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TECHNOLOGICAL MODELING OF THE PROCESS OF REAGENT REMOVAL OF PHOSPHORUS FROM WASTEWATER

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Abstract

The work is devoted to the study of the technology of urban wastewater treatment, specially designed to remove the biogenic element phosphorus. An analytical review of the achievements and publications on the study of the process of wastewater dephosphotation by the reagent method is given. Based on the analysis carried out, the results of our own experimental studies are proposed and substantiated. The dependence of the effect of dephosphotation of wastewater on the dose of the reagent when using mineral coagulants, taking into account changes in environmental conditions, has been established. To optimize the cleaning process, mathematical modeling methods based on influencing and determining factors were used. Graphs and regression equation obtained, which determine the dependence of the residual concentration of wastewater phosphates on the dosing conditions of the aluminum polyoxychloride reagent.

Keywords: wastewater treatment, dephosphotation, optimal planning, multifactorial experiment, aluminum polyoxychloride.

ТЕХНОЛОГИЧЕСКОЕ МОДЕЛИРОВАНИЕ ПРОЦЕССА РЕАГЕНТНОГО УДАЛЕНИЯ ФОСФОРА ИЗ СТОЧНЫХ ВОД

С. В. Андреюк, Т. И. Акулич, Е. С. Гогина, Д. В. Каперейко

Реферат

Работа посвящена исследованию технологии очистки городских сточных вод, специально предназначенной для удаления биогенного элемента фосфора. Приводится аналитический обзор достижений и публикаций по изучению процесса дефосфотации сточных вод реагентным методом. С учетом проведенного анализа предлагаются и обосновываются результаты собственных экспериментальных исследований. Установлена зависимость эффекта дефосфотации сточных вод от дозы реагента при использовании минеральных коагулянтов с учетом изменения условий среды. Для оптимизации процесса очистки использованы методы математического моделирования на основе влияющих и определяющих факторов. Получены графики и уравнение регрессии, которые определяют зависимость остаточной концентрации фосфатов сточных вод от условий дозирования реагента полиоксихлорида алюминия.

Ключевые слова: очистка сточных вод, дефосфотация, оптимальное планирование, многофакторный эксперимент, полиоксихлорид алюминия.

Introduction

The study of the mechanisms of complex processes and the properties of multicomponent systems, as well as their optimization in modern mathematical theory, makes it possible to model wastewater treatment processes based on influencing and determining factors. The object of the study was the reagent dephosphotation of wastewater using the method of optimal planning of the experiment [1].

A multifactorial experiment is widely used in modern scientific activity and is an effective means of processing and planning experimental studies. The effect of wastewater treatment, the residual content of impurities will be a response function with optimal design of the experiment. Mathematical models obtained using the methods of planning experiments are usually called experimental-statistical [2]. At the same time, the value of a mathematical description lies in the fact that it gives information: about the patterns of influence of individual factors on the response function; allows you to quantify the value of the response function for given values of factors; can serve as a basis for optimizing the process, its imitation [3].

Removal of biogenic elements (compounds of nitrogen and phosphorus), leading to eutrophication of water bodies, is currently one of the main directions in the field of wastewater treatment. The removal of nitrogen and phosphorus by the biological method are interrelated. Due to rather stringent requirements for the content of phosphorus in purified water, priorities are shifting towards the removal of phosphorus. When using a biological cleaning method, the efficiency in reducing the concentration of phosphorus is 78-80%. At the same time, the biological treatment process is considered to be very sensitive and unstable. The use of the method of chemical removal of phosphorus makes it possible to reduce its concentration at the outlet of the treatment plant by 95% (up to 0,5 mg/dm³).

In papers [4,5], the issues of mathematical modeling of the processes of flotation wastewater treatment are considered. Descriptions of thermodynamic and kinetic models of the flotation process are given. It is shown that the use of mathematical models of wastewater treatment devices allows optimizing their technological and economic performance without significant costs for additional experimental studies. Known is the development of a software package that mathematically describes the dynamics of anaerobic wastewater treatment using the example of traditional type reactors and reactors in which the stages of acid and methane fermentation are spatially separated [6], the process of membrane wastewater treatment has been studied [7]. Mathematical processing of the results of experimental studies with the help of interpolation polynomials has been carried out, a functional dependence of the change in the physicochemical parameters of the processes of membrane wastewater treatment has been established.

The essence of the method of chemical removal of phosphorus from wastewater is the addition of reagents, the formation and precipitation of undissolved phosphorus compounds and their removal with sediment. As reagents can be used:

- calcium compounds (calcium oxide CaO and calcium hydroxide $Ca(OH)_2$);
- aluminum compounds (aluminum sulfate $Al_2(SO_4)_3 \cdot 18H_2O$, aluminum oxychloride $Al_2(OH)_5Cl$, etc.);
- iron compounds (iron (III) chloride $FeCl_3 \cdot 6H_2O$, iron (II) sulfate $FeSO_4 \cdot 7H_2O$, etc.);

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– natural materials (clays, limestone, zeolite, dolomite, etc.);
– production waste (blast-furnace slag, sludge from water treatment facilities).

In works [8-11] the main attention is paid to the study of wastewater dephosphotation methods and the efficiency of their use. Each of the described methods has its own effect on the removal of phosphates from wastewater through the use of special reagents and their physical properties. There are known studies on mathematical modeling of wastewater dephosphotation processes by the method of a full factorial experiment [12-14]. In particular, the work [14] considers the features of constructing a mathematical model for the process of reagent dephosphotation of highly concentrated wastewater from a pig farm using iron sulfate as a reagent. A characteristic equation has been obtained for calculating the efficiency of removing phosphorus compounds depending on the dose of the reagent, temperature, and Eh. The work [15] analyzes the effect of phosphate ions on the cooling pond of the Rostov NPP and considers the use of a dephosphotation unit in the scheme of reconstructed treatment facilities in the «free» mode zone to reduce it using «Aqua-Aurat 30» as a coagulant. A comprehensive assessment of the efficiency of removing phosphorus compounds from wastewater with its accumulation in activated sludge is known using the innovative reagent preparation VTA Biokat P500 [16]. The results of joint biological and physicochemical purification are presented [17]. Because of modeling, the advantages of using combined chemical-biological dephosphotation of wastewater in aerotanks are shown. The need to improve biotechnologies for the removal of nitrogen and phosphorus from urban wastewater is being actualized [18].

Taking into account the analysis of publications and achievements in the field of optimizing the process of wastewater treatment from biogenic elements, the task of our own research was to obtain experimental-statistical regression equations that reflect the effectiveness of reagent treatment.

The purpose of the performed scientific research was to establish the dependence of the effect of dephosphotation of urban wastewater on the dose of the reagent when using various types of reagents by trial coagulation, taking into account changes in environmental conditions. To achieve this goal, the following research tasks were set to be solved:

1) an analytical review of the application of the method of reagent removal of phosphorus;
2) study of the kinetics of the process of chemical dephosphotation of wastewater;
3) selection of the optimal dose of coagulant depending on the ratio of the concentration of the reagent for metal to the initial concentration of phosphorus (Me:P ratio) at different pH and temperature values.

Materials and methods

Studies of the chemical dephosphotation of wastewater were carried out with the possibility of practical application of the reagent method for removing phosphorus at existing sewage treatment plants in the city of Brest [19, 20]. In the work, methods were used for determining wastewater phosphates, trial coagulation to select the optimal dose of the reagent, and technological and mathematical research methods were used, taking into account the current legal acts. Trial coagulation in the treatment of wastewater was carried out with a 1% solution of the coagulant polyoxychloride aluminum «Aqua-Aurat 30» (with a mass fraction of Al_2O_3 30%) at an initial concentration of phosphates of 10 mg/dm^3. Positive dynamics of purification was also obtained as a result of trial coagulation with iron sulfate (III) $Fe_2(SO_4)_3 \cdot 7H_2O$ reagent (the dose of a 1% solution varied from 18 to 63 mg/dm^3). Taking into account the analytical review of the application of the method of reagent removal of phosphorus and the study of the kinetics of the process of chemical dephosphotation of wastewater, the optimal design of the experiment was carried out using aluminum polyoxychloride.

Results and discussion

In the framework of experimental studies, in order to determine the optimal values of the parameters of the technological process of coagulation of phosphorus compounds in wastewater when modeling the treatment process, we considered the dependence of the residual concentration of phosphates, *Cres*, mg/dm^3, on three factors (table 1):

1) β-factor, taking into account the excess of the reagent, required for the deposition of 1 mol of phosphorus, mol/mol, over the calculated stoichiometric amount;
2) pH values of the medium;
3) ambient temperature, t, °C.

Table 1 – Conditions for conducting a complete factor experiment

Characteristics of the experiment plan	pH	β	t, °C
Basic Level	7,5	1,5	15
Variation interval	1	0,5	5

When conducting research on the treatment of a model solution with a phosphate concentration of 10 mg/dm^3 with «Aqua Aurat 30» reagent, it was established:

1) with an increase in the dose of coagulant (increase in the value of the β-factor), the cleaning effect is achieved from 68 to 91,5%;
2) the maximum effect of removing phosphates is at pH in the range of 6,5–7,5;
3) dephosphating efficiency increases with increasing temperature.

Based on the results of experimental data processing, the regression equation *Cres = f (pH, β, t)*, mg/dm^3, was compiled in the form of a polynomial of the second degree from three variables:

$$Cres = 1{,}24\,\beta^2 - 5{,}38\,\beta + 0{,}43\,(pH)^2 - 6{,}45(pH) + 0{,}01\,t^2 - 0{,}19\,t + 32{,}35. \quad (1)$$

The developed experimental-statistical model (1) makes it possible to represent the response surface on the factorial plane by lines of dependence of the residual concentration of phosphates *Cres* on the β-factor (the ratio of the concentration of the reagent for the metal to the initial concentration of phosphorus) and external environmental factors (Fig. 1, 2).

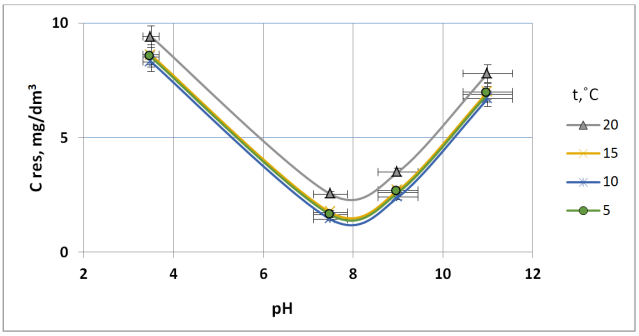

Figure 1 – Influence of the pH parameter on the process of phosphate removal at different water temperatures t,°C, and β-factor=2,17

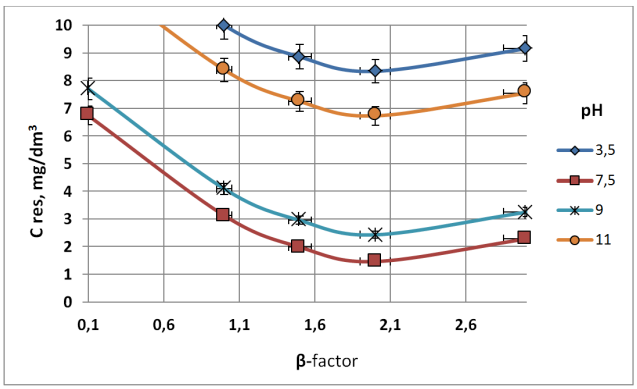

Figure 2 – Influence of β-factor on the process of phosphate removal at different pH and water temperature t=9,5°C

With the help of the obtained equation, it is possible to predict the efficiency of dephosphotation in a certain mode of conducting the wastewater treatment process. The reproducibility of the experiments was checked using the Cochran test (Gcalc=0,298; Gtabl=0,616). The significance of the regression coefficients was determined taking into account the value of Student's criterion (t=2,57 for the confidence probability P=0,95 and 5 degrees of freedom). The adequacy of the dependencies was confirmed by Fisher's test at a 5% significance level (Fcalc=3,54, Ftabl=5,05).

Table 2 shows the results of the effect of the dose of the injected reagent on the residual concentration of phosphates at different pH values at a wastewater temperature of 10°C.

Table 2 – Effect of pH and dose of the injected reagent on the effect of phosphate removal at a temperature of 10 °C

The hydrogen index pH	Residual phosphate concentration (*Cres*) and removal effect (*Эres*) at β-factor					
	1		1,5		2,0	
	Cres , mg/dm^3	*Эres* , %	*Cres* , mg/dm^3	*Эres* , %	*Cres* , mg/dm^3	*Эres* , %
6,5	3,20	68	2,11	78,9	1,22	87,8
7,5	3,12	68,8	1,98	80,2	1,46	85,4
8,5	3,00	70	2,00	80	1,55	84,5

An analysis of the equation for determining *Cres* depending on pH, β, t made it possible to establish that the minimum residual concentration of phosphates in the process of chemical wastewater treatment is achieved at certain values of the studied factors: pH=7,5; β=2,17; t=9,5 °C; the β-factor and pH of the medium have the greatest influence on the cleaning effect.

Conclusion

1. Removal of nutrients is an urgent task in the field of water resources protection; Analytical and experimental studies of the process of chemical dephosphotation of wastewater using reagents of aluminum polyoxychloride and ferrous sulfate were carried out.
2. Based on the results of a three-factor experiment using the «Aqua-Aurat 30» coagulant, a second-order regression equation was obtained, which is an experimental-statistical model of the process of reagent wastewater treatment from phosphates; all regression coefficients of the equation are significant.
3. At an initial concentration of phosphates of 10 mg/dm^3, the optimal values of the reagent dephosphotation parameters were established, at which the lowest residual concentration of phosphates in the treated water is achieved: pH=7,5; β=2,17; t=9,5 °C.
4. The resulting mathematical model of the process of reagent dephosphotation of wastewater makes it possible to select the optimal dose of coagulant depending on the ratio of the concentration of the reagent for metal to the initial concentration of phosphorus at various pH values and ambient temperatures.

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INCREASING THE EFFICIENCY OF NEURAL NETWORKS IN RECOGNITION PROBLEMS

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Abstract

The article describes the issues of increasing the efficiency of neural networks in terms of their design and coding of input and output signals. The application of multiple signal coding using extrapolation of the input parameters is described on the example of a system of recognition character sequences on images of arbitrary size with a complex background.

An effective combination of multiple positional and configuration-competitive coding for various types of signals makes it possible to achieve performance rates of the building number recognition algorithm of up to 74 images per second in the adaptive learning mode and 218 images per second in the recognition only mode.

The paper also outlines general recommendations for signal coding in artificial intelligence systems based on neural networks.

Keywords: neural networks, convolution neural network, neuroevolutionary learning, image recognition, character recognition, neural network learning, deep learning, reinforcement learning, extrapolation learning, positional coding, configuration coding, single coding, multiple coding, input coding, output coding.

ПОВЫШЕНИЕ ЭФФЕКТИВНОСТИ НЕЙРОННЫХ СЕТЕЙ В ЗАДАЧАХ РАСПОЗНАВАНИЯ

Я. А. Бурый

Аннотация

В статье рассмотрены вопросы повышения эффективности нейронных сетей с точки зрения их проектирования и кодирования входных и выходных сигналов. Описано применение множественного кодирования сигналов за счёт экстраполяции входного сигнала на примере системы распознавания цепочек символов на изображениях произвольного размера со сложным фоном. Эффективное сочетание множественного позиционного и конфигурационно-конкурентного кодирования для различных типов сигналов позволяет добиться показателей скорости работы алгоритма распознавания номеров зданий до 74 изображений в секунду в режиме адаптивного обучения и 218 изображений в секунду в режиме только распознавания.

Также в работе изложены общие рекомендации по кодированию сигналов в системах искусственного интеллекта, основанных на нейронных сетях.

Ключевые слова: нейронные сети, нейронная сеть свёртки, нейроэволюционное обучение, распознавание изображений, распознавание символов, обучение нейронных сетей, глубокое обучение, обучение с подкреплением, экстраполирующее обучение, позиционное кодирование, конфигурационное кодирование, одиночное кодирование, множественное кодирование, кодирование входных сигналов, кодирование выходных сигналов.

Introduction

The choice of a specific architecture of a neural network and the structure of its interface is an important part of the development of a computer vision system, since the accuracy and speed of the system depends on this choice.

Multilayer neural networks trained with gradient descent are capable to build complex multidimensional regions based on a large number of training parameters. Therefore, they can be used as classifiers in pattern recognition [1].

The highest invariance to distortions of the input signal has been achieved in neural networks of the convolutional type, such as the cognitron [2], neocognitron [3], and the convolution neural network. Convolutional neural networks evolved from a simpler type of neural networks called perceptrons. These are direct signal propagation networks with one hidden layer and a threshold transfer function [4] [5].

Convolutional neural networks have special convolutional layers. The neurons in these layers calculate the weighted sum (convolution) of the signals of their local receptive fields. The *receptive field* of a neuron is a region of the output signal of the previous layer with given sizes and with a center that, as a rule, geometrically corresponds to this neuron in the previous layer.

The *convolution neural network* also has additional pooling layers that perform local averaging of the signal, which greatly simplifies its architecture.

The architecture of convolutional neural networks mimics the work of the visual cortex as closely as possible. In view of this, they are widely studied from the point of view of building computer vision systems. They are successfully used in agriculture for segmenting aerial photographs of agricultural fields [6], for segmenting satellite images [7], in medicine for segmenting images of examined tissues [8], for recognizing emotions from images, for removing noise from images, and for solving many other problems.

However, the scope of application of convolutional neural networks is not limited to image processing tasks. This architecture is also widely used in other areas, such as speech recognition [9] and computer attack detection [10].

Neural networks are characterized by a large consumption of computing resources, especially in cases where high accuracy is required. This problem also exists for other algorithms from the field of artificial intelligence.

Therefore, it is necessary to take into account the limitations on the cost of computing resources, despite the widespread use and progress made in the field of neural networks. This is due to the fact that the maximum decision-making accuracy achieved and the amount of computing resources required for this are related to each other. This problem is especially relevant in embedded and real-time systems.

The purpose of the present research is to reduce the computing resources consumption of recognition systems and improve their performance while maintaining the given accuracy of decision making.

Maximizing of accuracy

Various improvements and sophistications of the system can be applied to improve recognition accuracy. These can be adding new layers and signal paths, applying teams of decision rules, as well as involving additional calculations for errors of the first and second kind with a corresponding slowdown in comparison with the primary version of the algorithm.

The idea of methods based on teams of decision rules is to combine the advantages of various algorithms in a single recognition system using multilevel analysis. First, it is necessary to apply separate algorithms to the recognizable image to obtain intermediate results, which are then used to do the final conclusion about the image belonging to a particular class.

In addition, different algorithms may behave differently depending on the external conditions in which the neural network operates. Different algorithms can be applied depending on these initial conditions, or areas of expertise. So, the entire original feature space is divided into areas of competence depending on the values of certain features defined in the image.

The maximum accuracy of recognition on a given neural network architecture is achieved with positional coding of variables contained in the output signal [11]. Fig. 1 shows an example of the positional and a configuration coding scheme for the number 3, respectively, for the output and input signals of a neural network.

It has also been observed that increasing the complexity of a neural network can have a significant effect on the overall recognition accuracy achievable.

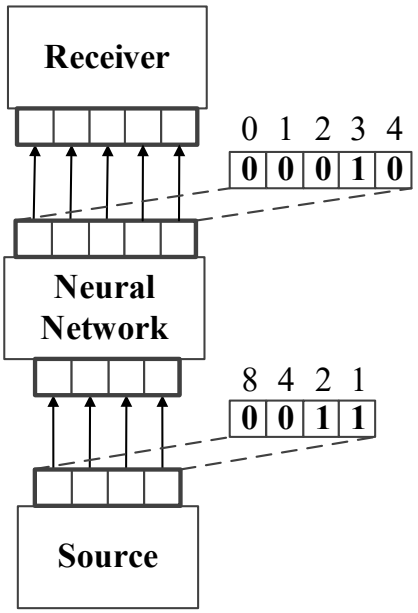

Figure 1 – An example of positional (top) and configuration (bottom) coding of input and output signals of a neural network

Table 1 – Description of the parameters of the convolution neural network 1

Layer number	Layer type	Feature map size	Number of feature maps	Receptive field size	Total number of neurons	Total number of connections
0	Input	28 x 28	1	0	784	0
1	Convolution, TanH	24 x 24	6	5 x 5 x 1	3 456	86 400
2	Pooling	12 x 12	6	2 x 2	864	3 456
3	Convolution, TanH	8 x 8	16	5 x 5 x 6	1 024	153 600
4	Pooling	4 x 4	16	2 x 2	256	1 024
5	Fully connected, output	1 x 1	10	4 x 4 x 16	10	2 560
Total:					6 394	247 040

Table 2 – Description of the parameters of the convolution neural network 2

Layer number	Layer type	Feature map size	Number of feature maps	Receptive field size	Total number of neurons	Total number of connections
0	Input	28 x 28	1	0	784	0
1	Convolution, ReLU	24 x 24	20	5 x 5 x 1	11 520	288 000
2	Pooling	12 x 12	20	2 x 2	2 880	11 520
3	Convolution, ReLU	8 x 8	50	5 x 5 x 20	3 200	1 600 000
4	Pooling	4 x 4	50	2 x 2	800	3 200
5	Fully connected, ReLU	1 x 1	500	4 x 4 x 50	500	400 000
6	Fully connected, output	1 x 1	10	500	10	5 000
Total:					19 694	2 307 720

Optimization experiments were carried out on a character recognition system based on a convolution neural network. The handwritten character base MNIST [12] and the building number base SVHN [13] were chosen as training sets. When the convolution neural network 1 [11] (Table 1) was changed to the convolution neural network 2 (Table 2), the maximum achievable accuracy of the recognition system based on it was increased from 0.9821 on the training and 0.9713 on the test set to 0.9996 on the training and 0.9933 on the test set for the MNIST handwritten character base. The maximum achievable accuracy of the recognition system for the digits of the SVHN building number base was similarly increased from 0.9131 on the training and 0.8902 on the test set to 0.9549 on the training and 0.9184 on the test set.

So, the number of convolution neural network connections increased from 247 040 to 2 307 720, i.e., by a factor of 9.34, while the number of incorrectly recognized characters in the MNIST base fell from 2.87% to 0.67%, i.e., by a factor of 4.28. Similarly, the number of incorrectly recognized characters in the SVHN base dropped from 10.98% to 08.69%, i.e. by 1.26 times.

Minimization of computing resources

Some types of tasks may require low consumption of computing power. For example, this may be important in embedded and real-time systems. These systems must respond in a timely manner to events occurring in the external environment. The main design goal in this case will be to increase the efficiency of the developed algorithms. However, this efficiency depends inversely on the complexity of the system and, accordingly, on the number of its connections.

A slight drop in the accuracy of the subsystems for determining the location, size and other numerical parameters of recognizable images has little effect on the final recognition accuracy. This is due to some invariance of convolutional neural networks to input signal deformations. In addition, the using of positional coding to represent numerical parameters will greatly influence the increase in the complexity of the neural network. This allows to recommend configuration coding of input and output signals in such cases.

There is configuration-competitive coding shows a higher accuracy by 3.41%, compared with configuration-threshold coding, on the same architecture of the convolution neural network [11].

Configuration coding makes it possible to reduce the complexity of the developed systems by reducing the number of their binary inputs and outputs. However, when configuration coding was applied directly to codes of recognizable classes, the decrease in the accuracy of the recognition system in [11] was 4.11%. Therefore, if high recognition accuracy is required, it is recommended to use positional coding to encode object types whenever possible. Configuration coding can be allowed here only in a limited range of tasks. It can, for example, significantly increase the efficiency of algorithms when the number of recognized types is very large.

Additional intermediate transcoding of signals from one representation to another may be appropriate in some cases.

Single and multiple coding of input and output signals of a neural network can be determined depending on the number of sources and receivers of its signals. A common practice is to build separate subsystems for different sources and receivers. Each subsystem can determine one certain characteristic of the image in case of recognition of multiple objects on it. These can be the number of characters in the image, their coordinates, sizes, and other parameters.

Schematic examples of such separate subsystems for recognition of various features are shown in Fig. 2 (a, b and c). They show a single output coding for all subsystems. Information from the outputs of each subsystem is intended for a separate receiver. The difference between them is as follows: Fig. 2a also shows single coding everywhere for the inputs of all subsystems, i.e., all subsystems receive data from different sources; neural networks 2 and 3 in Fig. 2b receive data simultaneously from two sources, i.e. multiple coding is used for their inputs; and Fig. 1c shows the limiting case of multiple coding of inputs of subsystems, when all of them receive signals from all sources at once. The maximum accuracy of decision-making can be achieved, presumably, precisely with such coding, since all neural network subsystems have maximum awareness, i.e., they receive data from all sources of the system. However, all subsystems also spend computing resources on receiving, storing and processing the same information, which is redundant and increases resource consumption.

There is it may be appropriate to generalize and move to the architecture shown in Fig. 2d. It presents the application of multiple coding of all inputs and outputs of a single neural network in the system.

