсистеми означає перехід управління економікою на принципово нову технологію, необхідну для виходу з глобальної кризи. У статті сформульовані основні принципи динамічної моделі міжгалузевого та міжсекторного балансу, яка може бути закладена в основу створення економічної кіберсистеми.

УДК 338.262

Экономическая наука и экономико-математическое моделирование / Ведута Е.Н., Джакубова Т.Н. // Математическое моделирование в экономике. – 2017. – № 3-4. – С. 10–22.

Глобальный кризис, потребовавший переосмысления экономических знаний и базирующихся на них экономико-математических моделей (ЭММ), заставляет вернуться к истокам экономической науки и ЭММ. Поэтому исключительную актуальность для выхода из глобального кризиса приобретает теория воспроизводства К. Маркса, изучающая объективные экономические законы, и базирующиеся на ней ЭММ для построения киберсистемы, помогающей выйти на траекторию общественного прогресса. В статье показано, что ЭММ, исторически возникшие для более глубокого понимания экономических механизмов, получили развитие в двух основных направлениях. Разработчики первого направления пошли по пути усложнения используемого математического аппарата и увеличения количества экзогенно задаваемых параметров в описании экономических систем для анализа и прогнозирования, основанного на экстраполяции. Начиная с 50-х годов прошлого века ускоренно развивается это направление, которое, по мнению многих исследователей, ушло в глубокий кризис из-за невозможности использования ЭММ и экономических теорий, на которых они базируются, для разработки антикризисных мер. Разработчики второго направления развивают ЭММ по пути все более полного отражения в модели действия объективных экономических законов для конструирования экономической киберсистемы, предполагающей использование современных информационных технологий как инструмента повышения эффективности управления. По сути, использование киберсистемы означает переход управления экономикой на принципиально новую технологию, необходимую для выхода из глобального кризиса. В статье сформулированы основные принципы динамической модели межотраслевого и межсекторного баланса (МОСБ), которая может быть в основе создания экономической киберсистемы.

УДК 004.047

Інноваційний інжиніринг як інструмент підтримки прийняття рішень / Краскевич В.Е., Селіванова А.В. // Математичне моделювання в економіці. – 2017. – №3-4. – С. 23–27.

Запропоновано метод оцінки інноваційного проекту на основі інноваційного інжинірингу як інформаційно-аналітичного інструменту. Застосування методології ситуаційного моделювання для оцінки ефективності технологічних рішень інноваційного проекту.

УДК 004.047

Иновационный инжиниринг как инструмент поддержки принятия решений / Краскевич В.Е., Селиванова А.В., // Математическое моделирование в экономике. – 2017. – №3-4. – С. 23–27.

Предложен метод оценки инновационного проекта на основе инновационного инжиниринга как информационно-аналитического инструмента. Применение методологии ситуационного моделирования для оценки эффективности технологических решений инновационного проекта.

МАТЕМАТИЧНІ ТА ІНФОРМАЦІЙНІ МОДЕЛІ В ЕКОНОМІЦІ MATHEMATICAL AND INFORMATIONAL MODELS IN ECONOMY

УДК 316.334.2;338.12

Моделювання регуляторів фінансових потоків у системному макроекономічному середовищі / Макаренко І.П. // Математичне моделювання в економіці. – 2017. – №3-4. – С. 28–41.

Досліджено особливості макроекономічного впливу на інноваційний процес розвитку в країнах із ринками, що розвиваються. Акцентовано увагу на економічних механізмах, які створюють зони нестабільного впливу інструментів монетарної і фіскальної політик. Визначено зовнішні і внутрішні фактори їх виникнення. Розглянуто грошовий, фінансовий та соціо-гуманітарний чинники, що реалізують функції перерозподілу фінансових потоків. Запропоновано економіко-математичний підхід до теоретичного моделювання процесів самоорганізації економіки.

УДК 316.334.2;338.12

Моделирование регуляторов финансовых потоков в системной макроекономической среде / Макаренко И.П. // Математическое моделирование в экономике. – 2017. – №3-4. – С. 28–41.