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All information transmitted to the system from the sources, in this case, will be located in only one place. Resource costs will not be duplicated. The signals for all receivers will contain the result of signal processing from all sources at the same time.

The described neural network, which has a minimal internal structure, will contain a subsystem containing knowledge common to all receivers, and subsystems for processing and storing knowledge specific to each signal receivers.

In [14], to create this architecture, extrapolating training of neural networks was used in [15]. The diagram of the resulting system is shown in Fig. 3.

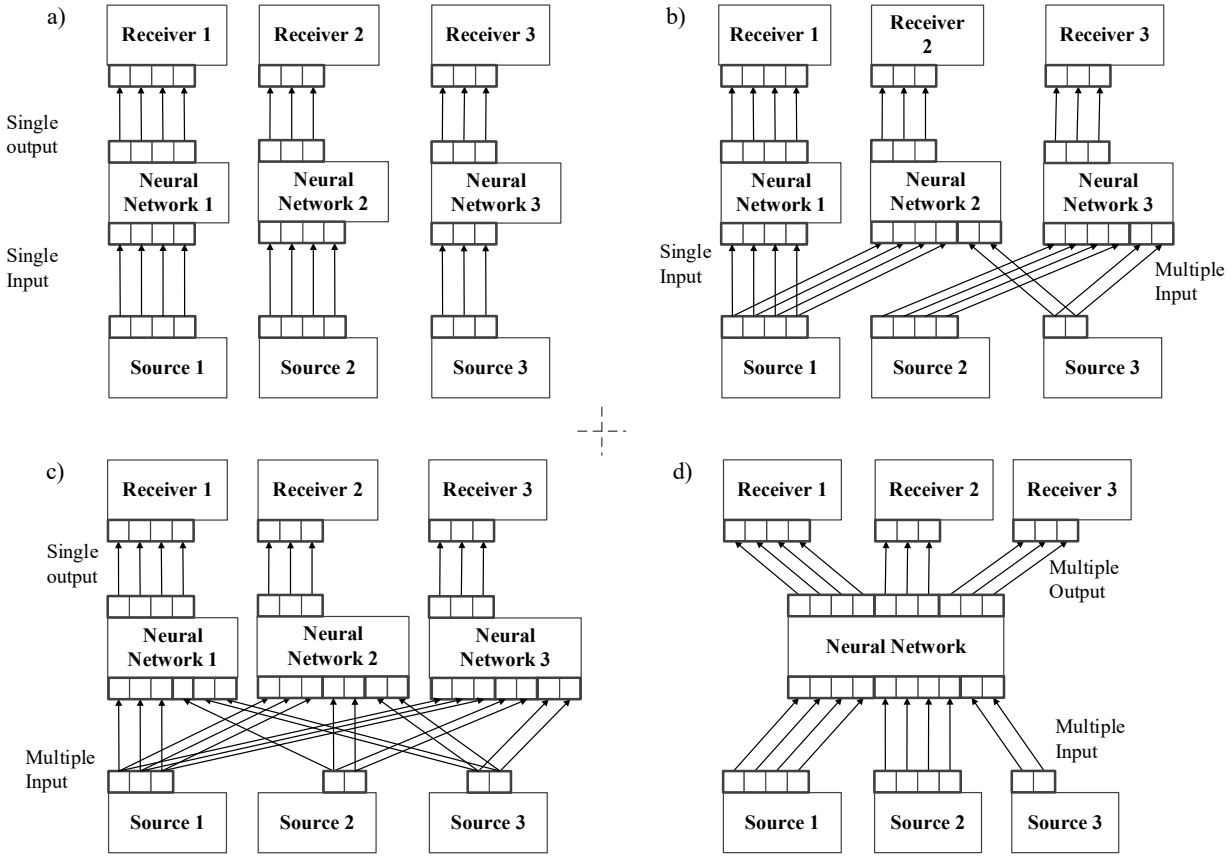

Figure 2 – Single and multiple coding of inputs and outputs of neural network subsystems

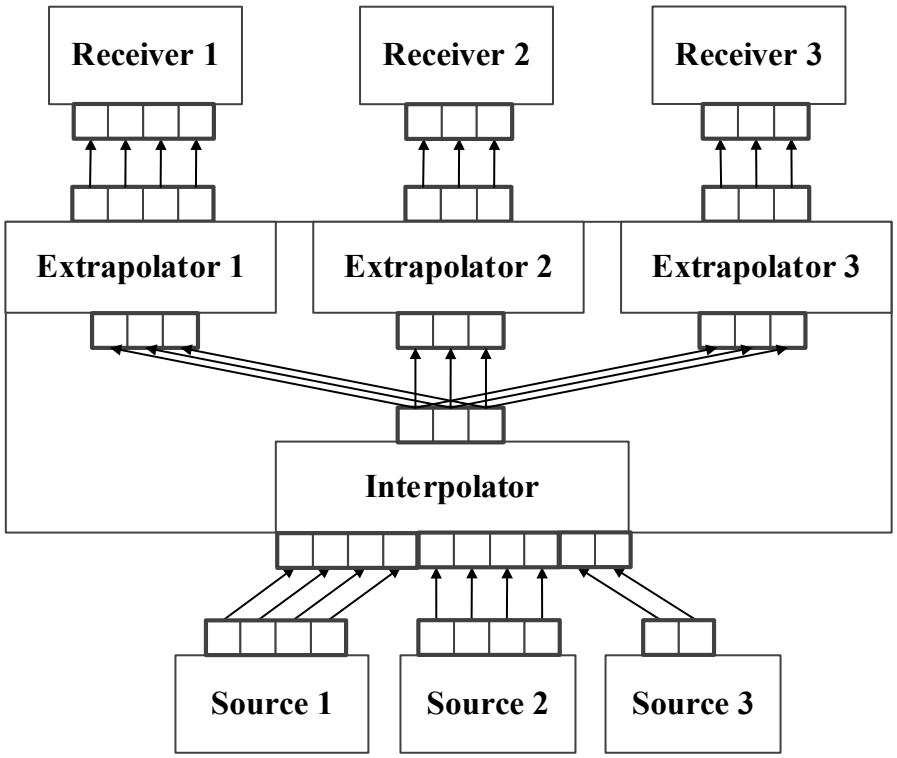

Figure 3 – The internal structure of a neural network with multiple coding of input and output signals

Different learning approaches can be applied to different types of subsystems. So, the interpolator is trained by the method of error back propagation, but extrapolators is trained with using evolutionary methods in [14]. The solution to the problem of determining image characteristics and recognizable characters using multiple coding of inputs and outputs is integrated here into a single recognition system trained using neuro-evolutionary reinforcement learning.

The following speed parameters were obtained with comparable accuracy indicators: the average training iteration duration is 1.7 sec., the population size is 2000 chromosomes, the average processing speed of chromosomes is 1176 per sec., the average processing speed of images with text sequences is 74 per sec. during the evolutionary process and 218 per sec. for an accelerated version of the algorithm. These results were obtained on a workstation CPU Intel Core i7 2.4 GHz, RAM 12 GB, GPU NVIDIA GeForce GT 650M.

Combining several recognition subsystems into one neural network may be associated with some loss of accuracy, as it is described in [15]. However, this effect can be reduced by adding additional neurons to the network. The accuracy achieved when training the basic recognition system was even exceeded by using an additional layer of neurons in the mentioned experiment.

Conclusion

Various optimizations of the neural network underlying the recognition system were tested to increase its accuracy and performance in the present research. Different architectures show different results on the same number of neurons, but despite this, in general, an increase in complexity has a positive effect on the achievable recognition accuracy. Also, the better informative and accuracy of the representation of the parameters encoded in the input signal of the neural network increase the quality of its work. But if its complexity, the number of sources, or the accuracy of data representation are decreased, then the final recognition accuracy also is decreased. Some optimization options show greater efficiency in terms of the ratio of computational cost gained to the loss of recognition accuracy, similar to the considered scheme for applying input signal extrapolation. But some options do not give a gain in efficiency at all. Anyway it is required to find a balance between the performance and work accuracy of the developed systems when implementing algorithms in the general case.

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URBAN PLANNING POST-PANDEMICS: VISION AND DIRECTION

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Abstract

The principles of the urban formation have always been built on socialization, the construction of public spaces and the systematization of the huge human masses' interaction. Of course, in the formation of urban space there are objects that allowing you to feel solitude, but still the city has always been a place of interaction. But the COVID-19 pandemic has changed modern views of the urban environment.

The article discusses the relevance of urban development in a pandemic situation. Examples of city development after pandemics in human history are given. It is considered how the COVID-19 coronavirus has changed the understanding of the organization of urban space and human housing. Possible options for changing the conditions of the urban area are analyzed. This research tries to review developed factors of the urban area under the influence of epidemics and their consequences, among which there may be changes in the organization of public spaces on a scale from specific urban are to global solution.

Keywords: pandemics, urban design, COVID-19, micro markets, vertical forest, distance park.

ГРАДОСТРОИТЕЛЬСТВО ПОСЛЕ ПАНДЕМИИ: ВИДЕНИЕ И НАПРАВЛЕНИЕ

М. М. Каширипур

Реферат

Принципы градостроительства всегда строились на социализации, построении общественных пространств и систематизации взаимодействия огромных человеческих масс. Конечно, в формировании городского пространства есть объекты, позволяющие ощутить уединение, но все же город всегда был местом взаимодействия. Но пандемия COVID-19 изменила современные взгляды на городскую среду.

В статье рассматривается актуальность развития городов в условиях пандемии. Приведены примеры развития городов после пандемий в истории человечества. Рассмотрено, как коронавирус COVID-19 изменил представления об организации городского пространства и жилья человека. Анализируются возможные варианты изменения условий городской территории. В данном исследовании предпринята попытка рассмотреть сложившиеся факторы городской среды под влиянием эпидемий и их последствий, среди которых могут быть изменения в организации общественных пространств в масштабе от конкретных городских до глобальных решений.

Ключевые слова: пандемии, градостроительство, COVID-19, микрорынки, вертикальный лес, дистанционный парк.

Introduction

The detection and spread of the coronavirus pandemic in all countries of the world since the beginning of 2020 has not only destroyed many lives, but also changed the perception of many images in various fields and sciences, and for one thing led to numerous shortcomings, including a crisis of governance and an economic crisis in cities. The big problem is that all these shortcomings manifested themselves sharply in settlements and cities, where architects and urban planners faced great challenges.

The coronavirus pandemic, which has affected almost all spheres of life of modern mankind, has become an occasion to rethink the strategy and tactics of social development. Urban problems are one of the topical directions of subsequent changes. These include challenges addressed to experts, administrative and management structures, and the citizens themselves.

Main part

Historical background: There are enough examples in the history of mankind of how epidemics and pandemics can change our habits and the environment that surrounds us. Street widening, zoning, the creation of parks and gardens, sewer systems, water supplies and public spaces are the most common answers to questions posed to urbanists and urban planners.

The plague epidemic in 1771 in Moscow showed the importance and necessity of competent development of urban space. The high population density and outdated sewerage system caused an outbreak of cholera in 1854 in London, which claimed the lives of more than 10 thousand inhabitants. In France in 1834, the poorest segments of the population suffered the most from cholera due to unsanitary conditions and a dense population. At the same time, parks were laid out in the cities of Europe and America - not only as an important element of a comfortable urban environment, but also as a way to make the air cleaner.

Over the past 20 years, there have been six major epidemics in the world: outbreaks of pneumonia, ebola, bird and swine flu. The COVID-19 coronavirus has spread rapidly around the world. Humanity has entered the era of pandemics, therefore, the living environment and the world around us must change to meet new needs. The coronavirus that causes a new type of pneumonia is spread around the world, covered 114 countries until March 2020 and was characterized by WHO as a COVID-19 pandemic. As of October 2022, over 627 million cases of the disease have been registered worldwide; over 6.5 million people have died and over 607 million have recovered. The COVID-19 pandemic has become a truly global problem, changing people's lives, causing social and economic upheaval. Numerous sports, religious, political and cultural events have been postponed or cancelled. Educational institutions were closed in 172 countries, affecting approximately 98.5% of the world's school and student population. The borders of many states were closed and emergency security measures were introduced. It is probable that all subsequent decades of our century will be a period of adaptation of cities to these conditions. Statistics on the spread of coronavirus showed that the largest number of diseases occurs in megacities.

Urbanization and pandemic situation: Active urbanization and the growth of cities lead to mass congestion of people in enclosed spaces. Vertical construction has become one of the main trends in the development of world architecture. Some specific technologies are being developed for vertical construction like as: vertical gardening, technologies for super-high-speed elevators, and design features of skyscrapers. And now the pandemic will become an occasion for arguing the negative aspects in the adoption of such concepts. How vulnerable are the inhabitants of mega- and gigapolises, where crowding leads to an increase in the number of infections now, we know firsthand (not by hearsay). Today, isolation is one of the main ways to fight the spread of infection. People living in small towns and in private country houses are in a winning situation. Does this mean that in the future we will see a significant outflow of population and increasing demand for private construction?

It is impossible to accurately predict whether the decentralization of cities will actively occur. However, urbanists undoubtedly face the task of finding fundamentally new architectural solutions for residential buildings and complexes in which people can easily communicate and lead their usual way of life. Even high-density structures can be created comfortable, with a well-balanced balance of private and public life and with all the services necessary for life [1].

Urban and architectural solutions: Currently, architects and designers are actively discussing and working on projects that update the main anti-epidemiological principles in urban planning and not only, but the main aspect will be the need for social distance, which leads to the creation of urban space. The modern epidemic is already beginning to affect the infrastructure of cities and other elements of the life of citizens. Sidewalk and commercial interior markings are already ubiquitous and changing the emotional environment of cities. In many countries, a disinfection system is being introduced at the entrances and exits of public buildings; elevators are being installed in which the buttons are replaced by pedals; and systems for issuing goods without contact with visitors have been developed. All these seemingly minor changes can change both the appearance of the city and the vector of development of the urban environment in the coming decades. Changes in urban spaces are already underway around the world: the expansion of sidewalks, an increase in the number of bike lanes, the exclusion of auto traffic from the central areas of cities, i.e. literally turning the city into a pedestrian or bike zone. We could number three main factor of urban structure which effected, transformed and redesigned during pandemics: streets, open and green spaces.

Based on the experience of 2020, it can be said that the pandemic is hitting hardest in large, densely populated cities and metropolitan areas, where maintaining social distance is becoming a serious task for citizens and representatives of management structures. It seems we need to change the functional, organization and spatial structure of cities. This puts urbanists in a new framework for urban planning and the organization of public spaces. Therefore, engineers, architects and urban planners must look for new solutions using modern practices.

Living conditions that involve walking and shopping close to home prove the need to develop pedestrian spaces and change the structure of service, focusing on 15-minute availability. It is believed that residential buildings with public service elements will again be in demand, when it will be possible to live comfortably for a long time without leaving from your home [2].

Of course, one of the most heated discussions is that the house is acquiring a new function - a workplace, or an office. During the pandemic, people were forced to switch to a remote work system. An interesting fact is that many employers saw a significant benefit in this solution and made certain conclusions. Already, many of them are expressing the opinion that after the lifting of quarantine, they will not return to the previous system of work. Thus, more attention will be paid to the layout, planning and equipment of the workplace in the house. This will require a change in spatial organization.

Office blocks and business centers will be transformed from places where people work, to become places - where they hold meetings and conferences. After the COVID-19 epidemic, residents will largely perceive the city and its spaces as a place for work combined with leisure. The boundary will be erased not only between the office and work in a remote format, but also between the home desktop and a park bench. It is significant that in many countries of the world, the issue of switching to a 4-day work week is being discussed.

It is assumed that *public places* will be actively developed on the outskirts of cities in order to relieve the center. The spaces of the former factory buildings, industrial clusters are being transformed into creative workshops, centers of contemporary art, educational centers, which corresponds to the concept of a post-pandemic city [3].

Significant changes may also affect public spaces. During the pandemic, online services of completely different categories of services received a huge boost for development. The question immediately arises - whether there will be a need for shopping centers and whether their reduction will occur. It is rather difficult to unambiguously predict the fate of shopping centers and some other public spaces. But here we can definitely note that the architect faces a new task - providing minimal contact of the user with the architecture for moving in space. This can be achieved through maximum automation. Some technologies will come to the aid of architects: automatic opening and closing doors, voice control in the elevator, fully automated check-in, etc.

Thanks to information technology, it became possible to create virtual spaces of social interaction. According to experts, the coronavirus pandemic has accelerated the development of wireless data transmission technologies, and also ensured their transition to a more advanced level - 5G and Wi-Fi 6. Statistics show that investment in improving these standards is growing rapidly compared to the previous year.

The revision of urban policy in the context of pandemics also means the dispersal of the service system, the modernization of important services and a network of small enterprises for the delivery of food products within walking distance.

Realization and design samples in urban area: Among the main trends in changing the urban area we could nominate the request for greening of living space and the use of roofs, balconies and walls. This technology is a concrete example of a new approach to the formation of a “green structure” of the city. Probably, our traditional ideas about the park in the post-pandemic time will change. A fundamental factor in the development of park space will be the achievement of a balance between buildings development and green space. The creation of the design of the park and its functions as a public space must be carried out in compliance with the rules of social distancing.

Shift architecture urbanism argues for micro markets that operate on a hyper local scale during pandemic shutdowns. They keep the food market traders and the whole supply chain behind them in business in order to provide fresh food in a safe way to the self-quarantined inhabitants of the city. Their hyper local character limits the amount of travelling through the city and their products on offer release the pressure on the supermarkets that have a hard time reducing the contamination risk (Pic. 1, a).

During the pandemic, the “Distance Park” which presented in Vienna Austria, allowed citizens to take walks along the landscape object while observing the distance. The layout of the space is reminiscent of a labyrinth, the pattern of which is similar to a fingerprint. Such scheme of the park allows you to organize routes about 600 m long, reaching the center, making a loop there and returning back. The walk averages about half an hour. At the beginning and at the end of the tracks, special modern devices are installed that allow you to control the number of visitors. Pedestrian areas are separated by a green fence of different heights. Thus, when visiting the park, people stay at a safe distance from each other (Pic. 1, b).

A Milan project called “Vertical Forest” is designed to purify oxygen in the city. This building is a unique architectural object and enlivens the face of the city. A distinctive feature of the project is a huge number of plants located on the roof, balconies and even indoors. The architectural bureau Stefano Boeri set a new trend in vertical gardening, thanks to which residential buildings with plants on different tiers and level began to appear around the world (Pic. 1, c).

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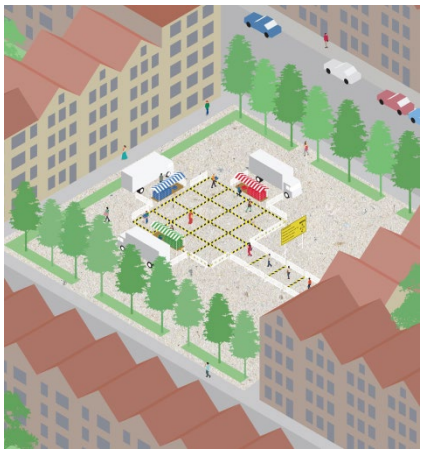
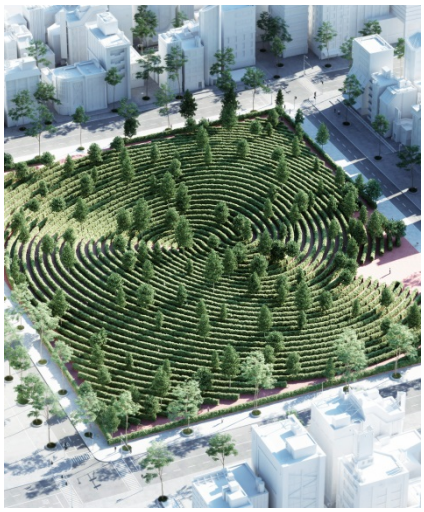


a. Project Micro market – Rotterdam, Netherland



b. Project Distance Park – Vienna, Austria

c. Project vertical forest – Milan, Italy

Picture 1 – Some design samples after pandemic COVID-19

Conclusions

The unexpectedness with which the pandemic entered our cities did not allow specialists to make any forecasts. The only thing that most of them agreed with is that the virus will go away, and cities, despite the fear of them, will remain, because in the history of civilization they have shown their importance as spaces of social interaction, centers of economic and political life.

Among architects, urban planners, engineers and designers, there have long been discussions about green and sustainable city, architecture and building. But the last pandemic experience shows us such a concept has still remained in its infancy and is used pointwise. Review different literature about cities suggests that the first step is to rethink the densification of cities. Either their decentralization will take place, or new innovative solutions will be taken to ensure security even in multifunctional complexes, and their automation. Architecture should shape the quality of our environment and promote health and well-being.

Regarding a good experience during COVID-19, some criteria of urban design should be revised more than before. These criteria consist of: new design concept for urban planning; urban environment quality; comfort and safety for residence (populations); infrastructure, transport and media development; policy and management.

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COMPARATIVE ANALYSIS OF THE CALCULATION OF THE STRESS INTENSITY FACTOR FROM THE RESULTS OF EQUILIBRIUM AND NON-EQUILIBRIUM TESTS

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Abstract

This article explores the practical use of methods for determining the stress intensity factor at normal separation: eccentric compression of notched cubes and four-point bending of a notched beam. During non-equilibrium tests, the stress intensity factor value was calculated from the value of the breaking load. During equilibrium tests, the stress intensity factor value was determined from the complete equilibrium deformation diagram, taking into account the energy indicators of destruction. The test used nanofiber-reinforced concrete, in which carbon nanotubes are used as crack propagation inhibitors at the level of the cementing agent, and various macro-sized fibers are used at the level of fine-grained concrete. As a result of the tests, it was found that the methods for determining the recovery factor from cubes with a notch and from deformation diagrams showed a good degree of convergence. Fiber reinforcement affects the fracture toughness of a nanocement composite, and high-modulus fiber has a greater effect on fracture toughness than low-modulus fiber. The stress intensity factor is a good indicator for comparing different types of fiber reinforcement in terms of their effect on fracture toughness.

Keywords: nanofibre-reinforced concrete, crack resistance, fracture toughness, stress intensity factor, nanotubes, dispersed reinforcement, deformation diagram, energy consumption.

СРАВНИТЕЛЬНЫЙ АНАЛИЗ РАСЧЕТА КОЭФФИЦИЕНТА ИНТЕНСИВНОСТИ НАПРЯЖЕНИЙ ПО РЕЗУЛЬТАТАМ РАВНОВЕСНЫХ И НЕРАВНОВЕСНЫХ ИСПЫТАНИЙ

Е. А. Садовская, С. Н. Леонович

Реферат

В данной статье исследовано практическое использование методов определения коэффициента интенсивности напряжений (КИН) при нормальном отрыве: внецентренное сжатие кубов с надрезами и четырехточечный изгиб балки с надрезом. При неравновесных испытаниях значение КИН рассчитывалось по величине разрушающей нагрузки. При равновесных испытаниях величина КИН определялась из полной равновесной диаграммы деформирования с учетом энергетических показателей разрушения. В испытании использовался нанофибробетон, в котором на уровне цементирующего вещества в качестве ингибиторов распространения трещин используются углеродные нанотрубки, а на уровне мелкозернистого бетона – различные фибровые волокна макроразмера. В результате испытаний установлено, что методы определения КИН по кубам с надрезом и по диаграммам деформирования показали хорошую степень сходимости. Фибровое армирование оказывает влияние на вязкость разрушения наноцементного композита, причем высокомодульная фибра оказывает большее влияние по показатель вязкости разрушения, чем низкомодульная. Коэффициент интенсивности напряжений является хорошим показателем для сравнения разных типов фибрового армирования по их влиянию на вязкость разрушения.

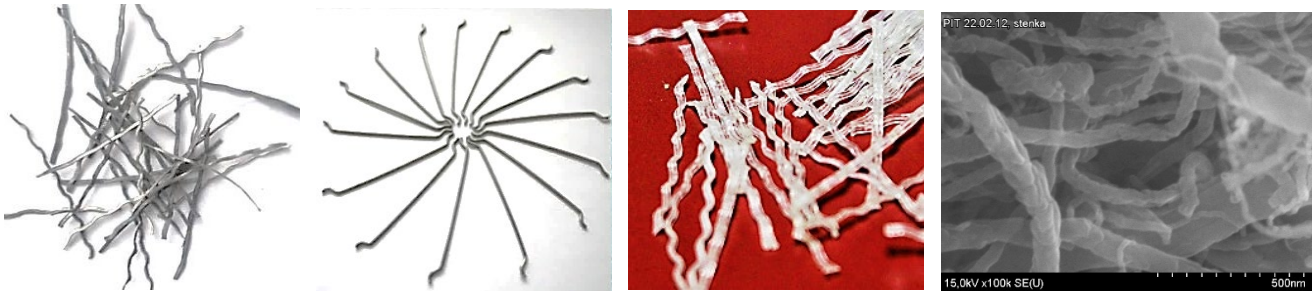
Ключевые слова: нанофибробетон, трещиностойкость, вязкость разрушения, коэффициент интенсивности напряжений, нанотрубки, дисперсное армирование, диаграмма деформирования, энергозатраты.

Introduction

Nanofibre-reinforced concrete, from the point of view of a multilevel system [1], is a concrete composite with crack propagation inhibitors at the level of cementing agent and fine-grained concrete. As inhibitors, carbon nanotubes [2–4] and various macrosized fiber fibers (Fig. 1) [5, 6] are considered.

One of the distinguishing features of dispersed reinforced concrete is an increased crack resistance index [7]. Crack resistance (fracture toughness) is characterized by the magnitude of the stress intensity factor (SIF). The existence of many calculation and practical methods for determining the recovery SIF [8-11], as well as the regular appearance of new ones, indicates difficulties in implementation and the presence of inaccuracies in their use.

The aim of the study is to develop a reliable method for calculating the stress intensity factor at normal separation of structural nanofibre-reinforced concrete based on the results of equilibrium and non-equilibrium tests.



1) 2) 3) 4)

1 – from sheet steel of a wave profile (FLV -0.9-50); 2 – made of steel wire with anchors (FPA -1.0); 3 – polymeric wavy (FPV-0.6-40); 4 – carbon nanotubes [6]

Figure 1 – Fiber

Materials and research methods

For the study, the following types of materials were used: Portland cement 500D20 JSC "Krasnoselskstroymaterialy"; construction sand (I class); rubble granite (III gr.); sulfoaluminate additive (RSAM), compacted condensed silica fume (MKU-85); chemical additive Relamix PC; nanomodified chemical additive ART-Konkrit R (aqueous suspension of nanostructured carbon (0.01-20 microns) and plasticizer).

The samples were made from the compositions of nanoconcrete mixtures A, Б, В, Г (table 1) with the addition of various types and amounts of dispersed fibers: Ф1 - wave steel fiber from a sheet (80 kg); Ф2 - steel wire anchor fiber (80 kg); Ф3 - wavy polymer fiber (4 kg).

Table 1 – Formulations of the studied compositions

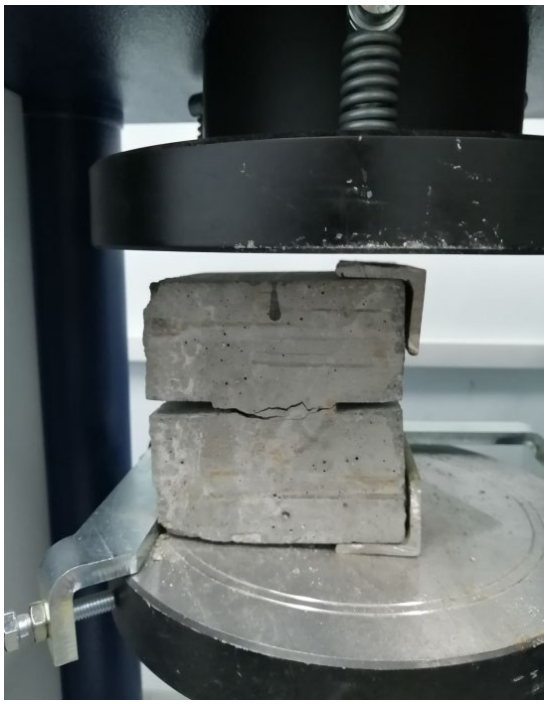
Compositions	Cement	RSAM / MKU-85	Rubble granite 5-20 mm	Rubble granite 5-10 mm	Sand	Nanomodified chemical additive (% by weight of binder)
А	400	-	1020	-	820	3.2 (0.8)
Б	445	-	1035	-	820	2.22 (0.5)
В	460	-	-	880	950	3.22 (0.7)
Г	485	40/45	-	825	800	4.65 (0.7)

Normal separation on cubes with a notch. For tests, cube samples 100x100x100 mm were used with notches in the form of symmetrical notches with a depth of h / 4 (where h is the height of the cube) made using diamond-coated cutting tools. Tests are carried out with eccentric compression (Fig. 2). Loading is carried out until the moment of separation of the sample into two parts or the formation of a crack, and the value of the destruction F_{IC} is recorded.

The value of the critical stress intensity factor for normal separation is calculated by the formula:

$$K_C^* = \frac{F_{Ic}}{b \cdot h^{1/2}} \left[\begin{array}{l} 18{,}3\left(\frac{a}{h}\right)^{1/2} - 430\left(\frac{a}{h}\right)^{3/2} + 3445\left(\frac{a}{h}\right)^{5/2} - \\ -11076\left(\frac{a}{h}\right)^{7/2} + 12967\left(\frac{a}{h}\right)^{9/2} \end{array} \right], \quad (1)$$

where F_{IC} is the load at which failure occurs, in MN;
b is the sample width, m;
h is the sample height, m;
a is the notch depth, m, $a = h/4$.



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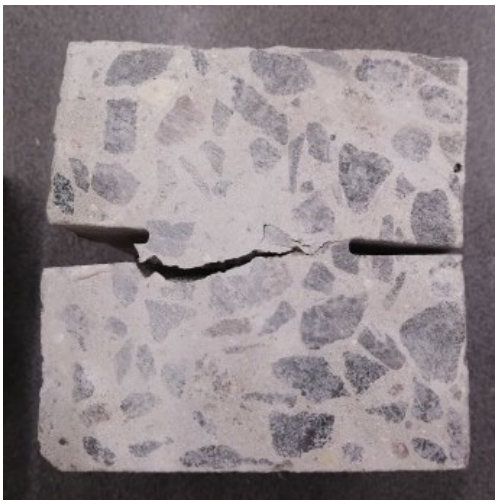

4)

1 – appearance of the test, 2 – halves of the sample after testing, 3 – tested concrete sample, 4 – tested nanofibre-reinforced concrete sample

Figure 2 – Normal pull test on notched cubes

Normal separation when bending beams. Prism specimens 100x100x400 with a notch in the middle third were tested for tensile bending according to a four-point loading scheme with fixation of the complete equilibrium fracture diagram [12] (Fig. 3).

Static critical stress intensity factor [GOST 29167]

$$K_i = \sqrt{G_i E_b} \quad (2)$$

where G_i – the specific energy consumption for static fracture up to the moment when the main crack begins to move J/m²;

E_{fb} – the initial modulus of elasticity of nanofibre-reinforced concrete (GPa), determined by the formula (SP 52-104-2006):

$$E_{fb} = E_b(1 - \mu_{fv}) + \mu_f E_f \quad (4)$$

where E_b – the modulus of elasticity of concrete, the normative one is adopted here;

E_f – the modulus of elasticity of the fiber;

μ_{fv} - fiber reinforcement coefficient by volume.

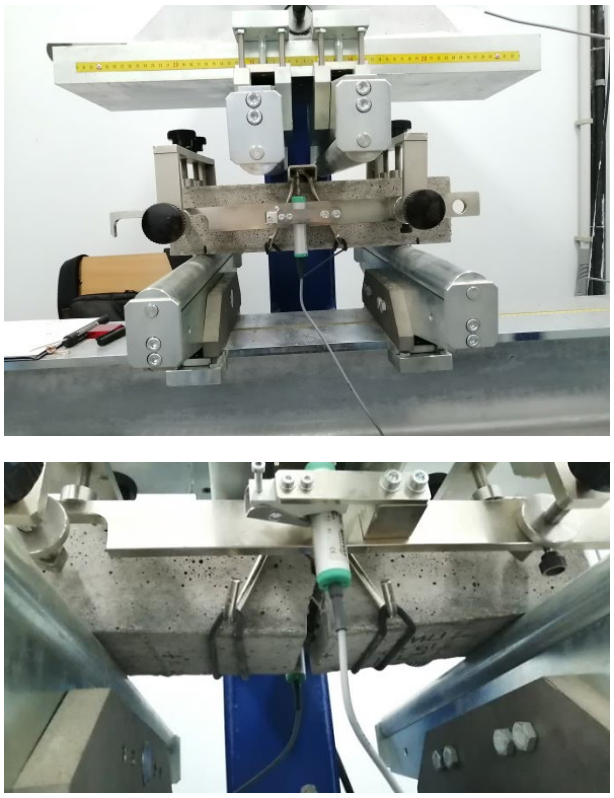

Figure 3 – Tensile testing of beam specimens in bending

In the nanofibre-reinforced concrete material, a pronounced plastic nature of tensile work is observed after the onset of cracking. In this case, the manifestation of the so-called deformation quasi-hardening can be achieved, which is characterized by the fact that after the onset of cracking, the stage of plastic tensile work of the material follows. In this case, the perceived stresses may exceed the stresses that cause cracking.

If there is a zone of quasi-hardening in the diagram after the appearance of the first crack, the deformations do not concentrate in this one crack [12]. The material retains the ability to distribute cracks along the length of the stretched zone of the sample, while the cracks remain very small opening. This is ensured by the fact that the fiber distributed throughout the entire volume, with a sufficient modulus of elasticity of its material, strength and embedding in the matrix, completely perceives the tension from the concrete matrix in the cavity of the nucleated crack, not allowing it to increase sharply. The absence of manifestations of brittleness in tensile work makes it possible to take sufficiently large values of the material's resistance to tension in strength calculations. During design, this makes the balance of design checks of strength and crack resistance similar to that characteristic of reinforced concrete, i.e. with conventional bar reinforcement.

Based on the data obtained, a graph of Deflection-Time and Load-Deflection is constructed. Since the energy for starting the main crack (the sum of the elastic energy and the energy of microcrack formation), being the area under the curve, can increase tenfold depending on the fracture point. The start of the main crack when testing unreinforced concrete, as a rule, coincides with the moment of sample failure. To determine the start time of the main crack when testing nanofibre-reinforced concrete beams, an expert assessment of the researcher is required (Fig. 4).

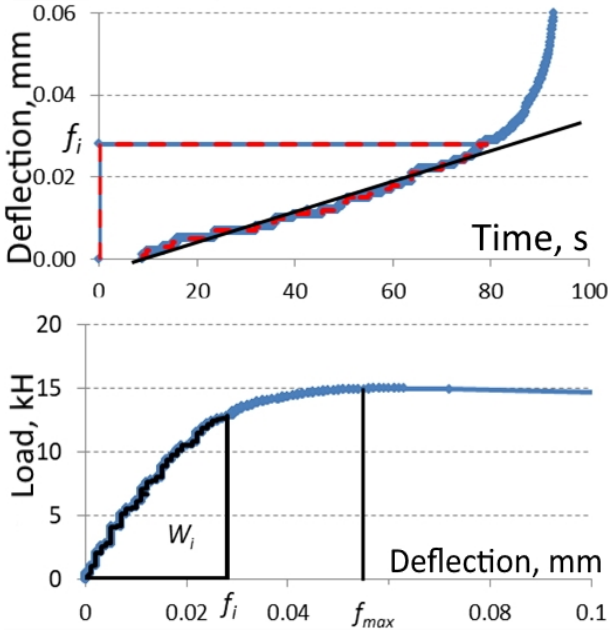

Figure 4 – Graphs of deformation

Analyzing the obtained deformation diagrams, one can obtain some important parameters characterizing the quality of the material under study: tensile strength in bending, deflection at maximum load (z_{max}), specific energy consumption for static fracture until the main crack begins to move (G_i) (Table 2).

The obtained values of the stress intensity factor during testing by the method of normal separation on cubes with a notch (K_c *), when testing for four-point bending of beams with a notch (K_i) and the average indicator (K) are shown in Figure 5.

Table 2 – Parameters of nanofibre-reinforced concrete from equilibrium strain diagrams

Compositions	Max. load, kN F	Reduced strength, MPa $f^* = \frac{F \cdot l}{b(h-a)^2}$	Deflection at max. load, mm f_{max}	Specific energy consumption, J/m² $G_i = W_i/A_c$	Critical stress intensity factor, MPa√m		Relative deviation from the mean
					K_i	K_c*	
А-Ф1	14.404	6.82	0.501	144.34	2.7	3.37	11%
Б-Ф1	14.97	6.91	0.200	26.56	1.0	1.01	0%
В-Ф1	16.011	7.58	0.671	91.75	1.8	2.05	7%
Г-Ф1	18.211	8.01	0.051	39.86	1.4	1.61	6%
А-Ф2	23.627	11.19	0.731	53.76	1.4	2.60	29%
Б-Ф2	16.207	7.67	0.671	82.28	1.8	2.24	11%
В-Ф2	16.313	7.72	0.200	55.12	1.4	1.32	2%
Г-Ф2	25.293	11.98	0.325	68.85	1.6	1.97	10%
А-Ф3	15.613	7.39	0.671	17.19	0.8	0.97	10%
Б-Ф3	15.111	7.15	0.055	37.59	1.17	0.99	8%
В-Ф3	11.121	5.27	0.051	21.04	0.8	0.69	9%
Г-Ф3	15.951	7.55	0.055	33.44	1.3	1.37	1%

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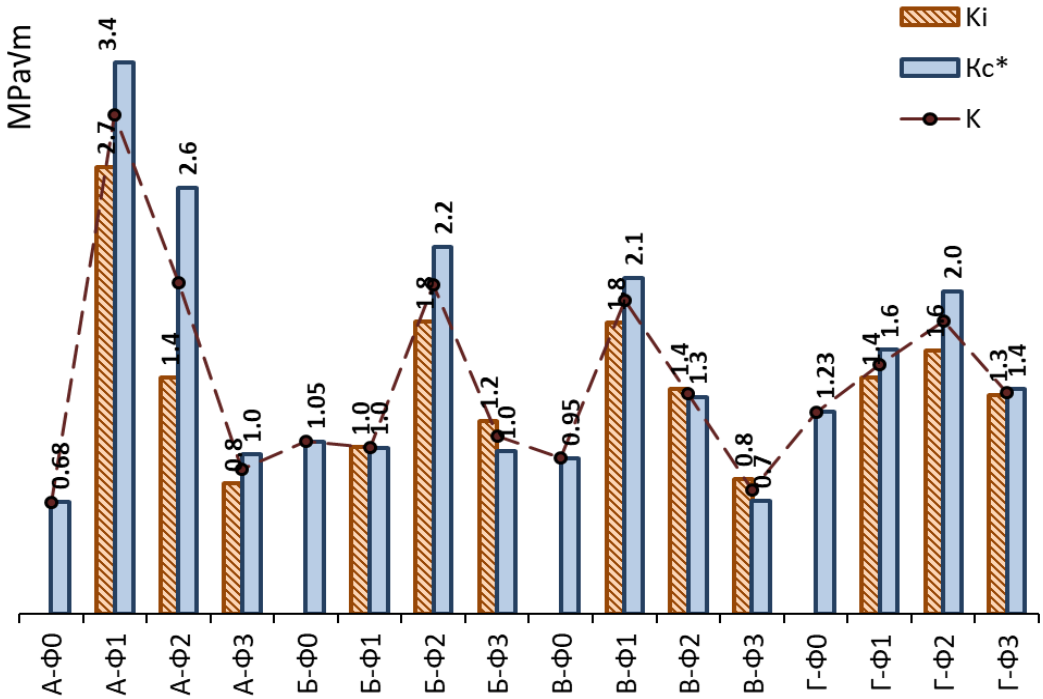

Figure 5 – Stress intensity factor for nanofibre-reinforced concrete

Analysis of results

Good convergence of test results by the test methods used is observed. The trend of change in the fracture toughness index obtained by different test methods has the same character.

In compositions А and Б, the high-modulus steel fiber (Ф1 and Ф2) has a greater effect on the fracture toughness index than the low-modulus one (Ф3).

In compositions Б and Г, steel wire fiber (Ф2) had the greatest effect on the fracture toughness index.

In all compositions, the effect of polymer fiber on the SIF value is the least and in some cases the value is close to unreinforced compositions. Fiber reinforcement with steel sheet fiber (Ф1) gives less stable fracture toughness than with steel wire reinforcement (Ф2).

Conclusions

1. Methods for determining the oil recovery factor from cubes with a notch and from deformation diagrams showed a good degree of convergence.
2. The stress intensity factor is a good indicator for comparing different types of fiber reinforcement in terms of their effect on fracture toughness.
3. High modulus fiber has a greater impact on fracture toughness than low modulus.
4. Fiber reinforcement affects the fracture toughness of the nanocement composite.

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QUANTIFICATION ASSESSMENT OF THE EXISTING REINFORCED CONCRETE STRUCTURES BASED ON FUZZY LOGIC

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Abstract

Fuzzy logic is the useful tool when assessing the existing reinforced concrete structures. The introduction of the method for quantitative assessment of the technical condition of the existing structures built on the fuzzy logic represents a transition to a new and higher-quality level for survey of constructions sites. As a result, it is seen that the assessment of the existing building with usage of the proposed expert system is in compliance with the estimation of the qualified experts.

Keywords: quantification assessment, fuzzy logic, existing structures, technical condition.

КОЛИЧЕСТВЕННАЯ ОЦЕНКА СУЩЕСТВУЮЩИХ ЖЕЛЕЗОБЕТОННЫХ КОНСТРУКЦИЙ НА ОСНОВЕ НЕЧЕТКОЙ ЛОГИКИ

В. В. Тур, Ю. С. Дордюк

Реферат

Нечеткая логика является полезным инструментом при оценке существующих железобетонных конструкций. Внедрение методики количественной оценки технического состояния существующих конструкций, построенной на инструментах нечеткой логики, представляет собой переход на новый и более качественный уровень обследования зданий и сооружений. В результате видно, что оценка существующего здания со сборными железобетонными элементами с использованием предложенной нечеткой системы имеет достаточно хорошее совпадение с результатами профессиональных экспертов.

Ключевые слова: количественная оценка, нечеткая логика, существующие конструкции, техническое состояние.

1 Introduction

Assessment of existing reinforced concrete structures is becoming a most important but complicated engineering task. General principles of sustainable development regularly lead to the need for an extension of a life of a structure, in most practical cases with severe economic constraints.

As it was shown in [1] visual inspection becomes the dominant practice in the management of maintenance, even when the importance of the structural elements are significant. Subjectivity heavily affects the process of assessment of degradation degree based on the results of visual inspection. Most of assessment approaches and methods are similar in principle, but vary in the details.

In order to use the visual inspection as a robust and reliable instrument to evaluate the safety level of an existing structural element, we decided to take advantage of the ability of Fuzzy Logic to treat uncertainty as expressed by linguistic judgements [2, 3].

In order to develop the multilevel expert system for existing structures assessment a Fuzzy Logic-based algorithm is proposed, which used the Fuzzy Logic Toolbox package of MatLab Software [1].

As it pointed in [1], «*a Fuzzy Logic is a versatile tool, particularly suitable for the management of decisional trees involving the processing of data endowed with «vague» nature (both numerical and qualitative one), and is naturally able to provide a linguistic, qualitative assessment of the health conditions of the building*».

In this context, the Fuzzy Logic appears the most qualified tool for the processing of numerical data and uncertain information in order to obtain a linguistic description of structural damage.

2 Rule-based Fuzzy model/Expert system development

The stages of development of the Fuzzy Logic System are presented in details in [4, 5]. For the development of the fuzzy production model for assessing of the existing structures performance it is necessary to formulate set, consisting the basic variables (see Table 1) which are characterized performance of element and set, characterizing (present) damage level (see Table 2).

Table 1 – Input linguistic basic variables

Designation linguistic variables	Description of the linguistic variables	Term-set
Phase A: Visual Inspection (A-1)		
x_1	Crack propagation (bending/shear)	T4 = {no «0»; single «S»; numerous «N»; massive «M»}
x_2	Positions of the cracks (bending/shear)	T4 = {no «0»; in the mid-span «1»; near support «2»; mid-span+ near support «3»}
x_3	The longitudinal corrosion cracks propagation	T4 = {no «0»; local «L»; partial «P»; solid «S»}
x_4	Corrosion damage (deteriorations)	T2 = {no «0»; yes «1»}
x_5	Surface degradation of concrete (deteriorations)	T2 = {no «0»; yes «1»}
x_6	Propagation of the longitudinal corrosion cracks in compression zone of the section	T2 = {no «0»; yes «1»}
Phase A: Basic Testing (A-2)		
x_7	Concrete cover to diameter ratio, $\frac{c}{\varnothing}$	T3 = {small «S»; mean «M»; large «L»}
x_8	Load-induced cracks width, w_k (bending/shear)	T4 = {small «S»; permissible «P»; exceeded «Ex»; excessive «E»}
x_9	Longitudinal corrosion cracks width, w_l	T3 = {small «S»; medium «M»; excessive «E»}
x_{10}	Level of the reinforcement corrosion	T3 = {small «S»; mean «M»; large «L»}
x_{11}	Deflection ratio, $\frac{\delta}{L}$	T4 = {small «S»; permissible «P»; exceeded «Ex»; excessive «E»}
Phase A: Damage Class		
x_{12}	Visual Inspection (A-1)	T3 = {critical «1»; significant «2»; minor «3»}
x_{13}	Basic Testing (A-2)	T3 = {critical «1»; significant «2»; minor «3»}
x_{14}	Documentation	T2 = {no «0»; yes «1»}

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Table 2 – Output linguistic basic variables

Designation linguistic variables	Description of the linguistic variables	Term-set
y_1	Damage level	T3 = {critical «1»; significant «2»; minor «3»}
y_2	Damage level	T3 = {critical «1»; significant «2»; minor «3»}
y_3	Damage class	T3 = {small «1»; moderate «2»; severe «3»}

As it was shown above, in the damage assessment of an existing buildings (structures), several input data are required (crack width and propagation, residual strength of materials, amount and condition of the steel reinforcement, deflection, corrosion level et al.) that will all be treated, according to previous remarks, as fuzzy sets. The common structure deficiencies associated with the deterioration of the structural element are corrosion of steel reinforcement and the cracking, scaling and spalling concrete, deflections. The ranges for basic variables and correlation function were adopted based on the own numerical and experimental studies [4-6].

3 Realization of the Fuzzy production model for assessment of existing structures in MatLab Software

Step 1: Fuzzification – Input Fuzzy. At this stage, we adopted the membership function for term-sets of input and output linguistic variables, as shown in Table 3. The most commonly used membership functions are the trapezoidal and triangular ones. These membership functions will be indeed the functions adopted in the proposed algorithm.

Table 3 – Membership functions mathematical descriptions

Designation of the linguistic variables	Membership function type	Mathematical description (upper index designate the corresponding term)
x_1	Trapezoidal	μ_Δ^0 (x; -1; -1; 0; 0), μ_Δ^S (x; 0.5; 0.5; 5; 15), μ_Δ^N (x; 5; 15; 35; 45), μ_Δ^M (x; 35; 45; 90; 100)
x_2	Triangular	μ_Δ^0 (x; -0.5; 0; 0.5), μ_Δ^1 (x; 0.5; 1; 1.5), μ_Δ^2 (x; 1.5; 2; 2.5), μ_Δ^3 (x; 2.5; 3; 3.5)
x_3	Trapezoidal	μ_Δ^0 (x; -1; -1; 0; 0), μ_Δ^L (x; 0.5; 0.5; 5; 15), μ_Δ^P (x; 5; 15; 35; 45), μ_Δ^D (x; 35; 45; 90; 100)
x_4	Triangular	μ_Δ^0 (x; -0.5; 0; 0.5), μ_Δ^1 (x; 0.5; 1; 1.5)
x_5	Triangular	μ_Δ^0 (x; -0.5; 0; 0.5), μ_Δ^1 (x; 0.5; 1; 1.5)
x_6	Triangular	μ_Δ^0 (x; -0.5; 0; 0.5), μ_Δ^1 (x; 0.5; 1; 1.5)
x_7	Trapezoidal	μ_Δ^M (x; -1; 0; 0.5; 1.5), μ_Δ^C (x; 0.5; 1.5; 2.5; 3.5), μ_Δ^E (x; 2.5; 3.5; 8; 10)
x_8	Trapezoidal	μ_Δ^M (x; -0.1; 0; 0; 0.1), μ_Δ^S (x; 0; 0.1; 0.35; 0.45), μ_Δ^P (x; 0.35; 0.45; 0.95; 1.05), μ_Δ^D (x; 0.95; 1.05; 1.2; 2)
x_9	Trapezoidal	μ_Δ^S (x; -0.1; 0; 0; 0.1), μ_Δ^M (x; 0; 0.1; 0.95; 1.05), μ_Δ^E (x; 0.95; 1.05; 2; 3)
x_{10}	Trapezoidal	μ_Δ^S (x; -1.5; 0; 0.5; 1.5), μ_Δ^M (x; 0.5; 1.5; 2.5; 3.5), μ_Δ^L (x; 2.5; 3.5; 5; 8)
x_{11}	Trapezoidal	μ_Δ^S (x; -0.001; 0; 0,0005; 0.0015), μ_Δ^P (x; 0.0005; 0.0015; 0.0035; 0.0045), μ_Δ^{Ex} (x; 0.0035; 0.0045; 0.0195; 0.0205), μ_Δ^E (x; 0.0195; 0.0205; 0.025; 0.03)
x_{12}	Triangular	μ_Δ^1 (x; 0.5; 1; 1.5), μ_Δ^2 (x; 1.5; 2; 2.5), μ_Δ^3 (x; 2.5; 3; 3.5)
x_{13}	Triangular	μ_Δ^1 (x; 0.5; 1; 1.5), μ_Δ^2 (x; 1.5; 2; 2.5), μ_Δ^3 (x; 2.5; 3; 3.5).
x_{14}	Triangular	μ_Δ^0 (x; -0.5; 0; 0.5), μ_Δ^1 (x; 0.5; 1; 1.5)
y_1	Triangular	μ_Δ^1 (x; 0.5; 1; 1.5), μ_Δ^2 (x; 1.5; 2; 2.5), μ_Δ^3 (x; 2.5; 3; 3.5)
y_2	Triangular	μ_Δ^1 (x; 0.5; 1; 1.5), μ_Δ^2 (x; 1.5; 2; 2.5), μ_Δ^3 (x; 2.5; 3; 3.5)
y_3	Triangular	μ_Δ^1 (x; 0.5; 1; 1.5), μ_Δ^2 (x; 1.5; 2; 2.5), μ_Δ^3 (x; 2.5; 3; 3.5)

Step 2: Setting Fuzzy Rules in accordance with Table 4. The base of the Rules of the Fuzzy production model is defined as a structure with an appropriate member of inputs x_i and one output y_i.