Исследованы особенности макроэкономического влияния на инновационный процесс развития в странах с развивающимися рынками. Акцентируется внимание на экономических механизмах, формирующих зоны нестабильного влияния инструментов монетарной и фискальной политик. Определены внешние и внутренние факторы их возникновения. Рассмотрены денежный, финансовый и социо-гуманитарный факторы, реализующие функции перераспределения финансовых потоков. Предложен экономико-математический подход к теоретическому моделированию процессов самоорганизации экономики.

УДК 330.34

Наближений метод розв'язування задачі про призначення/ Марко М. Я., Цегелик Г. Г. // Математичне моделювання в економіці. – 2017. – №3-4. – С. 42–49.

Запропонований наближений метод розв'язання задачі про призначення, який дає змогу так розподілити робітників по роботах, щоб загальна ефективність виконання всіх робіт була якомога найбільшою.

УДК 330.34

Приближенный метод решения задачи о назначении/ Марко М. Я., Цегелик Г. Г. // Математическое моделирование в экономике. – 2017. – №3-4. – С. 42–49.

Предложенный приближенный метод решения задачи о назначении, который позволяет так распределить рабочих по работам, чтобы общая эффективность выполнения всех работ была как можно большей.

АНАЛІЗ, ОЦІНКА ТА ПРОГНОЗУВАННЯ В ЕКОНОМІЦІ ANALYSIS, EVALUATION AND FORECASTING IN ECONOMY

УДК 504.75 + 004.942; 519.25; 621.791: 626/627

Удосконалення діагностичних моделей для прогнозування поведінки гребель, обладнаних автоматизованими системами моніторингу / Д.В. Стефанишин // Математичне моделювання в економіці. – 2017. – №3-4. – С. 50–61.

Запропоновано підхід до прогнозування поведінки гребель за даними інструментальних спостережень з врахуванням можливостей автоматизованих систем моніторингу. Підхід ґрунтується на використанні ситуаційних та індуктивних моделей, де ситуаційні моделі відповідають вибірковим рядам динаміки спостережених даних на обмежених інтервалах часу, а індуктивні моделі, що будуються за модельними даними, які визначаються з ситуаційних регресійних моделей, відображають еволюції діагностичних параметрів.

УДК 504.75 + 004.942; 519.25; 621.791: 626/627

Совершенствование диагностических моделей для прогнозирования поведения плотин, оборудованных автоматизированными системами мониторинга / Д.В. Стефанишин // Математическое моделирование в экономике. – 2017. – №3-4. – С. 50–61.

Предложен подход к прогнозированию поведения плотин по данным инструментальных наблюдений с учетом возможностей автоматизированных систем мониторинга. Подход основан на использовании ситуационных и индуктивных моделей, где ситуационные модели соответствуют выборочным рядам динамики данных наблюдений на ограниченных интервалах времени, а индуктивные модели, строящиеся по модельным данным, которые определяются при помощи ситуационных регрессионных моделей, отображают эволюции диагностических параметров.

УДК 53.043+004.942

Деякі особливості міграції тритію / О.О. Кряжич, О.В. Коваленко // Математичне моделювання в економіці. – 2017. – №3-4. – С. 62–73.

За підсумками спостережень, що відбувалися протягом ряду років, було виявлено, що різні показники активності тритію у вільній воді рослин, можуть бути обумовлені процесами життєдіяльності рослин, з урахуванням погодних умов, складу ґрунту, на

якому росли рослини. У статті представлені результати польових і лабораторних досліджень з пошуку рослин, які можуть виступати в якості надійного індикатора для визначення забруднення навколишнього середовища тритієм.

УДК 53.043+004.942

Некоторые особенности миграции трития / О.А. Кряжич, А.В. Коваленко // Математическое моделирование в экономике. – 2017. – №3-4. – С. 62–73.