Table 4 – Example of the fuzzy rules of the production model

Rule number	Antecedent	Consequent
Base of the rules R1		
R1.1	$(x_1 = 0 \wedge x_2 = 0 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 1 \wedge x_6 = 0) \vee$ $(x_1 = 0 \wedge x_2 = 0 \wedge x_3 = 0 \wedge x_4 = 1 \wedge x_5 = 1 \wedge x_6 = 0) \vee$ $(x_1 = S \wedge x_2 = 1 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 0 \wedge x_6 = 0) \vee$ $(x_1 = S \wedge x_2 = 2 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 0 \wedge x_6 = 0) \vee$ $(x_1 = S \wedge x_2 = 1 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 1 \wedge x_6 = 0) \vee$ $(x_1 = S \wedge x_2 = 2 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 1 \wedge x_6 = 0) \vee$ $(x_1 = S \wedge x_2 = 3 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 0 \wedge x_6 = 0) \vee$ $(x_1 = S \wedge x_2 = 3 \wedge x_3 = 0 \wedge x_4 = 0 \wedge x_5 = 1 \wedge x_6 = 0)$	$y_1 = 3$
<…>		
R3.3	$(x_{12} = 2 \wedge x_{13} = 1 \wedge x_{14} = 0) \vee$ $(x_{12} = 1 \wedge x_{13} = 2 \wedge x_{14} = 0) \vee$ $(x_{12} = 1 \wedge x_{13} = 1 \wedge x_{14} = 1) \vee$ $(x_{12} = 1 \wedge x_{13} = 1 \wedge x_{14} = 0)$	$y_3 = 3$

Step 3: Aggregation is the process by which the fuzzy set that represent the outputs of each rule are combined into a single fuzzy set. A rule premise in general is a compound fuzzy proposition. Aggregation only occurs once for each output variable, which is before the final defuzzification step. According to the original proposal of Zadeh for aggregation of the confidence level of assumption min-conjuction is used:

$$\alpha_i = \min\left\{\mu_{A_{i1}}(x_1), \mu_{A_{i2}}(x_2), \mu_{A_{i3}}(x_3), \mu_{A_{i4}}(x_4)\right\}, i = 1, 2, ..., n \quad (1)$$

Step 4: Activation. A fuzzy «IF-THEN» rule is a connection of two (compound) fuzzy propositions. Hence, this connective has to be interpreted within the framework of set theoretic or logical operators. The simplest interpretation is that of the conjuction of premise and conclusion, such that the appropriate operation is the minimum:

$$\mu_{B_i'}(y) = \min\left\{\alpha_i, \mu_{B_i}(y)\right\}, i = 1, 2, ..., n \quad (2)$$

Step 5: Accumulation. Usually, a rule base is interpreted as a disjunction of rules, i.e. rules are seen as independent «experts». Accumulation has the task to combine the individual «expert statements», which actually are fuzzy sets of recommended output values. Consequently, an appropriate accumulation operation is the maximum:

$$\mu_{B'}(y) = \max\left\{\mu_{B_1'}(y), \mu_{B_2'}(y), ..., \mu_{B_n'}(y)\right\} \quad (3)$$

Step 6: Defuzzification – from a fuzzy decision to real decision. As inference results in a fuzzy set, the task of defuzzification is to find the numerical value which «best» comprehends the information contained in this fuzzy set. A frequently used method is the so-called Center-of-Gravity defuzzification (CoG, also called Center-of-Area defuzzification CoA):

$$y' = \frac{\int_{Y_{\min}}^{Y_{\max}} y\mu_{B'}(y)dy}{\int_{Y_{\min}}^{Y_{\max}} \mu_{B'}(y)dy} \quad (4)$$

which chooses the y' – coordinate of the center of gravity of the area below the graph $\mu(y)$. This defuzzification can be interpreted as a weighted mean, i.e. each value y weighted with $\mu(y)$ and integral in the denominator serves for normalization.

4 Implementation of the Assessment Algorithm of the Proposed Expert System

According to [1] the whole phase is managed by a nested fuzzy algorithm: starting from the assessment of the single structural elements, and progressively proceeding through the structural hierarchy (element/storey/building), input data are processed and collated in order to obtain the new Phase – assessment of the whole building. It is worth remarking that part of the results provided by the preliminary investigation could be used also at this stage.

The starting point, as it has pointed out in numerious publications [7-10], is the availability of an inventory of data and information derived from the investigation on the analyzed building, the collecting and organization of which is performed by using the survey diagnostic forms, as it shown in [5].

As an example of the implementation of the proposed expert system results of the assessment of the existing building with precast concrete elements is presented.

Structure description. Precast ribbed slabs with size in plane 1.5x6 m, with height of the rib 300 mm. Longitudinal tensile reinforcement is Ø16 B400, concrete cover 32 mm (ratio c/Ø=2).

Results of the Visual Inspection and Basic Testing are presented in Diagnostic Protocol Example (Table 5).

Table 5 – The diagnostic protocol example

Phase A: Visual Inspection (A-1)					
Structural Member	***Precast ribbed slabs***				
General Description	*Size in plane 1.5x6 m, with height of the rib 300 mm*				
Propagation of the flexural (bending)/shear cracks, x_1	Parameter: propagation length of the damaged linear size, [%] span length				
	no	**single**	**numerous**	**massive**	
	0	0.5-10	10-40	>40	
Inspection results				*45%*	
Position of the flexural (bending)/shear cracks, x_2	Parameter: position in span				
	no	**mid-span**	**not sure**	**near support**	**mid-span+near support**
	0	1	1.5	2	3
Inspection results					×
Propagation of the longitudinal corrosion cracks, x_3	Parameter: propagation length, [%] span length				
	no	**local**	**partial**	**solid**	
	0	0.5-10	10-40	>40	
Inspection results				*45%*	
Corrosion damage (deterioration), x_4	Parameter: damage appearance				
	no	**not sure**	**yes**		
	0	0.5	1		
Inspection results			×		
Surface degradation of concrete (deterioration), x_5	Parameter: damage appearance				
	no	**not sure**	**yes**		
	0	0.5	1		
Inspection results			×		
Propagation of the longitudinal corrosion cracks in compression zone of the section, x_6	Parameter: damage				
	no	**not sure**	**yes**		
	0	0.5	1		
Inspection results	×				
Damage Level	***1 (critical)***				
Phase A: Basic Testing (A-2)					
Characteristic of the Structure	Parameters				
	Length, *l* [mm]		*6000*		
	Height, *h* [mm]		*300*		
	Concrete cover, *c* [mm]		*32*		
	Diameter of steel bar, Ø [mm]		*16*		

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Concrete				
Ratio $\frac{c}{\varnothing}$ (concrete cover/diameter), x_7	Parameter: $\frac{c}{\varnothing}$			
	small	**mean**	**large**	
	<1	1-3	>3	
Inspection results		*2*		
Flexural (bending) cracks, x_8	Parameter: crack width, w_k			
	small	**permissible**	**exceeded**	**excessive**
	no more 0.05 mm	from 0.05 to 0.4 mm	from 0.4 to 1 mm	more 1 mm
Inspection results			*0.8*	
Longitudinal corrosion crack, x_9	Parameter: corrosion crack width, w_l			
	small	**medium**	**large**	
	no more 0.05 mm	from 0.05 to 1 mm	more 1 mm	
Inspection results			*1.2*	
Reinforcement (steel)				
Level of the corrosion damage, x_{10}	Parameter: loss of the mass			
	small	**mean**	**large**	
	no more 1 %	from 1 to 3 %	more 3%	
Inspection results		*2.5%*		
Deflections, deformations				
Deflections, x_{11}	Parameter: relative deflection			
	small	**permissible**	**exceeded**	**excessive**
	no more 1/900	from 1/900 to 1/250	from 1/250 to 1/50	more 1/50
Inspection results			*1/85*	
Damage Level	***1 (critical)***			
Phase A: Damage Class				
Documentation	**no**	**partially**	**yes**	
	0	from 0 to 1	1	
	×			
Damage Class	***3 (severe damage)***			

General view of the structural element are presented in Figure 1. Results of the assessment with usage of the proposed algorithm are listed in Table 6 and are in compliance with the estimation of the qualified experts.

Table 6 – Results of the assessment

The structural element	Results of the assessment with usage of the proposed algorithm	Results of the estimation of the qualified experts
Precast ribbed slabs	Severe damage	Severe damage

Figure 1 – General view of the evaluated ribed slabs

5 Conclusions

1. An effective structural assessment expert system for evaluation of the existing reinforced concrete structural systems using Fuzzy Logic MatLab Toolbox was developed and verified on the real objects in this study.
2. Although the presented expert system based on close visual inspections and simple measurements, it may provide substantial assistance to more complicated work (for example, evaluation of existing structures based on detailed investigations).

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EXPERIMENTAL STUDIES OF THE BENDING RESISTANCE OF COMPOSITE BEAMS WITH LOOP CONNECTIONS BETWEEN PRECAST PARTS

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Abstract

Loop connections for precast concrete structures have various advantages in terms of ease of setting, high flexibility and strength. Despite the advantages, the widespread use of the loop connection in the construction industry is limited due to the lack of a design methodology in performance standards. Several available design techniques outlined in various studies are empirical upper bound solutions based on experimental observations and results that do not take into account all the factors that affect loop connection behavior and strength. However, the influence of the main parameters of the loop connection cannot be ignored for detailed evaluation and decision making when designing these elements. In this regard, this article presents the results of experimental studies of prefabricated monolithic beams with loop connections on self-stressing concrete and concrete on Portland cement. The distinctive features that affect the load carrying ability and the fracture behavior of such elements when using expansive concrete and concrete on Portland cement as a monolithic connection are revealed.

Keywords: loop connections, bending resistance, expansive concrete, beam elements, failure mode.

ЭКСПЕРИМЕНТАЛЬНЫЕ ИССЛЕДОВАНИЯ СОПРОТИВЛЕНИЯ ИЗГИБУ СБОРНО-МОНОЛИТНЫХ БАЛОК С ПЕТЛЕВЫМИ СТЫКОВЫМИ СОЕДИНЕНИЯМИ

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Реферат

Петлевое соединение для сборных железобетонных конструкций имеют различные преимущества, связанные с простотой установки, высокой гибкостью и прочностью. Несмотря на достоинства, широкое применение петлевого соединения в строительной отрасли ограничено из-за отсутствия методологии проектирования в нормативных документах. Несколько доступных методик к проектированию, изложенных в различных исследованиях, представляют собой эмпирические решения с верхней границей, основанные на экспериментальных наблюдениях и результатах, которые не учитывают все факторы, влияющие на поведение и прочность соединения. Тем не менее, влияние основных параметров петлевого соединения нельзя игнорировать для детальной оценки и принятия решения при проектировании данных элементов. В связи с этим, в данной статье представлены результаты экспериментальных исследований сборно-монолитных балок с петлевыми стыковыми соединениями на напрягающем бетоне и бетоне на портландцементе. Выявлены отличительные особенности, оказывающие влияние на несущую способность и характер разрушения таких элементов при использовании напрягающего бетона и бетона на портландцементе в качестве замоноличивания стыков.

Ключевые слова: петлевые соединения, сопротивление изгибу, напрягающий бетон, балочные элементы, характер разрушения.

Introduction

Loop connections of precast concrete structural elements have been the subject of research for several decades. Precast concrete buildings experience significant damage during earthquakes, which is mainly concentrated around the joint areas due to inadequate connection systems that tend to loosen during ground movement [1]. Inadequate anchoring between precast concrete elements has been found to be a major source of damage during several earthquakes around the world. The structural behavior of precast concrete elements is determined by the mechanism and resistance of the connections, which requires adequate load transfer and ductility. Often the connections between precast concrete elements are embedded with concrete without any mechanical connection, which leads to a gap between the precast parts of the structure, which in turn affects the performance of the structure due to partial load transfer [2–4]. Thus, mechanical connection is inevitable to achieve the monolithic behavior of the precast concrete system. The reinforcement of precast concrete elements sometimes itself acts as a mechanical connection, with the reinforcement of two precast concrete elements being connected in place [5].

Loop connections (U-shaped bars) are common in the construction industry and are widely used to connect precast concrete elements where the rebars are 180˚ bent, forming U-shaped bars, which are spaced apart to ensure transmission of forces.

There are many studies on the behavior of a loop connection under tensile and bending loads, but there is no systematic approach to its design, as well as studies related to the use of self-stressing concrete as a monolithic loop connection. In the light of the foregoing, this paper presents results of the experimental studies based on static tests of composite beams with a loop connection on self-stressing concrete and OPC concrete under the action of a bending, as well as their comparative analysis.

Experimental investigation

Test specimens. Despite of significant amount of experimental and theoretical studies of loop joints both in tension and in bending [6–11], there are still no studies that would study the effect of self-stressing concrete on the stress-strain state of such elements under the action of a static load. The creation of an initial stress-strain state at the expansion stage of the self-stressing concrete of the loop connection can contribute to an increase in the crack resistance (stiffness) of the connection. Most of the known analytical models for calculating the resistance of loop connections are based on the results of experimental studies, so they are not able to take into account the initial stress-strain state obtained at the expansion stage of self-stressing concrete.

Based on the foregoing, experimental studies of the bending resistance of loop connections on self-stressing concrete and OPC concrete were carried out.

As experimental specimens, composite beam elements of rectangular section with dimensions b x h = 150 x 200 mm and a length of 2370 mm with stirrups in the prefabricated parts of the beams were made and tested. These beams were formed in two stages:

1) Precast parts of composite beams with length of the 1010 mm with loop connections from reinforcement Ø10 S500 were made (see Figure 1a).
2) After 28 days of concreting the precast parts of the beams, the two halves were assembled and the loop connections 350 mm width were cast in place using self-stressing concrete and concrete on Portland cement (see Figure 1b).

The construction of the experimental beams is shown in Figure 1.

A total of 10 test beams were casted (5 beams with loop connection filled with OPC concrete and 5 beams with loop connection filled with self-stressing concrete).

Experimental beams with the loop connection on OPC-concrete were made without transverse reinforcement in the connections themselves (position 3 in Figure 1b).

The demolding of the experimental beams and control samples was carried out after the concrete had gained demolding strength (average compressive strength f_{cm}=11 MPa). The curing the of experimental beams and control samples took place for 28 days in moist conditions (control samples made of expansive concrete and loop connections of beams were moistened every day).

The measurement of the longitudinal deformations the looped joint in the experimental beams at the stage of hardening and the expansion of the self-stressing concrete in moist curing conditions was made with usage of the electronic an indicators with a division value of 0.001 mm on the base of 600 mm (when measuring deformations along the lateral boundaries of the experiment of the beam). On each beam, 4 benchmarks were installed on the top and bottom reinforcement (in the middle section of the span (cast-in-place part of the beam). Figure 2 shown the arrangement of the deformometers on the experimental beam.

The testing of the experimental beams was carried out with usage one hydraulic jack (load capacity 250 kN) after the concrete of the loop connection had gained at least 28-day strength. The load to the experimental beam was applied through the traverse at two points according to the scheme - a simply supported beam loaded with two forces. Such an arrangement of the hydraulic jack was adopted in order to obtain a zone of pure bending in the looped joint of the precast part of the beam. Test schemes for experimental beams are shown in Figure 3.

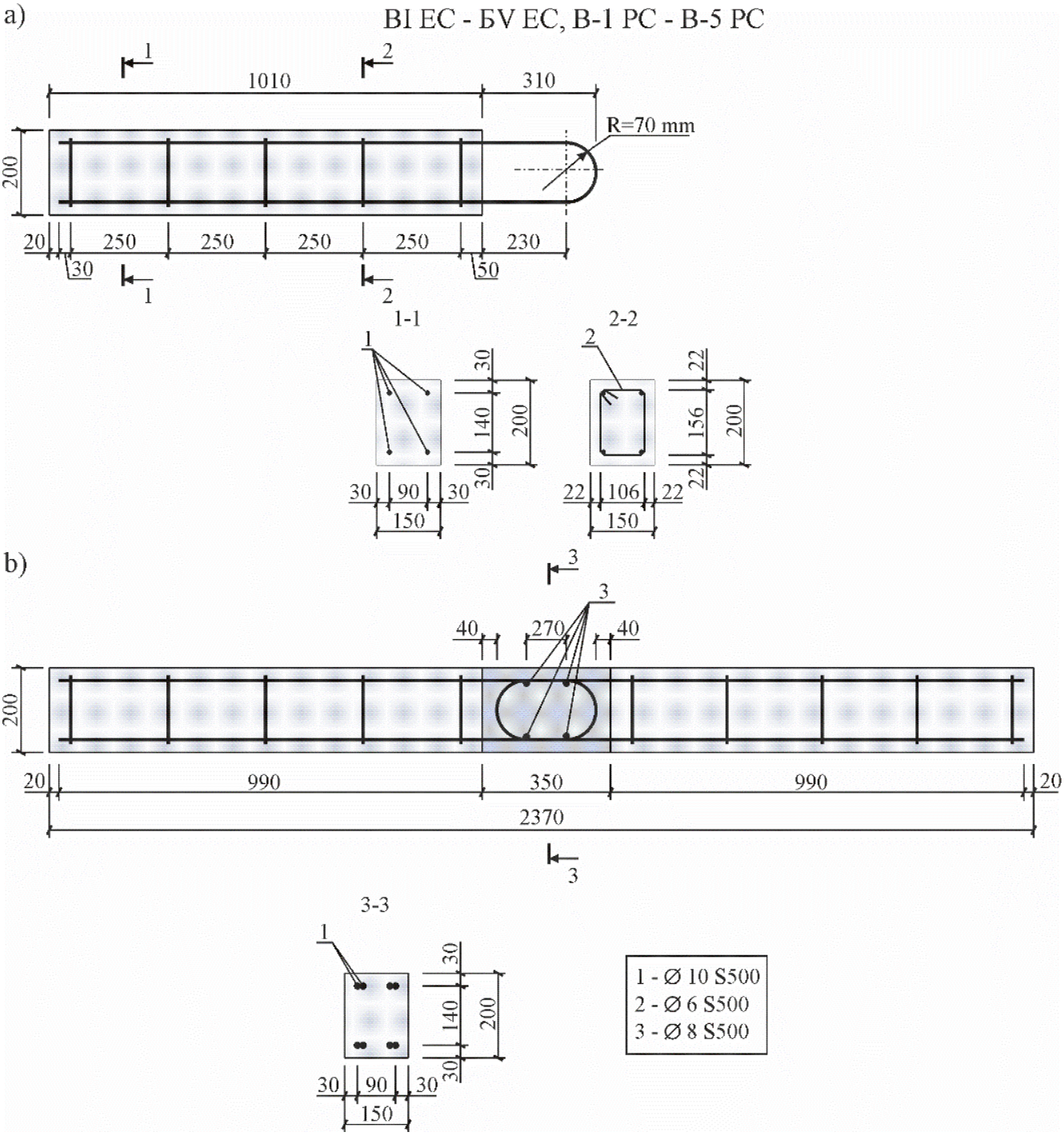

Figure 1 – Construction of experimental precast and cast-in-situ beams

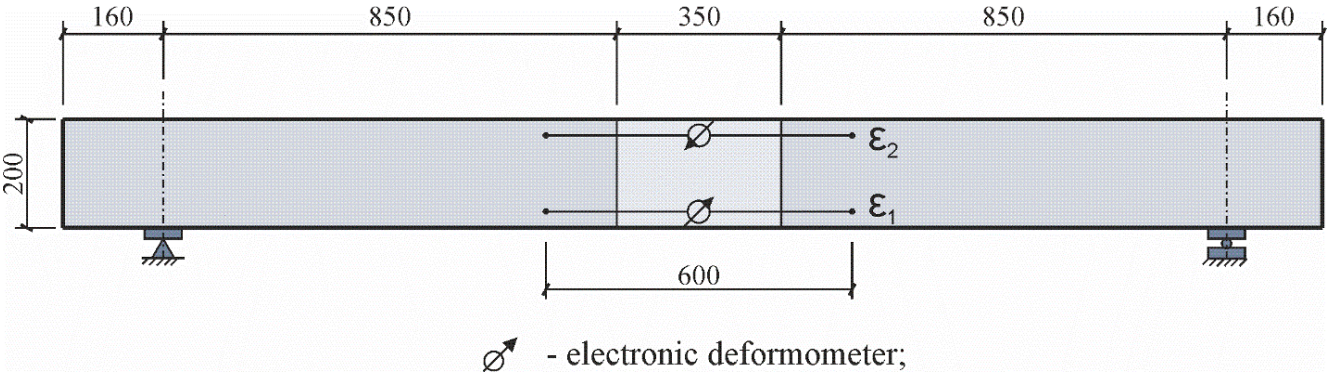

Figure 2 – Scheme of benchmarks arrangement on an experimental beam for measuring deformations at the self-stressing stage of concrete of a loop connection (BI EC – BV EC)

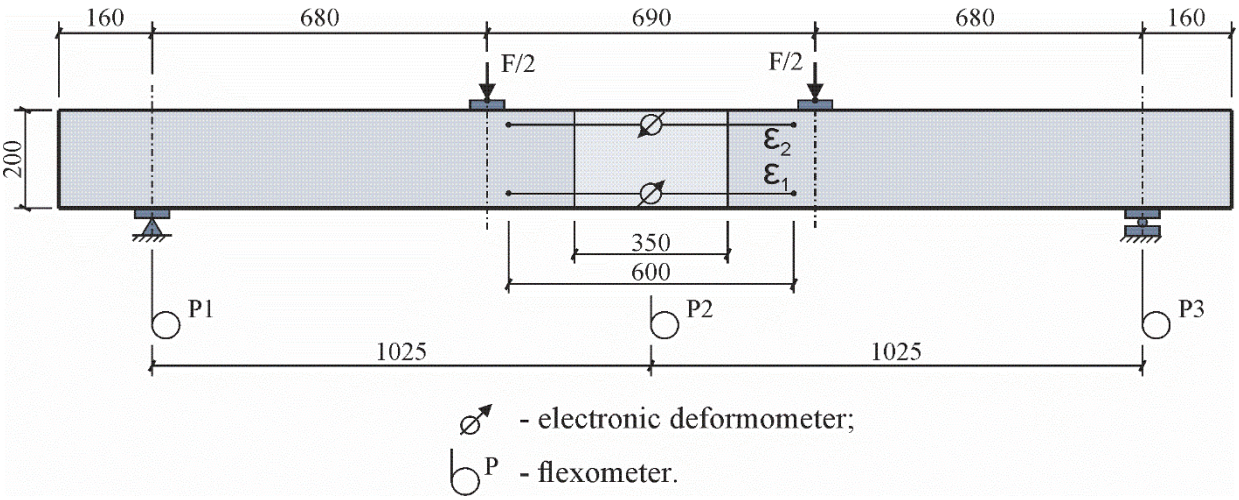

Figure 3 – Scheme of loading and arrangement of measuring instruments during static testing of experimental beams

Reinforcement

The reinforcement of the experimental beams was made with steel bars (Ø10 S500). As a stirrup of the precast parts of the beams, steel bars Ø6 S500 were used to create a spatial frame. Steel bars Ø8 S500 (beams BI EC – BV EC) were used as transverse reinforcement of the loop connections. Properties of reinforcement are presented in table 1.

Table 1 – Properties of reinforcement

Strength grade	Diameter Ø, mm	Yield stress level, MPa	Modulus of elasticity E_sx10^3, MPa	Position in figure 1
S500	6	587,1	200	2
	8	616,7	200	3
	10	649,4	200	1

Concrete

The selection of the nominal concrete composition was adopted taking into account the achievement of self-stress (except for the composition of beams B-1 PC – B-5 PC).

To achieve self-stressing of concrete, expanding additives CSA 20 were used (loop joint of beams BI EC – BV EC). The concrete mixture was prepared in a revolving-drum concrete mixer, followed by casing in the formwork and compaction with a deep vibrator.

Tables 2 and 3 resent the values mechanical properties of concrete, which was utilizing to casting of experimental beams. These results were obtained by the testing standard specimens at the time immediately before the loading.

Table 2 – The main properties of the concrete of the precast parts of the beams

Element	Beam signification	$f_{c,cube}$, MPa	$f_{cm,\ cyl}$, MPa	E_{cm}, GPa
Concrete of the precast parts of the experimental beams	BI EC, BII EC, B-1 PC – B-5 PC	28,9	21,3	31,5
	PIII EC – BV EC	34,8	30,6	35,0

Notes. $f_{c,cube}$, – mean cube compressive strength; $f_{cm,\ cyl}$, – mean concrete compressive strength based on cylinders (Ø150, h=300mm).

Table 3 – The main characteristics of concrete loop connections at the time of static testing

Element	Beam name	$f_{c,cube}$, MPa	$f_{cm,\ prizma}$, MPa	$f_{cm,\ cyl}$, MPa	E_{cm}, GPa	Free Linear Expansion, λ, %	Self-stresses, $f_{CE,k}$, MPa
Concrete loop connections	B-1 PC – B-5 PC	37,1	30,7	25,0	32,1	–	–
	BI EC – BV EC	29,9	59,1	16,6	34,1	0,95	2,8

Notes. $f_{cm,\ prizma}$ – mean concrete compressive strength based on prisms hardened under conditions of elastic restraint (100x100x400mm); $f_{cm,\ cyl}$. – mean concrete compressive strength based on cylinders hardened without axial elastic limitation (Ø150, h=300mm); $f_{CE,k}$ – mean self-stresses grade based on prisms (100x100x400mm); $\varepsilon_{CE,f}$ – strain free expansion based on cylinders (Ø150, h=300mm).

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Results obtained from experimental studies

Based on the value of the fixed longitudinal deformations by the time of the static test, the self-stress values of the concrete of the loop connection (beams BI EC – BV EC) were determined, which are presented in Table 4.

The cracking loads and failure loads recorded during static tests are presented in tables 5 and 6.

Table 4 – The values of self-stress at the moment of stabilization of the expansion

Beam designation	The values of self-stress σ_{CE}, MPa
BI EC	1,69
BII EC	1,44
BIII EC	1,85
BIV EC	2,05
BV EC	2,05

Table 5 – Results of static tests of composite beams with a self-stressed loop joint

Beam designation	$F_{cr}/2$, kN	M_{cr}, kN·m	$F_u/2$, kN	M_u, kN·m	Failure mode
BI EC	4,90	3,33	24,85	16,90	Compressed concrete failure in the precast part of the beam
BII EC	4,90	3,33	24,80	16,86	
BIII EC	7,40	5,03	25,10	17,07	
BIV EC	7,40	5,03	24,05	16,35	
BV EC	7,40	5,03	23,90	16,25	

Notes. $F_{cr}/2$ – cracking load; M_{cr} – cracking bending moment; $F_u/2$ – failure load; M_u – failure bending moment.

Table 6 – Results of static tests of composite beams with looped joint on OPC- concrete

Beam name	$F_{cr}/2$, kN	M_{cr}, kN·m	$F_u/2$, kN	M_u, kN·m	Failure mode
B-1 PC	2,40	1,63	22,40	15,23	Crushing of the concrete core inside the loop (loop connection area)
B-2 PC	2,40	1,63	22,40	15,23	
B-3 PC	2,40	1,63	21,40	14,55	
B-4 PC	2,40	1,63	22,05	14,99	
B-5 PC	2,40	1,63	23,30	15,84	

Composite beams with looped joints filled by the self-stressing concrete (beams BI EC – BV EC). The first flexural cracks appeared in all beams under load equal 0.2..0.31 $\boldsymbol{F_{tot,u}}$**.** It should be noted that the first cracks developed simultaneously in the precast parts and cast-in-suit concrete of the beam. Flexural cracks were distributed in near the same distance along the length of the beam span. Depth of the cracks observed about 50% of the height of the cross-section. It should be noted that in the cast-in-suit part (in the zone of the looped joint of the beam), cracks at the time of formation developed to a bottom part of the beam section (up to 15-20% of the height of the beam cross-section).

Cracks at the contact of precast parts and cast-in-situ concrete in all beams were formed at a load equal to ≈0.4 $F_{tot,u}$. (except for beam BII EC (≈0.3 $F_{tot,u}$.)), which may indicate the presence of compressive stresses at the contact between precast and monolithic parts which are formed at the stage of concrete self-stressing in the loop joint. It should be noted that these cracks, as the load increased, developed along the compressed reinforcement.

Cracks width at the contact of the precast and monolithic parts o f the beam under the applied loads had the largest value during static tests and under load close to the ultimate, the crack opening exceeded w_u=1,7 mm.

As the load increases, cracks developed and achieved near 88% of the cross-section height in all experimental beams.

The failure of all experimental beams occurred by the crushing of the compressed concrete in the precast part (under the applied concentrated force).

Self-stressing concrete contributes to the creation of the initial stress-strain state, which, in turn, affects the behavior of the beam during static tests.

Composite beams with looped joint filled with OPC-concrete (beams B-1 PC – B-5 PC). The first flexural cracks developed in all beams under load equal 0.10..0.11$F_{tot,u}$. It should be noted that the first cracks developed at the contact of the precast and monolithic parts of the beam, which at the time of formation reached 60..86% of the cross-section height. Cracks were distributed along the length of the span with approximately equal steps (see Figure 5). At the moment of formation cracks reached 15..50% of the height of the cross-section. It should be noted that in the monolithic part (in the zone of the looped joint of the beam), cracks at the time of formation developed to a lower height of the beam cross-section (up to 20-50% of the height of the beam cross-section).

As the load increased, cracks at the contact of precast parts and monolithic part in all beams (except for B-3 PC) developed along the compressed reinforcement.

As the load increased, cracks reached approximately 90% of the cross-section height in all experimental beams.

It should be noted that the critical crack was formed as a flexural crack outside the section of the direct insertion of the looped joint. As the load increased, the critical crack went around the looped joint on both sides of the joint. A compressed core is formed inside the loop connection, and the connections transfer tensile forces to the precast parts of the beam.

At the same time, this crack width is related with yielding of the reinforcing bars. However, this was not considered in the experiments. It should be concluded that the width of the crack opening increases due to the compliance of the concrete core enclosed within the loop. The failure of all experimental beams occurred when the concrete core was crushed inside the loop (looped joint).

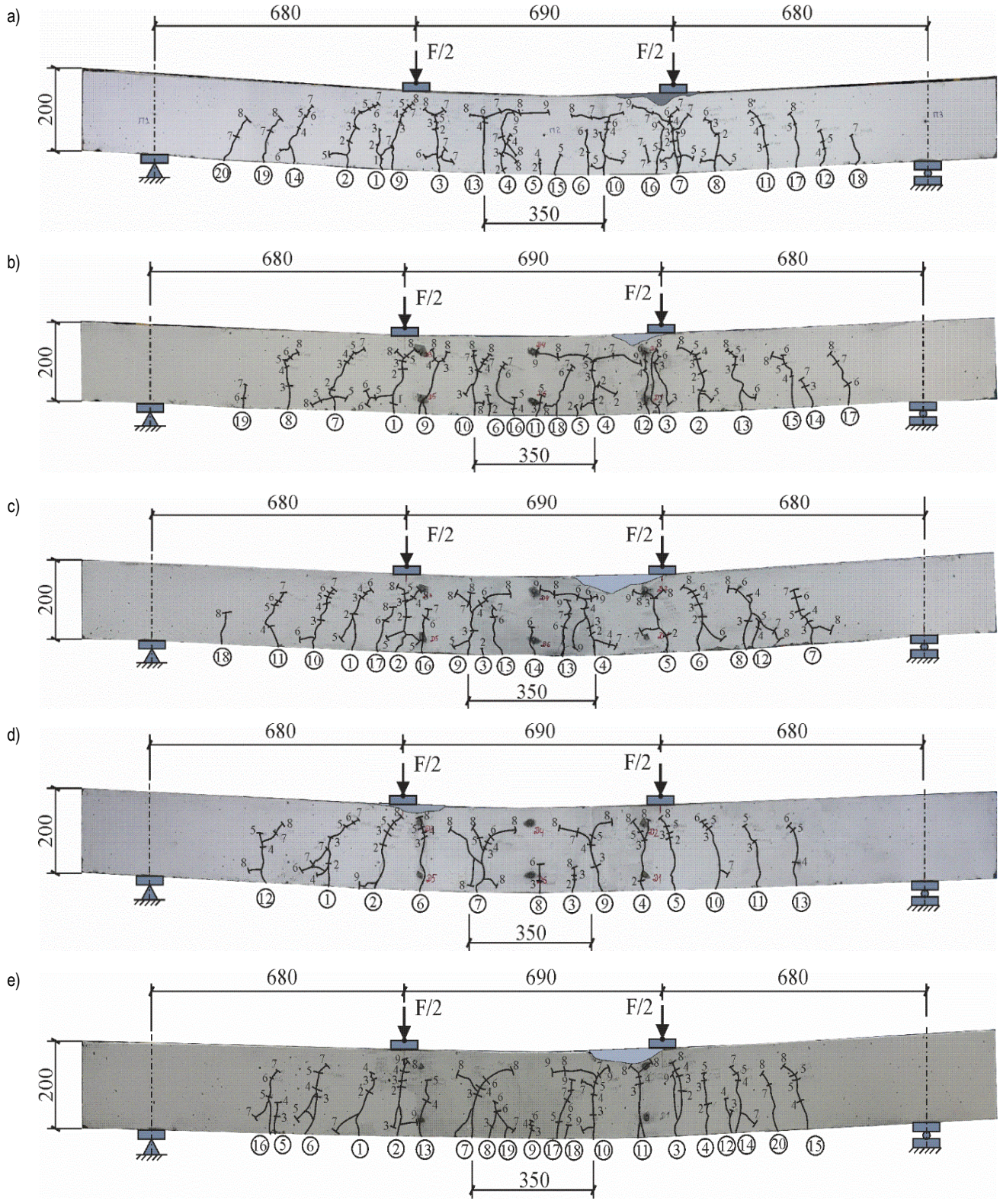
Differences in the behavior of precast and cast-in-suit beams with a loop connection on expansive concrete and concrete on Portland cement under the action of bending loads

The results of experimental tests are stable and repeatable. This conclusion is based on the fact that practically unchanged positions of the sections were observed in which flexural cracks were formed and the trajectories of their development (see Figures 4 and 5).

Based on the results of experimental studies of precast and composite beams with a looped joint on self-stressing concrete and OPC-concrete, a comparative analysis of the bending resistance and stiffness characteristics of these beams, recorded under the action of bending loads, was carried out. The results of comparison of deflections and relative deformations of tensile reinforcement and compressed concrete recorded in the course of static tests of all experimental beams are shown in Figures 6 and 7, respectively.

Based on the results of the comparative analysis presented in Figures 6 and 7, all experimental beams demonstrated the same behaviour at the initial stages of loading. However, composite beams with a looped joint filled with self-stressing concrete have a greater resistance (see Tables 5 and 6) and a lower bending stiffness under the ultimate load, compared with beams with a looped joint filled with OPC-concrete. Also, the usage of expansive concrete for filling of the looped joint increases crack resistance.

It is worth noting that precast and cast-in-suit beams with a loop connection on self-stressing concrete failed against the compressed concrete in the precast part (see Figure 4), while the failure of identical beams with a loop connection on Portland cement concrete occurred as a result of crushing of the concrete core inside the loop (see Figure 5).



a) – beam BI EC; b) – beam BII EC; c) – beam BIII EC; d) – beam BIV EC; e) – beam BV EC

Figure 4 – Cracks patterns for composite beams with a self-stressed loop joint

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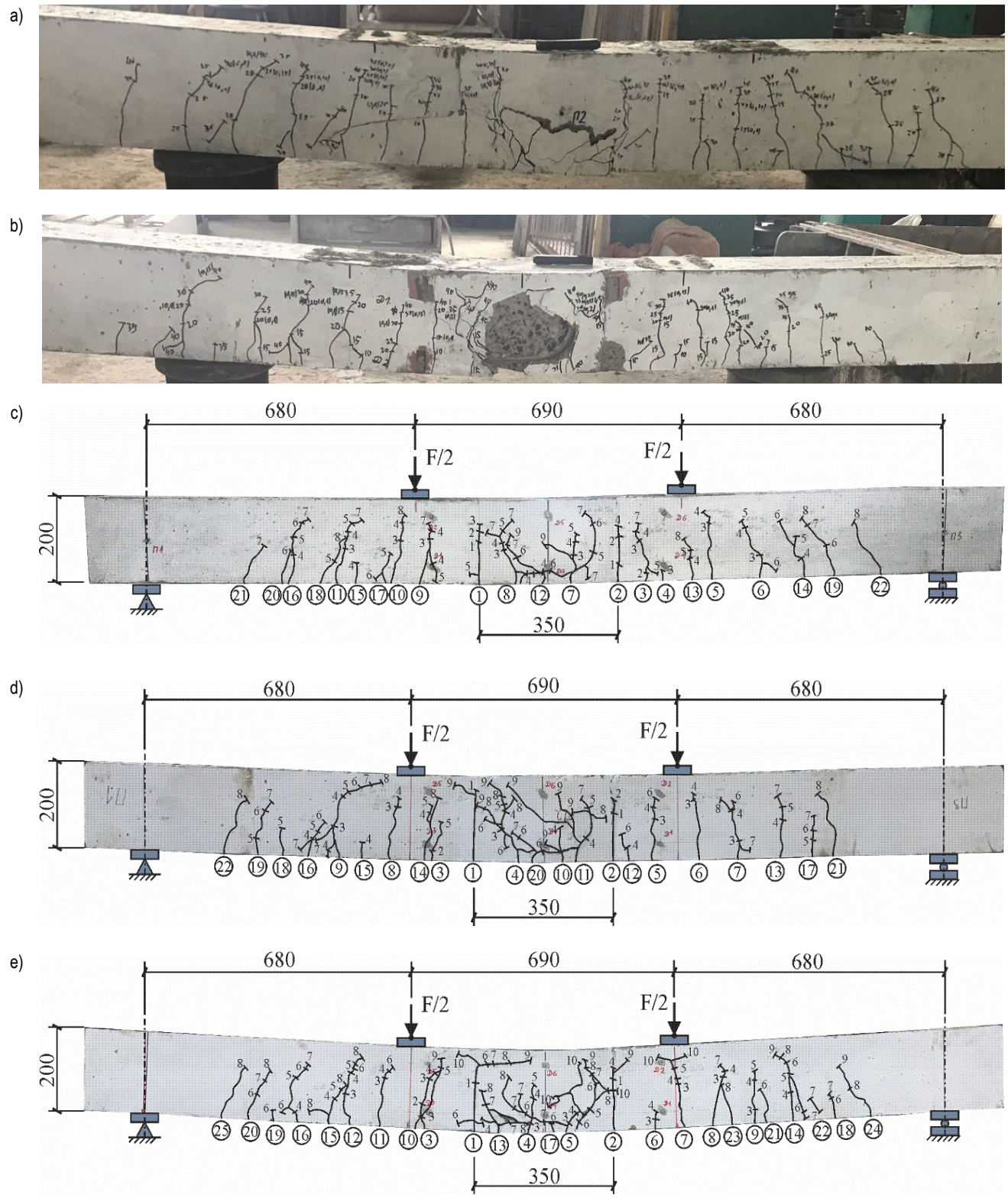

a) – beam B-1 PC; b) – beam B-2 PC; c) – beam B-3 PC; d) – beam B-4 PC; e) – beam B-5 PC

Figure 5 – Cracks patterns for composite beams with looped joint on OPC- concrete

Based on the results of the comparative analysis presented in Figures 6 and 7, all experimental beams demonstrated the same behaviour at the initial stages of loading. However, composite beams with a looped joint filled with self-stressing concrete have a greater resistance (see Tables 5 and 6) and a lower bending stiffness under the ultimate load, compared with beams with a looped joint filled with OPC-concrete. Also, the usage of expansive concrete for filling of the looped joint increases crack resistance.

It is worth noting that precast and cast-in-suit beams with a loop connection on self-stressing concrete failed against the compressed concrete in the precast part (see Figure 4), while the failure of identical beams with a loop connection on Portland cement concrete occurred as a result of crushing of the concrete core inside the loop (see Figure 5).

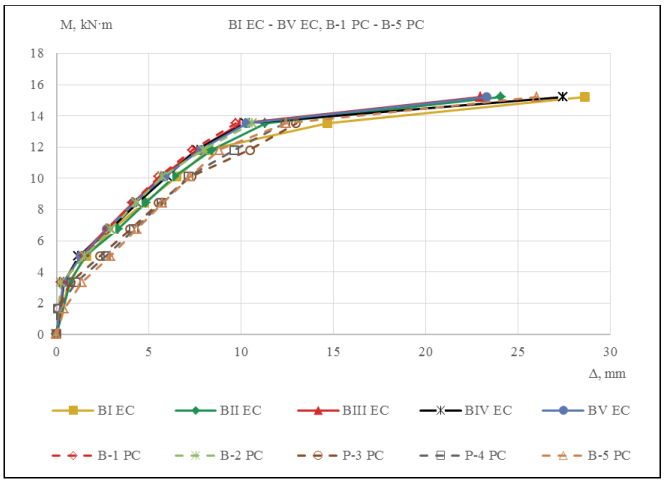

Figure 6 – Relation "moment – deflection" for tested beams (beams BI EC – BV EC, B-1 PC – B-5 PC)

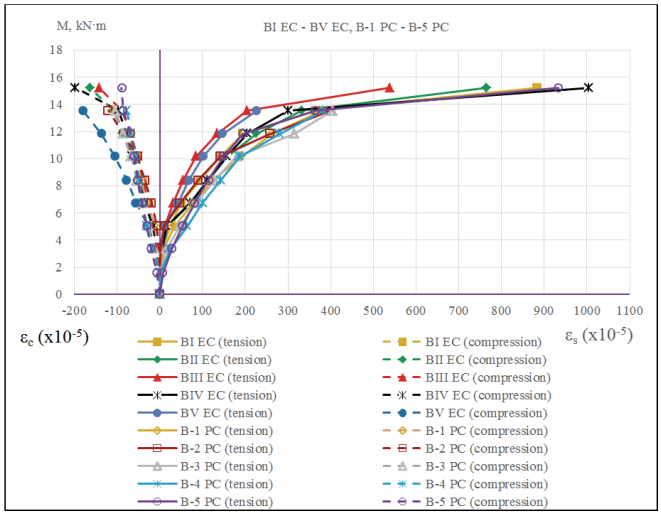

Figure 7 – Relation "moment – strains" for tested beams (beams BI EC – BV EC, B-1 PC – B-5 PC)

Conclusion

This paper presents the results of experimental studies of the bending resistance of the composite beams with a looped joints filled by self-stressing concrete and OPC-concrete. After analyzing the results of tests of beams under the action of a bending moment, as well as investigating the effect of self-stressing concrete of a looped joint on cracking and bearing capacity, we can draw the following preliminary conclusions:

1. The use of looped joints makes it possible to ensure the joint operation of individual precast parts of elements in a fairly wide range of loading.
2. The difference between the use of self-stressing concrete and concrete on Portland cement as a monolithic loop connection of composite beams is the failure mode. Self-stressing concrete contributes to the creation of a single structure consisting of precast parts with looped joint. This conclusion is confirmed by the fact that the failure occurs by the crushing of the compressed concrete of precast parts of elements, while the failure of composite beams with a looped joint filled with concrete on Portland cement occurs by crushing the concrete of the compressed core enclosed between the loop connections. It should be noted that the deformability and strength under the action of a bending moment in loop connections on expansive concrete is higher than on concrete on Portland cement.

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INFLUENCE OF CYCLIC LOADING PARAMETERS ON FATIGUE CHARACTERISTICS OF DIE STEEL

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Abstract

Studying the fatigue characteristics of structural materials is a time-consuming process. The possibility of using high loading frequencies on the example of 5CrNiMn steel is presented in this paper.

The results of studies of structurally sensitive characteristics are microhardness, electrical resistance and dislocation density. It is established that the nature of their change does not change with increasing loading frequency.

Based on the obtained results the common nature of the accumulation of fatigue damage is assumed.

Keywords: steel, microhardness, electrical resistance, testing, fatigue.

ВЛИЯНИЕ ПАРАМЕТРОВ ЦИКЛИЧЕСКОГО НАГРУЖЕНИЯ НА УСТАЛОСТНЫЕ ХАРАКТЕРИСТИКИ ШТАМПОВОЙ СТАЛИ

С. Е. Бельский, А. В. Блохин, Адель Абдель Бассет Рашид

Реферат

Исследование характеристик усталости конструкционных материалов – длительный и трудоемкий процесс. В данной работе на примере стали 5 CrNiMn показана возможность использования высоких частот нагружения для таких исследований.

Приведены результаты исследований структурно-чувствительных характеристик: микротведость, электросопротивление и плотность дислокаций. Установлено, что характер их изменения не меняется с ростом частоты нагружения.

На основе полученных результатов выдвинуто предположение о единой природе накопления усталостной повреждаемости.

Ключевые слова: сталь, микротвердость, электросопротивление, испытания, усталость.

Introduction

For the manufacture of products operating under conditions of cyclic loads as well as thermal changes die steels of the 5CrNiMn type are usually used. The durability of such equipment is largely determined by a complex of mechanical properties especially the fatigue characteristics of the material. The determination of such characteristics is also necessary for the selection of rational parameters for thermal and chemical-thermal treatment of such products. However, the methods of low-frequency testing currently used are very time-consuming and energy-intensive especially when a large number of loading cycles (10^6–10^7 cycles) have been run. Therefore, in this paper, we consider the possibility of using high loading frequencies (18.0 kHz) for the implementation of fatigue tests of die steel [1-4].

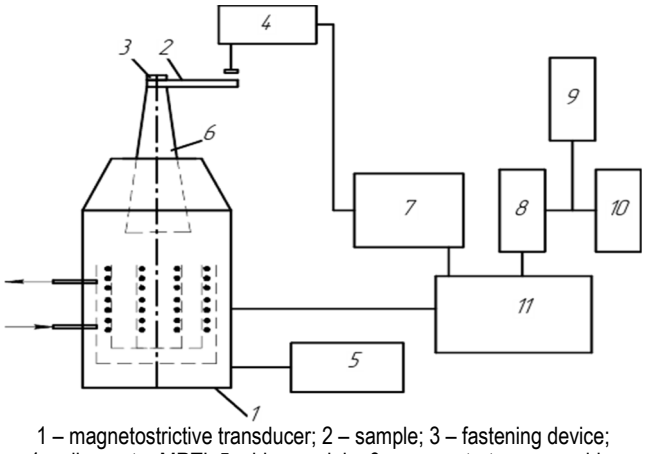
Materials and research methods

Difficulties with fatigue testing are caused by a limited list of equipment that allows loading model samples according to various schemes in a wide frequency range. The most accessible for the implementation of loading in the frequency range of 3-44 kHz are test facilities with excitation of vibrations by magnetostrictive packages. They can be used to implement various loading schemes: tension-compression; symmetrical (asymmetric) cycles of alternating bending and torsion. A further increase in the loading frequency is limited by a significant heating of the test specimens which can lead to a significant effect on the research results [1-4].

To determine the effect of frequency loading on the fatigue characteristics of materials, as well as the nature of changes in their physical and mechanical properties we used test equipment that allows loading test specimens with the following frequencies: 0.15; 3.0; 9.0; 18.0 kHz [5,6] (Figures 1, 2).

To load test specimens at high (more than 0.3 kHz) frequencies, magnetostrictive stands operating in self-oscillatory mode were used. The schematic diagram of the stands is shown in Figure 1. Magnetostrictive transducers served as active elements of these installations. They convert electrical vibrations into mechanical ones.

The parameters describing the micro structure of the elements of the oscillating systems of the test installations were selected in such way as to obtain a single oscillatory circuit with the same natural frequency, which made it possible to obtain the maximum values of the amplitude of the cyclic stresses in the sample for oscillation with minimal energy consumption when working at the selected resonance frequency. The test complexes operated in auto-oscillating mode.