В результате наблюдений ряда лет, что разные показатели активности трития в свободной воде растений, может быть обусловлен процессами жизнедеятельности растений, с учетом погодных условий, состава почвы, на которой росло растение. В статье представлены результаты полевых и лабораторных исследований по поиску растений, которые могут выступать в качестве надежного индикатора для определения загрязнения окружающей среды тритием.

УДК 346:338.246.88

Управління відходами: проблеми обліку / І.В. Кременовська // Математичне моделювання в економіці. – 2017. – №3-4. – С. 74–83.

Дослідження присвячено оглядові статистичних даних у сфері утилізації та переробки твердих побутових відходів у різних областях України. У статті наведено відомості щодо кількості, обсягу та морфологічного складу твердих побутових відходів за інформацією, одержаною від органів місцевого самоврядування міст, які є обласними центрами України (за винятком території тимчасово окупованих окремих районів Донецької та Луганської областей і Автономної Республіки Крим). На підставі аналізу підходів до формування звітності, які склалися у різних містах, показано наявність суттєвих розбіжностей й невідповідності деяких облікових показників, які впливають на стан роботи зі здійснення обрахування маси та обсягу твердих побутових відходів, а також визначення їх морфологічного складу. Сформульовано пропозиції щодо уніфікації підходу до здійснення обліку кількісних і якісних показників твердих побутових відходів, що сприятиме більш точному визначенню їх обсягу, маси та складу для підвищення ефективності заходів з їх утилізації.

УДК 346:338.246.88

Управление отходами: проблемы учета / И.В. Кременовская // Математическое моделирование в экономике. – 2017. – №3-4. – С. 74–83.

Исследование посвящено обзорные статистических данных в сфере утилизации и переработки твердых бытовых отходов в разных областях Украины. В статье приведены сведения о количестве, объема и морфологического состава твердых бытовых отходов по информации, полученной от органов местного самоуправления городов, которые являются областными центрами Украины (за исключением территории временно оккупированных отдельных районов Донецкой и Луганской областей и Автономной Республики Крым). На основании анализа подходов к формированию отчетности, сложившиеся в разных городах, показано наличие существенных разногласий и несоответствия некоторых учетных показателей, влияющих на состояние работы по осуществлению расчета массы и объема твердых бытовых отходов, а также определение их морфологического состава. Сформулированы предложения по унификации подхода к осуществлению учета количественных и качественных показателей твердых бытовых отходов, что будет способствовать более точному определению их объема, массы и состава для повышения эффективности мер по их утилизации.

УДК 004.942

Моделювання гасіння пожежі в екологічній системі дерев і кущів / Бекетова Г. М. // Математичне моделювання в економіці. – 2017. – №3-4. – С. 84–90.

У роботі представлений підхід до математичного моделювання спрямованого гасіння пожеж в екосистемі дерев і кущів. Враховано, щодо ефективного гасіння пожежі в природній екосистемі необхідно забезпечити рівномірний і досить потужний вплив дисперсного потоку по всій площі горіння вогнища. Представлена модель може бути використана в якості базової при плануванні заходів попередження, локалізації і ліквідації пожеж у природних екосистемах поблизу промислових центрів. Даний підхід дозволить попередити розвиток пожежі і забруднення навколишнього середовища продуктами горіння.

УДК 004.942

Моделирование тушения пожаров в экологической системе деревьев и кустарников / А.Н. Бекетова // Математическое моделирование в экономике. – 2017. – №3-4. – С. 84–90.

В работе представлен подход к математическому моделированию направленного тушения пожаров в экосистеме деревьев и кустов. Учтено, относительно эффективного тушения пожара в природной экосистеме необходимо обеспечить равномерное и довольно мощное влияние дисперсного потока по всей площади очага горения. Представленная модель может быть использована в качестве базовой при планировании мер по предупреждению, локализации и ликвидации пожаров в природных экосистемах вблизи промышленных центров. Данный подход позволит предупредить развитие пожара и загрязнения окружающей среды продуктами горения.

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