1 – magnetostrictive transducer; 2 – sample; 3 – fastening device; 4 – vibrometer MRTI; 5 – bias module; 6 – concentrator-waveguide; 7 – amplitude stabilization device (PSA); 8 – frequency meter; 9 – oscilloscope; 10 – output to a computer; 11 – amplifier and signal generator

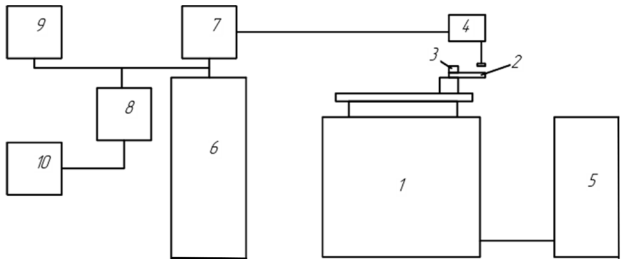
Figure 1 – Schematic diagram of the complex carrying out loading in a wide range of frequencies and temperatures

To increase the amplitude of sample oscillations, conical, stepped cylindrical and ampoule-stage concentrators were used. The mounting geometry of the samples was chosen to achieve a reduction in resonantly oscillating masses. To improve the reliability of sample fixing, a fixing

device was used (patent RB No. 12601). The proposed design made it possible to increase the accuracy of sample positioning and ensure the stability of the friction coefficient.

The test complexes operated in a self-oscillating mode, and the required amplitude of the sample oscillations was maintained using a special device for stabilizing the amplitude of the PSA [5,6].

To carry out fatigue tests at a low frequency of bending vibrations a test setup based on an electrodynamic vibration stand of type B3 was used (Figure 2).



1 – vibrator VE; 2 – sample; 3 – fastening device; 4 – vibrometer MRTI; 5 – bias module; 6 – amplifier; 7 – amplitude stabilization device (PSA); 8 – frequency meter; 9 – oscilloscope; 10 – output to the computer

Figure 2 – Schematic diagram of a low-frequency test stand for kinematic excitation of bending vibrations

Fatigue testing of cyclic samples for cyclic tension-compression of low frequency (150 Hz) was carried out by force excitation on the same electrodynamic shaker with some of its modernization. To control the level of cyclic stresses, the shaker was additionally equipped with a multi-channel strain gauge of the Spider type. The values of cyclic stresses acting both in the dangerous section of the sample and in other sections with a lower level of stresses were determined using strain gauges glued in different parts. The use of 3 to 5 strain gauges made it possible to determine the stress state of the sample with a higher accuracy at various amplitudes of its oscillations.

Studies on the effect of amplitude-frequency and temporal loading parameters on the course of fatigue damage processes in the materials under study were carried out by tracking the kinetics of the following properties: microhardness, fine structure, electrical resistivity, magnetic characteristics and microstructure.

To study the effect of frequency on the kinetics of hardening-softening processes of the studied materials, we observed the change in microhardness during cyclic loading at various bending stresses. For this reason the value of the initial microhardness (Hμ) was preliminarily determined before testing, and then measurements of Hμ were carried out in the zone of action of cyclic stresses of the selected value after the aging time.

The microhardness of the materials was measured using a PMT-3M and Duramin 5 device, which made it possible to conduct studies for the entire range of materials with the same relative measurement errors due to approximately the same dimensions of the imprint diagonals.

To study the processes of fatigue damage to materials at the microlevel during cyclic deformation in a wide frequency range we used a Bruker X-ray diffractometer in order to study the kinetics of structure-sensitive characteristics were studied using.

Structural changes caused by static and cyclic stresses affect both the mechanical and electrophysical properties of materials. Studies of changes in electrical resistance (electrical conductivity) make it possible to trace not only the kinetics of damage accumulation in weak and most favorably oriented in relation to the applied stress microvolumes of the material, but also allow us to identify the periods of the fatigue process, their duration in relation to the total durability. So, on the basis of the E7-20 immittance meter, a setup was created [7] which makes it possible to determine the change in the electrical resistance of the materials under study. The schematic diagram of the installation is shown in Figure 3.

The objects of research were samples made of 5CrNiMn steel.

Research results

Analyzing the whole complex of the results obtained in the context of the influence of the amplitude-frequency and time parameters of loading of test specimens on the kinetics of the physical and mechanical properties of the studied material, proved that that the most intensive changes in the structural-sensitive characteristics for the selected levels of alternating stresses occur under cyclic loading up to 10^7 cycles. Therefore, for example, an increase in the microhardness of die steel 5CrNiMn was noted already after 10^5 loading cycles (Figure 4).

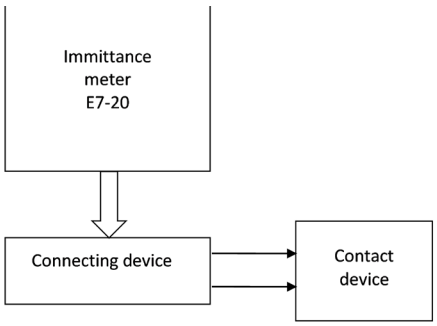
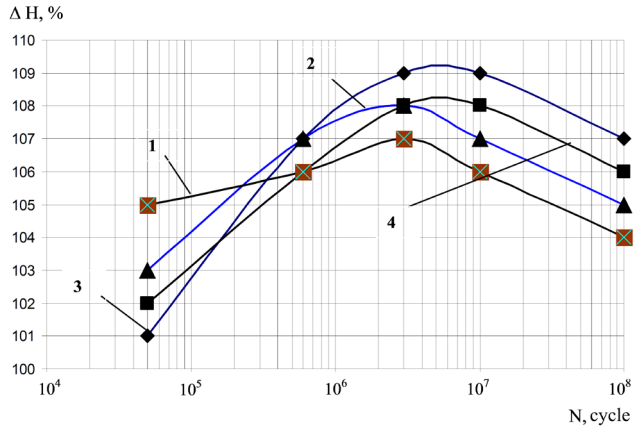


Figure 3 – Block diagram of the installation for measuring electrical resistance

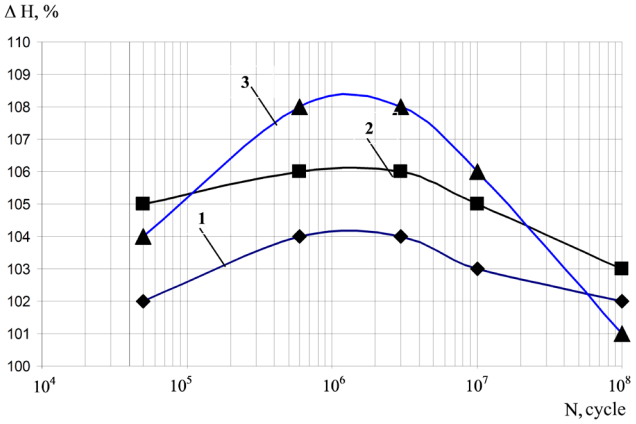
The fine structure of the studied materials is also characterized by the most significant change in the relative density of dislocations during the first loading cycles. Later on, with the cycles running saturation occurs which is replaced at the stage of microcrack development by a gradual transition through the extremum (Figure 5).

It should be noted that due to the high sensitivity of the dislocation density to the action of cyclic stresses, the hardening process proceeds with a pronounced intensity on the basis of up to 10^6 cycles, and subsequently, after 2×10^6 cycles predominantly softening processes are observed.



1 – 0.3 кHz; 2 – 3.0 kHz; 3 – 9.0 kHz; 4 – 18.0 kHz

Figure 4 – Influence of the frequency of alternating bending on the kinetics of microhardness of steel 5CrNiMn



1 – 346 MPa; 2 – 254 MPa; 3 – 135 MPa

Figure 5 – Influence of the magnitude of cyclic stresses of alternating bending on the kinetics of microhardness of steel 5CrNiMn

Certain regularities can be seen in the transformation of the physical and mechanical characteristics of materials. During cyclic deformation, hardening of materials occurs at the initial stages of loading which is

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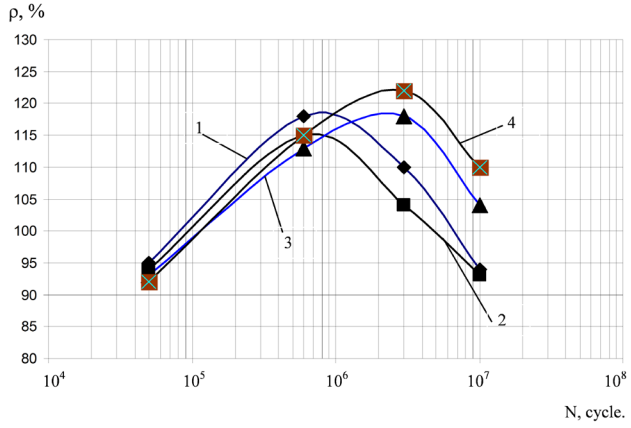
reflected in an increase in microhardness, an increase in the density of dislocations and microstresses. Then, it's the stage of saturation, replaced on large test bases by the stage of softening, characterized by a drop in the values of the above characteristics.

The observed effects of the kinetics of a number of structurally sensitive properties depend on the amplitude-frequency and are determined mainly by the nature of the distribution and interaction of defects in the crystal lattice. The dislocation density at the first stage of testing increases at all studied frequencies, which indicates the beginning of the process of material hardening. In the initial stage of loading, only oscillatory movement of segments of pinned dislocations around the equilibrium position takes place. The subsequent imposition of alternating stresses with a high frequency of the half-cycle of oscillations leads to the activation of dislocations present in the material, it helps them overcome potential barriers and move through obstacles, thereby causing plastic deformation. The continuation of cyclic loading causes the appearance of new defects due to the action of dislocation sources activated in the first loading cycles, as well as sources arising due to the interaction of dislocations located in adjacent parallel slip planes. As a result, the density of dislocations and point defects (interstitial atoms and vacancies) increases significantly. At a certain concentration of defects, both dislocations and vacancies, their mass breakdown from obstacles occurs that causes a violation of interatomic bonds. The determining factor in this case is an increase in the dislocation density with an increase in the number of loading cycles, which is confirmed by X-ray diffraction studies (Figure 6).

An increase in the density of dislocations is explained not only by the translational motion of decoupled dislocations, but also by their multiplication mainly through the operation of Frank-Read sources.

The cessation of the increase in the density of dislocations occurs due to the deceleration of the action of the source of their multiplication by stresses from previously emitted dislocations. The process of annihilation of dislocations of the opposite sign emitted during cyclic loading by sources located in parallel atomic planes is also possible. Along with an increase in the density of dislocations at the initial stage of loading, an increase in the concentration of point defects is also observed, which is also confirmed by a decrease in electrical conductivity. An increase in the number of vacancies can be associated with an increased mobility of dislocations under alternating loading, since excess vacancies appear as a result of the nonconservative movement of thresholds on dislocations. When a certain number of loading cycles is reached, the material is saturated with vacancies, which, effectively interacting with moving dislocations, cause their pinning and disappearance. With a further increase in the number of loading cycles, a group of vacancies with a high activation energy is formed. In addition, an increase in microhardness occurs due to intense plastic deformation of microvolumes of the material. In this case, the nucleation and development of submicrocracks takes place in the walls of dislocation cells. A softening process develops when the plastic deformation of the material increases. This process is characterized by a decrease in the density of dislocations, a decrease in the level of microstresses and microhardness. The absence of significant qualitative differences in the nature of the development of the dislocation structure at high and low loading frequencies leads to an analogy in the kinetics of changes in the considered quantities in the studied frequency range.



1 – 0.3 kHz; 2 – 3.0 kHz; 3 – 9.0 kHz; 4 – 18.0 kHz

Figure 6 – Influence of the frequency of alternating bending on the kinetics of the dislocation density of steel 5CrNiMn

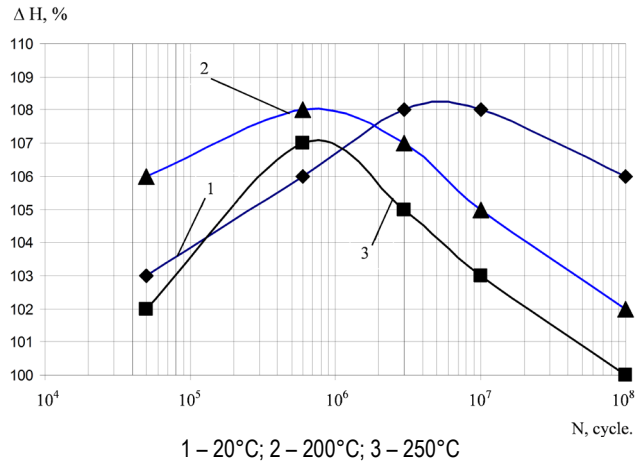
An increase in the density of dislocations is explained not only by the translational motion of decoupled dislocations, but also by their multiplication mainly through the operation of Frank-Read sources.

The cessation of the increase in the density of dislocations occurs due to the deceleration of the action of the source of their multiplication by stresses from previously emitted dislocations. The process of annihilation of dislocations of the opposite sign emitted during cyclic loading by sources located in parallel atomic planes is also possible. Along with an increase in the density of dislocations at the initial stage of loading, an increase in the concentration of point defects is also observed, which is also confirmed by a decrease in electrical conductivity. An increase in the number of vacancies can be associated with an increased mobility of dislocations under alternating loading, since excess vacancies appear as a result of the nonconservative movement of thresholds on dislocations. When a certain number of loading cycles is reached, the material is saturated with vacancies, which, effectively interacting with moving dislocations, cause their pinning and disappearance. With a further increase in the number of loading cycles, a group of vacancies with a high activation energy is formed. In addition, an increase in microhardness occurs due to intense plastic deformation of microvolumes of the material. In this case, the nucleation and development of submicrocracks takes place in the walls of dislocation cells. A softening process develops when the plastic deformation of the material increases. This process is characterized by a decrease in the density of dislocations, a decrease in the level of microstresses and microhardness. The absence of significant qualitative differences in the nature of the development of the dislocation structure at high and low loading frequencies leads to an analogy in the kinetics of changes in the considered quantities in the studied frequency range.

Obviously, with an increase in frequency an increase in the rate of deformation of metals occurs at the same number of loading cycles. Thus, relaxation processes which play a significant role under static loading slow down with increasing loading frequency. In proportion to the loading frequency, the number of cycles before the start of the softening process also increases. An increase in frequency leading to an increase in the rate of elastic deformation, also contributes to an increase in the rate of dislocation motion; this increases the efficiency of their reproduction. In addition, with increasing frequency, the number of vacancies also increases, and their extremely high concentration arises, as a result of which they condense into disks parallel to the most densely packed planes. When a certain critical disk size is reached, its sides are flattened and connected together. It forms a dislocation loop. All this leads to hardening, resulting in an increase in the density of dislocations and microhardness.

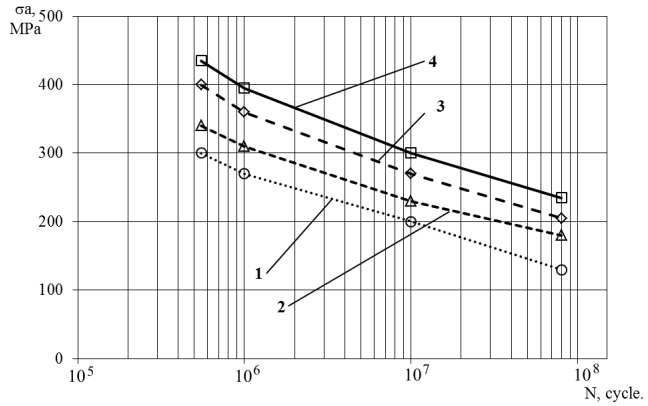
It should be noted that similar processes are also typical for elevated test temperatures of 5CrNiMn die steel (Figure 7). An increase in temperature contributes to an earlier occurrence of hardening-softening processes due to the activation of the interaction of dislocations and point defects, as well as the movement of dislocations.

The test results also showed that the shape of the fatigue curves does not change with increasing frequency (Figure 8). The fatigue curves for different frequencies are almost equidistant. One can note a monotonic increase in fatigue life with increasing loading frequency. Similar results were obtained at different temperatures (Figure 9).



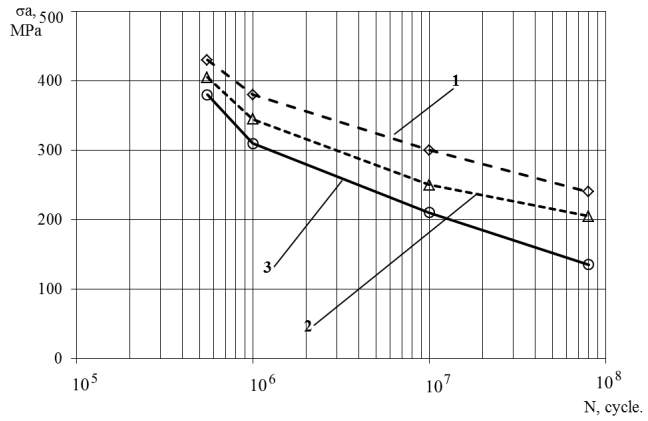
1 – 20°C; 2 – 200°C; 3 – 250°C

Figure 7 – Change in the microhardness of steel 5CrNiMn at different test temperatures (loading frequency 18.0 kHz)



1 – 0.3 kHz; 2 – 3.0 kHz; 3 – 9.0 kHz; 4 – 18.0 kHz

Figure 8 – Fatigue curves for steel 5CrNiMn when tested at different loading frequencies



1 – 20°C; 2 – 200°C; 3 – 250°C

Figure 9 – Fatigue curves for steel 5CrNiMn at different test temperatures (loading frequency 18.0 kHz)

Conclusions

The above studies have shown that despite certain quantitative differences in the kinetics of the physical and mechanical characteristics of the materials the process of fatigue failure develops according to the same patterns that are characterized by a combination of hardening-softening processes. This confirms the unified physical nature of the development of fatigue damage in the considered range of frequencies and temperatures and, therefore, the fundamental possibility of implementing accelerated fatigue tests using high loading frequencies.

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ON THE WEAR MECHANISM OF CARDAN GEAR JOINTS

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Abstract

In connection with the improvement of vehicles, power plants, an increase in their power, operational life, requirements for reliability and safety of use necessitate the development of new modifications of the main components and assemblies, incl. drive shafts. In this paper, an analysis of the main types of wear of cardan gears operating in various conditions is carried out. It is shown that the main types of wear of universal joints are: fatigue and abrasive wear, false brinelling, pitting, fretting. To reduce the effect of these types of wear, a comprehensive approach has been proposed, which consists in the development of highly effective methods for hardening the working surfaces of parts, the creation of thin-film composite coatings for friction parts, the development of new compositions of new generation lubricants based on mineral and synthetic oils.

Keywords: design, cardan shaft, wear, friction, materials.

О МЕХАНИЗМЕ ИЗНАШИВАНИЯ ШАРНИРОВ КАРДАННЫХ ПЕРЕДАЧ

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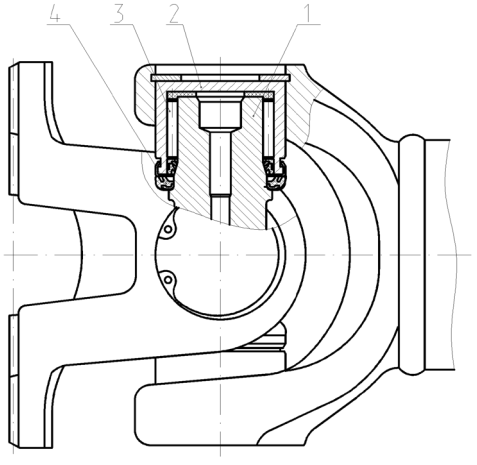
Реферат

В связи с совершенствованием транспортных средств, энергетических установок, увеличением их мощности, эксплуатационного ресурса, требований по надежности и безопасности использования возникает необходимость разработки новых модификаций основных узлов и агрегатов, в т.ч. приводных валов. В данной работе проведен анализ основных типов изнашивания карданных передач, эксплуатирующихся в различных условиях. Показано, что основными видами изнашивания универсальных шарниров являются: усталостный и абразивный износ, ложное бринеллирование, питтинг, фреттинг. Для снижения влияния данных видов изнашивания предложен комплексный поход, заключающийся в разработке высокоэффективных методов упрочнения рабочих поверхностей деталей, создания тонкопленочных композиционных покрытий для деталей трения, разработке новых составов смазочных материалов нового поколения на основе минеральных и синтетических масел.

Ключевые слова: конструкция, карданная передача, износ, трение, материалы.

Introduction

Cardan gears are currently an integral part of the transmission of modern vehicles such as cars, tractors, heavy motorcycles, diesel locomotives, etc., as well as some stationary installations, such as rolling mills and others, in which it is necessary to transfer torque between units that have relative movements during operation.



1 – cross; 2 – bearing housing; 3 – needle rollers; 4 – seal

Figure1 – Cardan joint

The reliability of the driveline is determined mainly by the reliability and service life of the hinge (Figure 1), i.e. the service life of the pair of needle bearing - cross spike. In this regard, the issue of increasing the resource of cardan joints should be given great attention [1–3].

The purpose of this work is to determine the mechanism of wear of the needle bearing of the driveline.

Research methodology

Structurally, the cardan needle bearing is made in the form of a cup, which is the outer ring, and a set of needle rollers (Figure 2). The spike of the cross serves as the inner ring (Figure 3). Bearing rings are made of steel 15G1 TU 14-1-3938-85, ShH15N15, ShH15SG GOST 801-78; needle rollers made of steel ShH15 GOST 801-78. The cross is made of steel 20HGTR TU 14-1-704-72, 60PP TU 14-1-1926-76. The hardness of the surfaces of rings, needle rollers, cross spikes should be 62...66 HRC. The roughness of the raceway should be no more than R_a 0.63 μm, needle rollers not more than R_a 0.16 μm, cross spikes not more than R_a 0.32 μm. The difference in size of the needle rollers in the bearing should be no more than 2 microns.

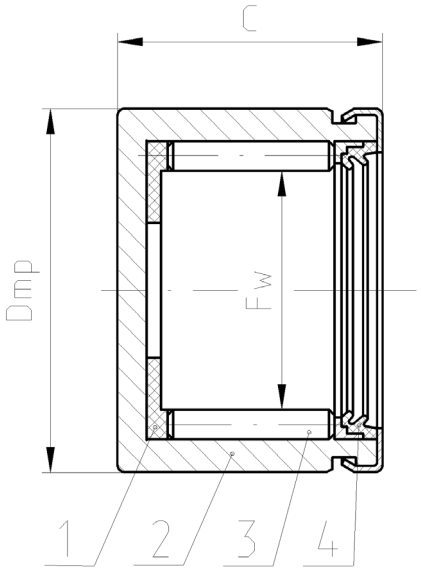
Research results

A feature of the kinematics of a needle bearing is that the nature of the movement of the rollers along the treadmills during rocking motion is determined by the fact that the rollers both slide and roll, and the rolling takes place mainly in the loaded zone. The nature of the movement of the needle is strongly influenced by the viscosity of the lubricant. A viscous

lubricant "extinguishes" the inertia of the rotation of the needle; with lubricants with a low viscosity, the needles show a tendency to rotate in the unloaded zone.

The needle bearing has a large number of small elements (needles) that form narrow slots, which contributes to the capillarity of the entire system and the retention of lubricant near the contact points of the bearing elements. The oil cushion between the needles and the treadmills is continuously crushed under load, as a result of which semi-dry friction prevails in the bearing and there is no hydrodynamic floating of the layer of needles. This is facilitated by the operating conditions of the oscillating motion with small oscillating angles, as well as the relationship between the sizes of the elements, which makes it unlikely that the formation of oil cushions between the needles and the raceway [3–5].

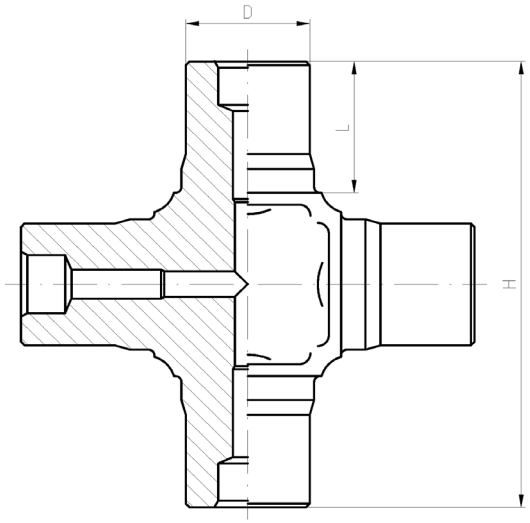
The loading of cardan needle bearings is determined by the magnitude and nature of the torque of the cardan shaft, bending vibrations caused by the imbalance of the cardan shaft, torsional vibrations of the transmission, as well as the forces arising in the spline connection of the cardan shaft during movements.



F_w – hole diameter of the needle roller;
D_{mp} – outer diameter; C – bearing width

1 – washer; 2 – outer ring; 3 – needle roller; 4 – seal

Figure 2 – Pivot bearing cardan transmission



D – is the diameter of the spike of the cross;
L – is the length of the spike of the cross;
H – is the distance between the ends of the spikes of the cross

Figure 3 – Joint cross drive line

During the operation of cardan needle bearings, rolling, rolling with slipping and axial micro-movements of bearing parts relative to each other under load in the presence of lubricant take place, and the penetration of moisture, abrasive particles, as well as access of atmospheric air to the contact zone is not excluded.

With the relative movement of bodies under the action of a compressive load, there is resistance to their mutual movement, i.e. we have external friction. When cardan needle bearings operate under normal operating conditions, two types of external friction occur in the contact zone:

1. Dry friction, when the surfaces are covered with hard films that are less durable than the base material;
2. Boundary friction when surfaces are covered with liquid films.

Friction has a dual molecular-mechanical nature. It is due to the overcoming of the adhesive bond between two surfaces, usually between the films with which solid bodies are coated, and the volumetric deformation of the material (mutual penetration) occurring in a thin surface layer at a depth comparable to the penetration depth.

Depending on the magnitude of the adhesion forces and the depth of penetration, five types of violation of frictional bonds that occur in the process of friction can be distinguished:

1. chip-cut material;
2. plastic pushing;
3. elastic deformation;
4. destruction of films (adhesive destruction);
5. destruction of the base material (cohesive destruction).

Repeated violation of frictional bonds causes the process of destruction of the material. The predominant type of fracture during friction depends both on the properties of rubbing bodies and on external conditions (loads, speeds and amplitudes of displacements, media, etc.). In this regard, it is possible to classify the types of wear. The main types of needle bearing wear are:

1. grasping of the 1st kind;
2. oxidative wear;
3. thermal wear;
4. abrasive wear;
5. smallpox (fatigue) wear.

Let us consider in more detail the types of wear encountered during the operation of needle bearings.

Seizure wear of the 1st kind is a process of destruction of rubbing surfaces, expressed in plastic deformation of surface layers and the occurrence of local metal bonds, welding bridges with their subsequent destruction, accompanied by transfer, spreading of metal on a harder surface and separation in the form of wear particles of this transferred layer metal.

Oxidative wear under boundary lubrication conditions with dry friction is a process of gradual destruction of the surfaces of a needle bearing during friction, which is expressed in a complex combination of oxygen adsorption phenomena on friction surfaces, oxygen diffusion in surface layers, simultaneous plastic deformation of the metal with the formation of chemically adsorbed films, solid films solutions and chemical compounds of metal with oxygen and their separation from friction surfaces.

The oxidation process on the surfaces of a needle bearing occurs when plastic deformations of the order of 0.1 ... 0.01 μm of the thinnest surface layers of the metal and the phenomena of chemical adsorption and diffusion of oxygen into the plastically deformed surface layers occur together. The resulting new structure upon repeated repeated deformation is brittle destroyed, after which new layers of the underlying metal enter the process.

When working with small angles of inclination of cardan gears in conditions of vibration, cyclic loads, the presence of micro-displacements and slippage of rolling elements, as well as the difficulty in removing wear products from the contact zone due to the design features of the hinge lubrication system, a characteristic type of wear of cardan needle bearings is fretting - corrosion.

Fretting can be defined as a type of wear that occurs when two surfaces in contact, nominally stationary with respect to each other, periodically move slightly relative to each other. A feature of fretting is that the products are not removed from the contact zone. A necessary condition for the occurrence of fretting is the presence of a relative displacement or sliding of surfaces with a certain amplitude. The magnitude of damage for

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steels is directly proportional to the magnitude of the slip amplitude within 0.010 ... 0.229 mm. The value of wear particles for steels lies in the range of 0.1 ... 1.0 mcm. Particles formed in the presence of air are red-brown in color. Chemical analysis showed that the product of contact corrosion (fretting) is iron oxide Fe_2O_3, the presence of ferrous oxide FeO and magnetite $Fe_3O_4$was also found. The initial wear products also contain metallic iron. A significant increase (12 times) in air nitrogen absorption by friction surfaces during fretting was also established: In the absence of oxygen and moisture, fretting has much in common with friction wear, such as first-class seizing.

Thermal wear or wear by seizure of the 2nd kind is a process of intensive destruction of the surfaces of a needle bearing during sliding friction, due to local heating and softening of the metal, desorption and combustion of the lubricant, resulting in seizure followed by tearing of the metal, its smearing and separation of microparticles from the surface friction. Thermal wear takes place in cardan needle bearings only during operation of bearings that already have wear and do not have a built-in polymer washer between the end of the cross and the bottom of the bearing.

Abrasive wear is a process of destruction of the friction surfaces of a needle bearing, due to the presence of an abrasive medium in the friction zone and is expressed in local plastic deformation, the presence of micro-scratches, micro-cuts by abrasive particles of the friction surfaces. Abrasive wear takes place during the operation of cardan needle bearings in dusty conditions in violation of the tightness of the seals.

Smallpox (fatigue) wear is a process of destruction of the friction surfaces of a needle bearing, due to plastic deformations, internal stresses, metal fatigue phenomena and is expressed in the formation of microcracks, cracks, depressions, etc. on the friction surface.

In most cases, fatigue failure of needle bearings cannot be explained by any single mechanism and is the result of several independent processes, including corrosion, abrasive wear, etc. Fatigue failure under contact stress conditions is a consequence of the combined action of several types of damage that occur and propagate at different speeds and independently of each other. Consider some of the types of destruction of needle bearings [4,5].

Destruction from oxide non-metallic inclusions causing stress concentration. Damage is characterized by:

- subsurface propagation from the source;
- spalling (pitting) after fatigue fracture reaches the surface from a small depth;
- Fatigue crack propagation under load.

Destruction from the geometric stress concentration, which occurs due to:

- low viscosity lubricant;
- tangential forces of prevailing sliding.

Peeling (pitting) is characterized by a limited penetration depth of fatigue cracks under the surface and their predominant propagation over the surface to a depth of no more than 0.013 mm.

Pitting occurs due to:

- low viscosity lubricant;
- a large number of protrusions, the height of which exceeds the thickness of the lubricating layer.

Subcrustal fatigue of case-hardened needle bearing parts is due to:

- insufficient hardness of the core;
- insufficient thickness of the cemented layer compared to the curvature of the contacting elements.

Difficulties associated with detecting the initial stage of the development of the destruction of the joints of the cross - a needle bearing, especially during operation, as well as the variety of operational, technological and load factors that affect the performance of cardan joints, make the task of studying the types of wear and their causes quite difficult. In this regard, at present, in the literature there are various, often contradictory, ideas about the mechanism of formation and development of destruction of parts of cardan joints, especially when considering the initial stages of destruction.

Consider the most common types of destruction of cardan needle bearings, cross spikes and seals, as well as their causes.

The type of wear, the nature of damage, its intensity depend on the type of car, the angle of installation of the driveline, operating conditions. The most common types of damage to parts of cardan joints include the appearance of traces of false brinelling on the cylindrical working surfaces of the spikes of the crosses and bearing cups and fatigue failure of the working surfaces.

As a rule, under normal operating conditions, the destruction of the elements of the hinge does not begin with wear of the seals and the penetration of abrasive particles and moisture into the interface of the needle bearing with the spike of the cross, but with the destruction of the working surfaces of the crosses, rolling elements and bearing cups in the normal state of the lubrication system. Before the appearance of visible signs of destruction, wear of the hinge elements occurs, leading to an increase in the gap and distortion of the shape of the working surfaces. Then there are traces of indentation of the ends of the needles on the bottoms of the glasses, which is explained by the presence of axial components of the forces that occur when the needle is skewed, due to the presence of an inter-needle gap and deformation of the assembly under load. Axial forces lead to periodic displacement (slip) of the needles along the axes. Then there is the formation of initial dents on the surfaces of the spikes and glasses, after which there is an intensive development of false brinelling grooves, fatigue chipping, intensive wear of the needles, in which the needles can acquire a square section or break.

The initial wear on the seals and the stud surfaces under the seals significantly reduces the initial interference. After the development of significant destruction of the elements of the hinge, the seal loses its ability to hold internal pressure and prevent the penetration of abrasive particles and moisture into the interface, the temperature regime is disturbed. As a result of the changes that have occurred, as well as the accumulation of wear products, oxidation and thickening of the lubricant occur.

The final stage of destruction is characterized by extensive chips and scuffs on the working surfaces.

Conlusion

Therefore, it is advisable to look for ways to increase the resource at the first stage of damage formation, i.e. to prevent the occurrence of plastic deformations in the surface layers of the metal, to ensure the tightness of the connection. Therefore, to increase the resource, it is necessary to reduce the loading of the working surfaces of cardan needle bearings, increase the resistance of the surface layer to plastic deformations and contact fatigue damage, reduce the axial components of the displacement forces in the splined joint, and create new designs of sealing elements.

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EVALUATION OF NATURAL GRASSLANDS DETERMINED BY REMOTE SENSING AND GIS APPLICATIONS IN THE HIGHLANDS OF EASTERN TURKEY

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Abstract

The aim of this study was to assess the natural grassland regions for livestock production in the highlands of Eastern Turkey by utilizing Remote Sensing (RS) techniques and Geographic Information Systems (GIS) applications.

It was concluded that the natural grasslands make up 2/3 of the whole study area in Kars province. However, in terms of plant cover density this only accounts for 1/3rd of the entire area. In other words, just 181 275.7 hectares out of a total of 638 393.5 hectares of grassland are in a better state for cattle grazing. Finally, digital maps of the greatest quality grasslands were produced.

Keywords: natural grasslands, remote sensing, geographic ınformation systems, satellite ımages, digital maps.

ОЦЕНКА ЕСТЕСТВЕННЫХ ЛУГОПАСТБИЩНЫХ УГОДИЙ, ОПРЕДЕЛЯЕМЫХ С ПОМОЩЬЮ ДИСТАНЦИОННОГО ЗОНДИРОВАНИЯ И ПРИМЕНЕНИЯ ГИС В ВЫСОКОГОРНЫХ РАЙОНАХ ВОСТОЧНОЙ ТУРЦИИ

Я. Бозкурт, А. Вагапова

Реферат

Цель этого исследования в том, чтобы оценить естественные пастбищные районы для животноводства в высокогорных районах Восточной Турции с использованием методов дистанционного зондирования (ДЗ) и приложений геоинформационных систем (ГИС).

Сделан вывод о том, что естественные пастбища составляют 2/3 всей исследуемой территории Карсской области. Однако, с точки зрения плотности растительного покрова, это составляет только 1/3 всей площади. Другими словами, только 181 275,7 га из 638 393,5 га лугопастбищных угодий находятся в лучшем состоянии для выпаса скота. В заключении были составлены цифровые карты лугопастбищных угодий с высоким разрешением.

Ключевые слова: природные пастбища, дистанционное зондирование, геоинформационные системы, спутниковые снимки, цифровые карты.

Introductıon

Remote sensing (RS) is known as a science of acquiring and interpreting information from a distance using sensors that are not in direct contact with the item being viewed. In this definition, aerial, satellite, and spacecraft observations of the surfaces and atmospheres of the planets in the solar system are included (Jensen, 1996).

A geographic information system (GIS) is a system for recording, storing, analyzing, and managing geographically referenced data and associated properties. In other word, it is a computer system that integrates, stores, edits, analyzes, shares, and displays geographically related data (Chandrakar and Thomas, 2010).

RS and GIS technologies have been of great use to planners in planning for efficient use of natural resources at national, state and district levels. Application of these technologies in the management of natural resources are increasing rapidly due to great strides made in spaceborne RS satellites in terms of spatial, temporal, spectral and radiometric resolutions (Venkataratnam, 2001). RS and GIS are being used increasingly as tools to assist in grassland resource inventory and integration of data and as a mechanism for analysis, modelling, and forecasting to support decision-making.

For the assessment of grasslands and the estimation of fodder availability, as well as the monitoring of natural range resources, remote sensing satellite images and Geographic Information Systems (GIS) are commonly implemented (Singh et al., 2011). Because in many developing countries, grazing resources are limited and natural grasslands are becoming more scarce, there is a higher need to effectively manage grasslands for maximum livestock feed production and environmental improvement (Roy and Singh, 2013).

Grasslands have been studied and monitored using satellite data in several different ecosystems and over seasonal and interannual periods to verify variability, production gains, and resilience. Because of its functions in maintaining atmospheric composition and improving local climate and soil moisture, grassland is an important aspect of terrestrial ecosystems. Grasslands provide the foundation for the existence and development of animal husbandry, in addition to their function in environmental conservation (Sala and Paruelo, 1997).

The composition of grasslands varies across the different topographic conditions due to variation in the species prevailing, rainfall patterns, animal grazing pressure, and successional status of plant species. Grasslands are often explored through field-based examinations in only a few places of the world (Pandey at al., 2021). Because grasslands cover a large spatial extent in isolated places and are physically difficult to reach, traditional evaluation methods are inefficient and expensive (Asrar et al., 1986). Remote sensing techniques that are more advanced are far more useful in scanning pastures, meadows and grasslands with fewer errors and corruption (Liu et al., 2001; Akiyama and Kawamura, 2007; Nayak et al., 2010).

Remote sensing technologies with proper representation of the number of pixels on a satellite picture that can be mapped with corresponding grass cover area can be used to determine percent grass cover (Friedl et al., 1994)

Overgrazing, inappropriate land use, drought, and other natural and human factors have combined to cause serious problems with grassland resources in recent years, including a decrease in vegetation biomass and coverage, a decline in productivity, a decline in forage quality, and a general decrease in grassland livestock capacity (Zhang et al., 2013).

Therefore, it was aimed to classify grassland types and to determine the potential grassland areas to be utilised for beef cattle producition in the highlands of Eastern part of Turkey with special reference to Kars Province located in the North-East, using RS techniques and GIS applications.

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Material and methods

Beef cattle production is carried out in general in vast conditions and on grasslands in the Eastern portion of Turkey, where the study area (Kars Province) is located, accounting for 41.4 percent of the country's total grassland area (Avcioglu, 2000). In terms of both the number of cattle and sheep (big and small animals) and the larger area of grassland accessible, Kars province is unique in the region (Anonymous, 1984).

Study area covered provincial boundaries of study area with an altitude of above 2000 m. The area of Kars province is 918.117 ha. It lies between 260 000-390 000 km East, 4 420 000 - 4 530 000 km North according to UTM Geographic Coordinate System. Ardahan province is in the North; Agri is in the South; Erzurum is in the West and Armenia is in the East. Figure 1 shows geographical location of the study area.

ArcGIS, Arc-Info and ERDAS Imagine softwares were used for the correction of the data obtained, interpretation, analysis and mapping of grasslands. GPS (Magellan 315) connected intensive ground truthing (GT) and in order to obtain the geospatial data on pasturelands, field samplings were conducted. Moreover, for supervised image classification of satellite images, these grasslands were analyzed, sampled, and GPS positions (43 points: latitude, longitude, and altitude) were recorded.

LANDSAT 5 TM satellite images taken were used and land use and land cover classification maps were produced using GIS. In order to determine the current status of grasslands, red (0.45-0.52 µm), near infra-red (0.52-0.60 µm) and infra-red (0.63-0.69 µm) bands of Landsat images were used to find the grasslands and unsupervised classification was applied and the distribution map of grasslands showing the present status was produced (Figure 2).

Results and discussion

According to the findings, the grassland area in the province was 638968.3 ha, or 66.7 percent of the total area. The grassland types I, II, and III, which accounted for 22.6, 34.1, and 10% of the total grassland area in the research region, occupied 216917.7, 326334.7, and 95716 hectares, respectively.

As it is indicated in Figure 2B, land use types classified as lakes, horticultural areas, pasture and shrubs, irrigated and non-irrigated areas, viniculture, abandoned and industrial areas including settelment areas are shown. However, forestry areas are indicated with dark green in the West part of the study area. Garssland areas are scattered all over the study area and shown light green while yellow coloured areas are non irrigated agricultural lands.

It was discovered that grassland areas cover 2/3 of the total area of Kars province. However, this only accounts for a third of the entire area in terms of plant cover density. In other words, just 181 275.7 ha of the total grassland area of 638 393.5 ha is in a better state in terms of plant cover for cattle to graze on. It was also discovered that the greatest quality grasslands for beef cattle production are found in the province's northwest corner, from the west of the Sarikamis forests to the north-western range of the Allahuekber mountains and the foothills of the Erdagi mountains (Figure 3).

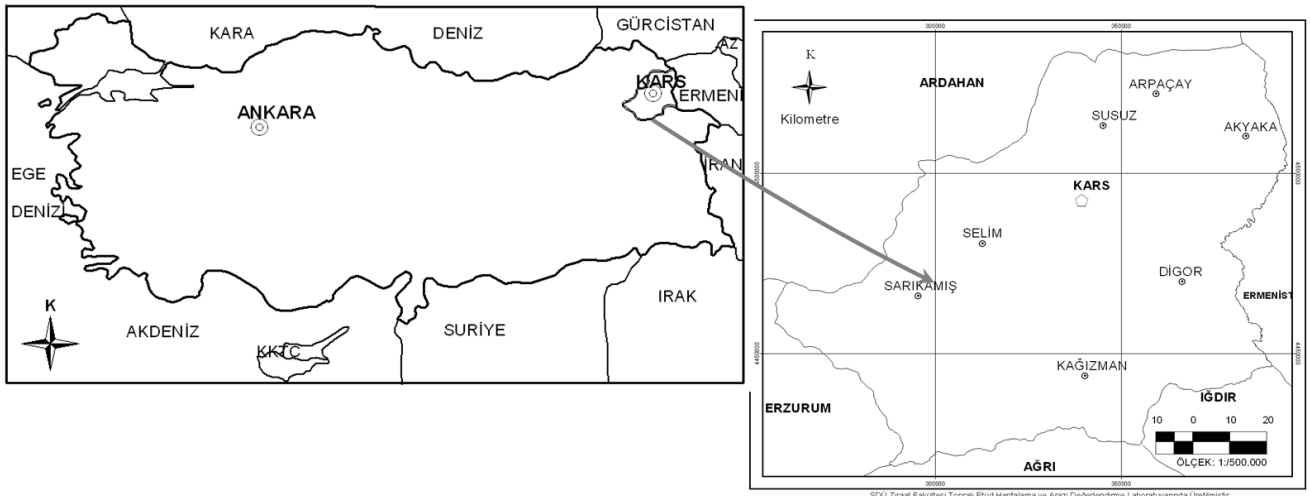

Figure 1 – Geographical location of the study area

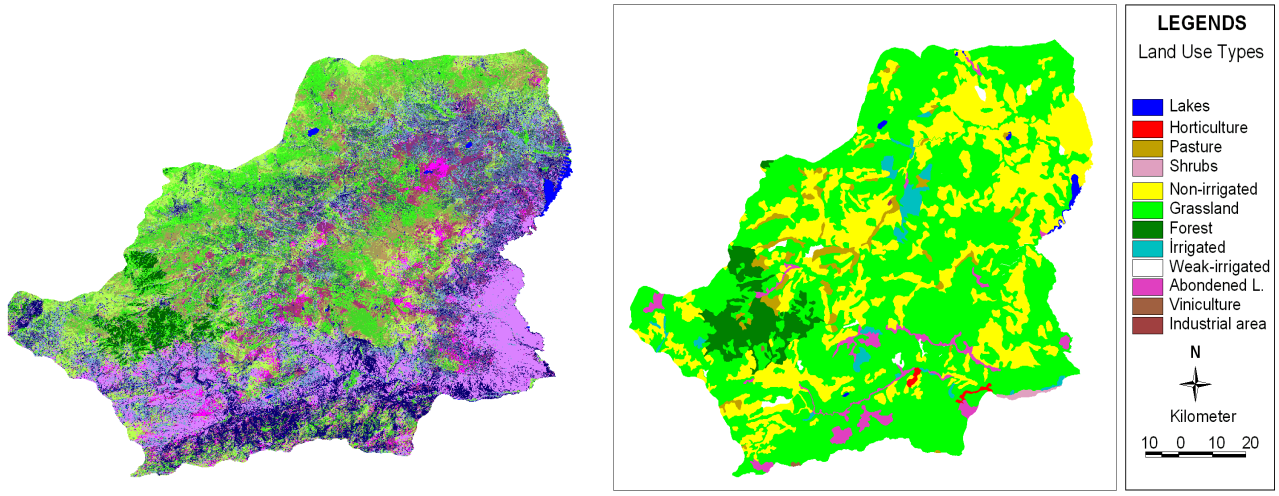

Figure 2 – Classified satellite data (A) and the map produced from these data (B)

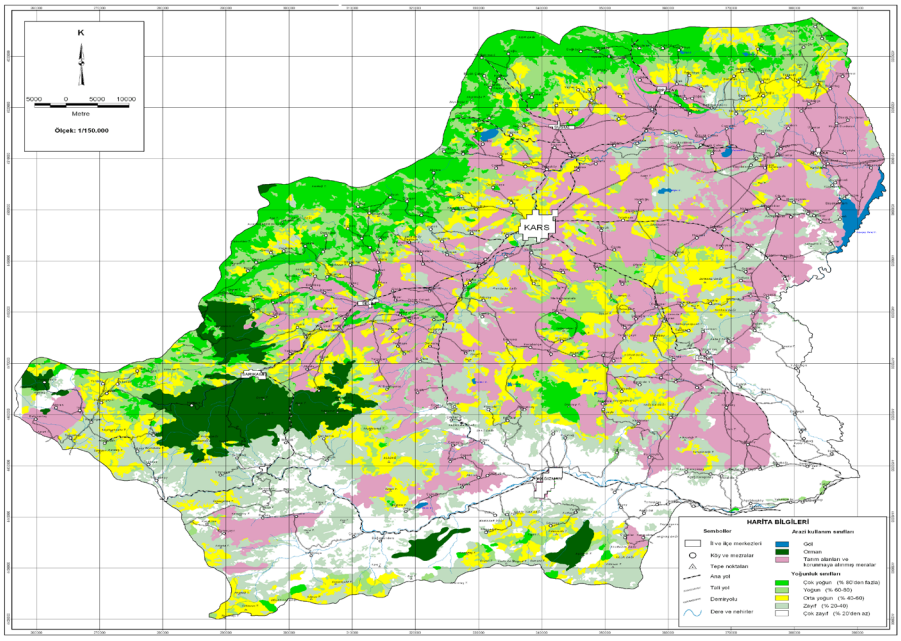

Figure 3 – Land use map of Kars and grassland classification distribution

As it is indicated in Figure 3, lakes are blue coloured, irrigated and non-irrigated agricutural areas are shown in pink colours. However, forestry areas are indicated with dark green in the West and some part of the South of the study area. Garssland areas are classified according to biomass intensity all over the study area and those shown in green areas lie upwards in the North West with very intensive level of more than 80% and light green areas with intensive level between 60-80% while yellow coloured areas are mid-level intensity between 40-60%, grey coloured areas are weak intensity level between 20-40% and white coloured areas are very weak intensity of less than 20%.

The grasslands in the study area have also been classified as Type I, II and III together with 3 sub-classes within each type according to biomass quality and vegetation cover and compared according to NDVI (Normalised Difference Vegetation Index). This work will be published in the future.

Conclusıons

It was concluded that in this region, where the economy is based on animal production, determination of grassland areas, stocking rates, estimation of biomass available for grazing, the length of vegetation period, and monitoring the change in grassland must all be included in Regional Development Plans, and the findings of this study can help improve beef cattle production in the region.

The results will undoubtedly influence grazing management decisions such as determining the start date of the grazing season, stocking rate, and the most appropriate grazing systems for the region. Therefore, monitoring the biomass and productivity of vegetation in a timely and accurate manner is an important subject for grassland resource management and of great significance for the scientific utilization and development of grassland resources.

To reduce the degradation of grassland and to keep grazing ecofriendly and sustainable, it is essential to study its current status with a degree of its severity both spatially and temporally so that appropriate pasture management strategies can be made.

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THE CONTRIBUTION OF CLIMATIC AND ANTHROPOGENIC FACTORS TO CHANGES IN THE RUNOFF OF PLAIN RIVERS

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Abstract

The changes in the annual runoff of plain rivers are estimated on the method that based on the restoration of the natural runoff of the last decades, during which significant anthropogenic changes took place. For these purposes, we used data on the runoff of rivers (tributaries of the considered rivers and their upper parts), the water regime of which is relatively slightly changed by anthropogenic impact. Data on restored river flow were compared with anthropogenic-altered flow for this period and for the base period preceding it, when anthropogenic impact can be neglected. It is shown that climatic and anthropogenic factors act on the runoff both unidirectionally, increasing or decreasing it, and in opposite directions. At the same time, the influence of anthropogenic factors, mainly reservoirs and water consumption, they are commensurate with the influence of climatic factors, and in many cases exceeds it.

Keywords: river flow changes, base period, period of significant anthropogenic impact, flow restoration method, anthropogenic factors, climatic factors.

ВКЛАД КЛИМАТИЧЕСКИХ И АНТРОПОГЕННЫХ ФАКТОРОВ В ИЗМЕНЕНИЯ СТОКА РАВНИННЫХ РЕК

О. Мешик, Л. Махмудова, А. Жарылкасын, А. Канатулы, М. Жулкайнарова

Аннотация

Оценены изменения годового стока равнинных рек на основе метода, основанного на восстановлении естественного стока последних десятилетий, в течение которых происходили его существенные антропогенные изменения. Для этих целей использованы данные о стоке рек (притоков рассматриваемых рек и их верхних частей), водный режим которых относительно слабо изменен антропогенным воздействием. Данные о восстановленном речном стоке сравнивались с антропогенно-измененным стоком за этот период и за предшествующий ему базовый период, когда антропогенным воздействием можно пренебречь. Показано, что климатические и антропогенные факторы действуют на сток как однонаправленно, увеличивая или уменьшая его, так и в противоположных направлениях. При этом влияние антропогенных факторов, главным образом водохранилищ и водопотребления, соизмеримо с влиянием климатических факторов, а во многих случаях превосходит его.

Ключевые слова: изменения речного стока, период значительного антропогенного воздействия, способ восстановления стока, антропогенные факторы, климатические факторы.

Introduction

The change in river flow in recent decades is due to the influence of both climatic factors and anthropogenic impacts. Revealing their role is extremely important for understanding the genesis of hydrological changes that have already occurred and possible in the future, as well as for taking measures to reduce or even completely eliminate their undesirable consequences. A combination of natural, mainly climatic, and anthropogenic factors also results in long-term changes in runoff. At the same time, the ratio of the composition of natural and anthropogenic factors to the ongoing changes remains insufficiently studied, despite the fact that the relevant studies were and are being conducted at the Institute of Geography and Water Security, Republican State Enterprise "Kazhydromet", the Government Hydrological Institute of Roshydromet (State Hydrological Institute) [1-4].

Insufficient knowledge is largely due to the close interweaving of natural and anthropogenic factors influencing the runoff, the difficulty of their separation. The complexity of solving this problem lies in the fact that climatic and anthropogenic changes in river runoff are closely interrelated and often affect the runoff not directly, but indirectly through relief, soil. Therefore, it is impossible to absolutely accurately separate the contribution of climatic and anthropogenic factors to the formation and change of river runoff, and one has to be content with relative estimates. Usually, they represent the value of deviations of the runoff from some basic values (for example, from its norm, the average long-term runoff or the runoff of some other period), calculated by different methods. Quite a large number of works [4-11] are devoted to the assessment of the ratio of climatic and anthropogenic factors in hydrological changes. However, this issue requires further study. In this work, an attempt was made to assess the impact of both, a complex of natural-climatic and anthropogenic factors, and the contribution of climatic and anthropogenic factors, respectively, to the change in the annual runoff of plain rivers.

Research methods

The concept of the study is based on an independent approach, in which the integral assessment of the influence of the considered runoff factors is based on the restoration of the conditionally natural annual runoff. With the regression relationships help of the annual runoff of large rivers and their tributaries (rivers-indicators), located in the formation area of the runoff in the main river under conditions of relatively small anthropogenic impact, and comparison of the restored runoff with the actual runoff. The developed approach makes it possible to identify long-term integral changes in river runoff – an assessment of the change in river runoff due to natural and climatic factors (by relationships between the flow of the main river and the flow of indicator-rivers).

For each river of the studied water management basin, the boundaries of the base periods (when anthropogenic impact can be neglected) and periods of significant anthropogenic impact were determined. For these periods, the average runoff values were calculated, as well as their difference. The difference shows the total changes in runoff that occurred under the influence of both anthropogenic impacts and climatic factors

(Table 1). At the same time, as it can be seen, the boundaries of the periods differ on the rivers under consideration, which is explained by the time of the onset of a significant anthropogenic impact [9].

To determine the contribution of anthropogenic and climatic factors to the total runoff change that occurred, presented in Table 1, a method based on the restoration of the natural (more precisely, conditionally natural) runoff of the studied rivers was applied. The method proceeds from regression relationships between the runoff of large rivers and their tributaries (indicator-rivers). The watersheds of indicator-rivers belong to the main area of runoff formation under conditions of relatively weak anthropogenic impact.

For this method, the assessment of the contribution of anthropogenic impacts and climate change to the total changes in runoff is based on a comparison of the runoff for the base period, relatively weakly affected by economic activity, with the actual and restored (conditionally natural) runoff for the period of significant anthropogenic impact.

Table 1 – Change in the volume of annual runoff under the total impact influence of climatic and anthropogenic factors, relative to the base period

River - point	Base period		Period of significant anthropogenic impact		Flow change		
	years	runoff volume, million m^3	years	runoff volume, million m^3	average for the year		total, million m^3
					million m^3	%	
Tobyl - Kostanay	1931-1963	523	1964-2019	293	-230	-44.0	-12880
Yesil - Astana	1933-1970	183	1971-2019	129	-54.0	-29.5	-2646
Yesil - Kamennyi Karier	1933-1970	1302	1971-2019	1211	-91.0	-6.99	-4459
Yesil - Petropavlovsk	1932-1970	1772	1971-2019	1930	158	8.92	7742
Nura - Balykty	1935-1973	189	1974-2019	325	136	72.0	6256
Nura - Romanovka	1933-1973	529	1974-2019	636	107	20.2	4922
Sarysu - №189	1932-1965	84.7	1966-2019	80.7	-4.00	-4.72	-216

At the same time, the difference between the restored (conditionally natural) runoff for the period of intense anthropogenic impact and the runoff of the base period characterizes the impact of climate change (assuming that they are not the result of human activity), and the difference between the restored (conditionally natural) and actual (observed) runoff period of intense anthropogenic impact – the contribution of anthropogenic impact on the total changes in runoff.

When restoring the conditionally natural runoff, it is taken into account that the long-term hydrological series of the rivers under consideration are heterogeneous in terms of the impact of anthropogenic factors on it and consist of two parts. The first part of the series includes long-term data relating to the period before the onset of a noticeable impact of anthropogenic factors. The second part consists of a long-term series, the annual runoff in which is changed to varying degrees as a result of the anthropogenic factors impact. As rivers-indicators of climatic conditions for the restoration of annual flow, data on tributaries were used, where economic activity is relatively insignificant. The annual runoff of this period was restored by two methods. One of them proceeds from regression relationships between the runoff of the main river and the runoff of rivers that are indicators of climatic conditions (tributaries and upper parts of the main river), characterized by relatively weak anthropogenic disturbances of the water regime. One of the first to use it was I.A. Shiklomanov [13-14].

This method has been further developed, and the resulting regression relationships are characterized by a fairly high reliability. The multiple linear correlation coefficients are in the range of 0.8-0.9, and the errors of the regression coefficients are two times less than their absolute values.

The calibration of the parameters was carried out on the basis of data from parallel observations over the years with no noticeable influence of anthropogenic factors on the upper and lower sections of the calculated sections. Part of the long-term series of annual and seasonal runoff, restored by one of the above methods, was combined with its other part, the runoff of which was not noticeably disturbed by anthropogenic impact. Thus, the general series of conditionally natural runoff were compiled, the average values of which were compared with the base and actual runoff for the period of significant anthropogenic impact.

Results and discussion

Changes in the annual runoff on the rivers that is under consideration (Table 1) had a multidirectional character – the total runoff on the Tobyl River during the period of significant anthropogenic impact decreased, and on the Nura River it increased due to the transfer of runoff from the Ertis – Karaganda canal. At the same time, the runoff of Tobyl near the city of Kostanay changed most noticeably in 1964-2019 decreased in comparison with the base period by more than 12800 million m^3 (over 200 million m^3/year), on the river Yesil in the alignment of Astana for the period from 1971-2019 the decrease in annual runoff amounted to more than 2600 million m^3 (about 50 million m^3/year), on the river Sarysu decline in annual runoff over the period from 1966-2019 amounted to more than 200 million m^3(5 million m^3/year), which had a very negative impact on the water management and hydro ecological situation in the basins. Table 2, Figure 1 shows the results of assessing the contribution of climatic and anthropogenic factors to these changes, calculated using the restoring conditionally natural flow method.

Table 2 – Changes in annual runoff over the period of significant anthropogenic impact, calculated by the restoring its conditionally natural values method, million m^3

River - point	Anthropogenic changes		Climate change	
	total for the period	average for the year	total for the period	average for the year
Tobyl - Kostanay	-10416	-186	-2464	-44
Yesil - Petropavlovsk	-13328	-272	21070	430
Nura - Balykty	3404	74.0	2852	62.0
Nura - Romanovka	-5566	-121	10488	228
Sarysu - №189	-1528	-28.3	1312	24.3

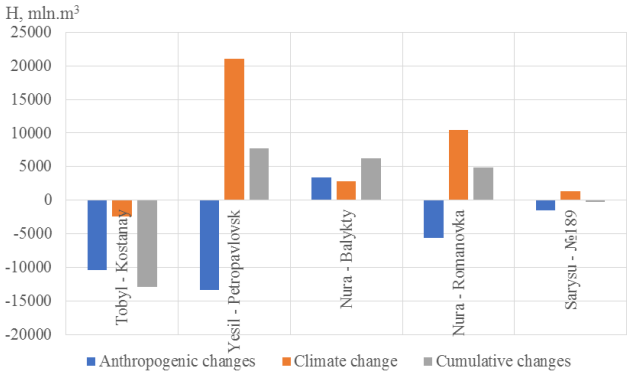

Figure 1 – Climatic and anthropogenic changes in runoff (H, million m^3)

As follows from Table 2, anthropogenic and climatic changes in the annual runoff on the river Tobyl were unidirectional – downward, and the share of anthropogenic changes is more than 80 %, respectively, the share of climate change is 20 %. On the rivers Yesil, Nura, Sarysu, the effect of anthropogenic and climatic factors was multidirectional with the predominant influence of anthropogenic factors. On the river Nura, the share of anthropogenic changes in the upper reaches is more than 54 %, respectively, the share of climate changes is 46 %, in the lower reaches 87 and 13 %, respectively.

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Conclusions

The obtained estimates of changes in the volume of annual runoff under the influence of the climatic and anthropogenic factors total impact of relative to the base period showed the following:

– Tobyl – the decrease in runoff is more than 40 %;
– Yesil in the alignment of Astana, the decrease leaves 30 %, further downstream in the alignment with Kamennyi Karier – 7 %;
– Sarysu – the decrease in runoff is 5 %;
– Nura – increase in runoff due to the transfer of runoff from the Ertis – Karaganda canal.

An assessment of the anthropogenic and climatic factors contribution to changes in annual runoff observed during the period of significant anthropogenic impacts of river basins so different in terms of water content and natural and economic conditions, such as Tobyl , Yesil, Nura, Sarysu, obtained by applying the method of restoring conditionally natural flow, showed the following picture – the share of anthropogenic and climatic factors in the decrease in annual runoff when using the method of restoring conditionally natural runoff is estimated on the river. Tobyl in 80 % and 20 %; on the river Yesil 70 % and 30 %; on the river Nura 87 % and 13 % respectively.

The methodological foundations development of the proposed approach to the study of modern changes is seen in the following directions. To restore long-term runoff series and to assess, on this basis, the relationship between climatic and anthropogenic factors in the past long-term changes in the runoff of large rivers, it is promising to use the relationships between runoff and its climatic factors using models that describe the processes of runoff formation with varying degrees. However, it should be borne in mind that such approaches have limitations and therefore it is necessary to use several methods and approaches for mutual control of the results.

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PROGNOSTIC METEOROLOGICAL REGULATION IN SOLAR ENERGY ENGINEERING

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Abstract

This paper considers an idea of saving energy resources by using meteorological data. Applying a prognostic meteorological approach to regulate parameters of a heat medium in solar thermal collectors allows decision-makers to regulate the temperatures designed, which might improve the efficiency in heating buildings.

Keywords: solar thermal collector, prognostic meteorological approach, solar radiation, heat supply, heat carrier.

МЕТЕОПРОГНОСТИЧЕСКОЕ РЕГУЛИРОВАНИЕ В ГЕЛИОЭНЕРГЕТИКЕ

О. П. Мешик, К. О. Мешик, М. В. Борушко, В. А. Морозова

Аннотация

В работе рассматриваются вопросы энергоресурсосбрежения на основе использования метеорологической информации. Метеопрогностическое регулирование параметров теплоносителя позволяет адаптировать подготавливаемые температуры, тем самым повышая эффективность отопления зданий.

Ключевые слова: гелиоколлектор, метеопрогностический подход, солнечное излучение, теплообеспечение, теплоноситель.

Introduction

In this research solar thermal collectors are taken as an alternative partial substitute for conventional heat sources. According to Solar Heat Worldwide 2021 [1], the solar thermal market is growing steadily. The global solar thermal energy yield increased from 51 TWh in 2000 to 407 TWh in 2020, i.e., it grows by 10 % annually.

In Belarus the share of renewable energy resources in the total energy yield is increasing gradually. According to REN21 and the United Nations Economic Commission for Europe [2], the estimated 7 % share of renewable energy in the total final energy consumption in 2025 was already reached in 2018. The target share of 9 % in 2035 is likely to be reached much earlier due to the complete commissioning of Belarusian nuclear power plant. What is more, some research [3] estimates solar power potential in the area as quite sufficient to be used in both solar heating collectors and PV systems.

Highly efficient operation and optimization are of high priority for any heating system. These criteria depend not only on the heat carrier's properties and its economic feasibility but also the effectiveness in regulating parameters of the heating system.

This research is based on a prognostic meteorological approach used to regulate the parameters of the heat carrier in a predictive way [4]. A number of basic criteria necessary to provide algorithms for predictive control have some internal and external factors.

Internal factors directly affect the microclimate of the room. The main internal factor is temperature regime as it constantly changes due to its interaction with outside disturbance agents. Local building codes [5] regulate a standard inside temperature range within 18-24 °C. Often dwellers expect more optimal temperature parameters which are taken into account in prognostic meteorological approach which can contribute to much more comfort during the heating season. There are other unregulated internal factors that influence the microclimate in the room. These are household appliances, people in the room, etc. It is difficult to calculate the heat produced by them as it depends on how long they work generating heat. However, it is possible to calculate the heat lost through the walling and hysteresis of water heating systems.

External factors mean meteorological characteristics making impact on the walling. The most important one is dynamic changes of ambient air.

Methods and Materials

In this research we developed a method for a combined use of solar thermal collectors as a primary heat source and a prognostic meteorological approach in order to determine the most accurate parameters for the heat carrier with the optimal operational efficiency of the heating system.

The paper is based on meteorological observation data registered in 2021-2022 by Belhydromet (Belarus state institution "Republican centre for hydrometeorology, control of radioactive contamination and environmental monitoring") [6]. These data allow us to analyse temperature fluctuations in the area under study. API Яндекс.Погоды [7] is used as a source of prognostic meteorological data.

The authors of the research applied such methods of processing statistical and experimental data as regression analysis, time series analysis, analytical generalization of meteorological data with further calculation, etc. The calculation is automated with the use of SunCalc JavaScript library and MS Excel software.

Results and Discussion

We estimate the performance of flat-plate collectors by identifying hourly peaks in thermal energy generation and total daily sums. The efficiency factor of solar collectors is interpreted with the following formula [8]

$$\eta = \frac{Q_{gk}}{F_{gk} \cdot Q}, \quad (1)$$

where Q_{gk} is thermal energy generated by the solar collector per unit of time, W; F_{gk} is solar collector area, m^2; Q is total solar radiation reaching the solar collector's surface, W/m^2.

Q_{gk} parameter characterizes effective work of the solar collector since in general terms it represents the difference between the solar radiation absorbed by the plate and the one reflected back to the environment. The calculation is performed with the following equation [9]

$$Q_{gk} = q_o \cdot F_{gk} \cdot \left(Q(m \cdot l) - W \cdot \left(T_{vch} - T_{vych}\right)\right), \quad (2)$$

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where q_o is heat transfer coefficient of the solar collector; m is capacity of the outer layer of the solar collector to transmit solar radiation; l is absorption of solar radiation by the inner layer of the solar collector; W is heat loss of the solar collector, $W/(m^2 \cdot °C)$; T_{vch}, T_{vych} are inlet/outlet temperatures of the heat carrier in the solar collector's pipelines, °C.

It is necessary to consider heat losses of the solar collector as total sums. That is why it is necessary to single out separately heat lost through the upper and lower surfaces, as well as through the side walls of the body frame [9]

$$W = W_v + W_n + W_b \,, \tag{3}$$

where W_v, W_n, W_b are heat losses through the upper, lower and side surfaces of the collector, $W/(m^2 \cdot °C)$.

Heat loss through the side walls is extremely low provided that the thermal insulation is sufficient. We accept that $W_b \approx 0\ W/(m^2 \cdot °C)$ in the solar collector chosen for our study. Thus, the calculation of heat loss through the upper and lower surfaces is as follows [9, 10]:

$$W_v = \left(\frac{N}{\frac{344}{T_P} \cdot \left(\frac{T_P - T_V}{N + f}\right)^{0.31}} + \frac{1}{h_{konv}} \right)^{-1} + \\ + \frac{\sigma \cdot (T_P + T_V) \cdot \left(T_P{}^2 + T_V{}^2\right)}{\left(\varepsilon_P + 0.0425N(1-\varepsilon_P)\right) + \left(\frac{2N+f-1}{\varepsilon_S} - N\right)}, \tag{4}$$

$$W_n = \frac{1}{\frac{a_1}{b_1} + \frac{a_2}{b_2}}, \tag{5}$$

where N is the number of glass surfaces, pcs; σ is Stefan-Boltzmann constant, $W/(m^2 \cdot K^4)$; ε_P is emissivity factor of the plate; ε_S is emissivity factor of the glass; T_P is temperature of the plate, °C; T_V is air temperature within the collector, °C; h_{konv} is plate convection coefficient, $W/(m^2 \cdot °C)$; f is convection function [11]; a_1, a_2 are thickness of the insulating layer and the wall, m; b_1, b_2 are heat transfer coeficient of the insulating layer and the wall, m.

If you want to determine a heat transfer coefficient q_o, you must have data about the efficiency of the whole collector E_{gk} and the efficiency of its individual fin E_r. These parameters are calculated by the formula [10]:

$$q_o = \frac{G \cdot c_t}{W} \cdot \left(1 - e^{\frac{-W \cdot E_{gk}}{G \cdot c_t}}\right), \tag{6}$$

$$E_{gk} = \frac{1}{\left(\frac{d \cdot W}{\pi \cdot D \cdot h}\right) + \left(\frac{d \cdot W}{P}\right) + \left(\frac{d}{(d-D) \cdot E_r + D}\right)}, \tag{7}$$

$$E_r = \frac{th \sqrt{W/_{k \cdot v}} \cdot \frac{1-D}{2}}{\sqrt{W/_{k \cdot v}} \cdot \frac{1-D}{2}}, \tag{8}$$

where G is heat carrier flow rate through the solar collector, m^3/h; c_t is specific heat capacity of the heat carrier in the solar collector, J/(kg · °C); E_{gk} is solar collector efficiency; d is distance between the pipelines of the solar collector, m; D is outer diameter of the collector pipeline, m; h is intensity of heat transfer from the pipeline wall to the heat carrier; P is conductivity of the connection of the surface with the pipeline, m· °C/W; E_r is efficiency index of the solar collector fin; k is coefficient of thermal conductivity of the plate, W/(m ·°C); υ is plate thickness, m.

We calculated solar radiation on sloped surfaces depending on geographical position in our previous studies [11]. In order to enhance performance, we can adjust the collector's orientation in two different ways. We can adjust the inclination angle of the collector's receiving surface β annually or monthly. Thus, the orientation conditions are described by the following equations:

$$\beta^g = \varphi \,, \tag{9}$$

$$\beta_n^{mes} = \varphi + \mu_n^{mes} \,, \tag{10}$$

where φ is latitude of the geographical point, rad; μ_n^{mes} is additional angle in a certain time period, rad (Table 1) [12].

Table 1 – Additional angle β_n^{mes} in certain time periods, rad

Time period	Gradation	β_n^{mes}	μ_n^{mes}
December 8 – January 22	1	β_1^{mes}	$\mu_1^{mes} = +23.5$
January 23 – February 7	2	β_2^{mes}	$\mu_2^{mes} = +20$
January 8 – January 21	3	β_3^{mes}	$\mu_3^{mes} = +15$
January 22 – March 6	4	β_4^{mes}	$\mu_4^{mes} = +10$
March 7 – March 21	5	β_5^{mes}	$\mu_5^{mes} = +5$
March 22 – April 2	6	β_6^{mes}	$\mu_6^{mes} = 0$
April 3 – April 16	7	β_7^{mes}	$\mu_7^{mes} = -5$
April 17 – April 30	8	β_8^{mes}	$\mu_8^{mes} = -10$
May 1 – May 21	9	β_9^{mes}	$\mu_9^{mes} = -15$
May 22 – June 5	10	β_{10}^{mes}	$\mu_{10}^{mes} = -20$
June 6 – July 7	11	β_{11}^{mes}	$\mu_{11}^{mes} = -23.5$
July 8 – August 11	12	β_{12}^{mes}	$\mu_{12}^{mes} = -20$
August 12 – August 25	13	β_{13}^{mes}	$\mu_{13}^{mes} = -15$
August 26 – September 8	14	β_{14}^{mes}	$\mu_{14}^{mes} = -10$
September 9 – September 21	15	β_{15}^{mes}	$\mu_{15}^{mes} = -5$
September 22 – October 5	16	β_{16}^{mes}	$\mu_{16}^{mes} = 0$
October 6 – October 18	17	β_{17}^{mes}	$\mu_{17}^{mes} = +5$
October 19 – November 2	18	β_{18}^{mes}	$\mu_{18}^{mes} = +10$
November 3 – November 22	19	β_{19}^{mes}	$\mu_{19}^{mes} = +15$
November 23 – December 7	20	β_{20}^{mes}	$\mu_{20}^{mes} = +20$

The prognostic meteorological approach to regulating operation cycles of a heat supply system is implemented in our previous research [13]. The study is based on the principle of combining a primary heat source with adjusting the temperatures in the supply and return pipelines taking into account the meteorological factor to reduce the overall fuel and energy costs.

We take a flat-plate solar collector FKF240 as an example to perform our calculation [14] (Fig. 1). Its technical specification is presented in Table 2.

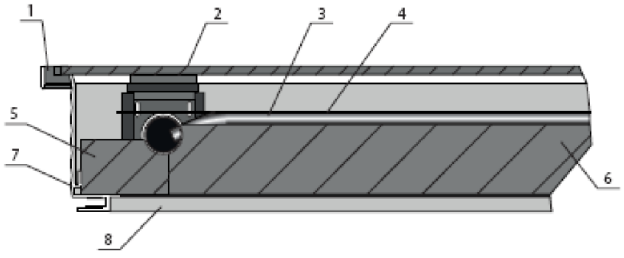

Figure 1 – FKF240 (1 – sealing; 2 – protective glass; 3 – heat pipe; 4 – absorber; 5, 6 – thermal insulation (side and bottom); 7 – frame; 8 – base

Table 2 – FKF240 technical characteristics

Size: L x W x H, mm	Heat carrier flow rate, m^3/h	Pipeline diameter, mm	Absorber material	Plate heat transfer, W/(m · °C)	Plate thickness, mm
2100 x 1200 x 115	15-40	22	Al	197	5

The collector is installed at 51,889803° N. lat., 23,812028° E. long. (Belarus, Brest region, Stradech). The measurements were taken from 10:00 to 17:00 on December 22, 2021.

The solar radiation reaching the collector in the daytime is presented in Figure 2.

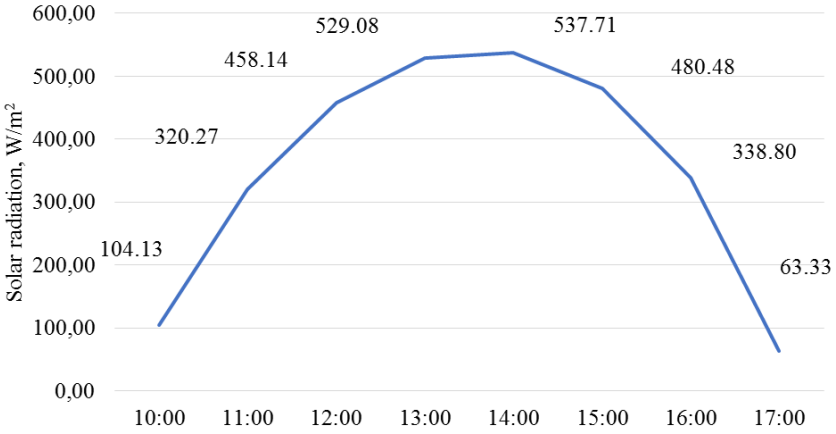

Figure 2 – The course of total solar radiation (22.12.2021)

After adjusting the heat medium parameters in the heating system with prognostic meteorological approach the temperature values reduced (Table 3).

Table 3 – Temperature fluctuations in inlet and outlet pipelines adjusted for meteorological data (22.12.2021)

Time	00:00	03:00	06:00	09:00	12:00	15:00	18:00	21:00
Ambient temperature, °C	-4.1	-4.9	-7.6	-8.4	-8.7	-7.9	-7.4	-10.8
Inlet pipeline temperature, °C	65.9	66.3	70.7	72.5	72.8	71.1	70.4	76.3
Outlet pipeline temperature, °C	56.1	57.9	60.3	70.4	70.6	60.8	60.2	62.8

The cost of energy resources is reduced by 16 % by using meteorological indicators in the collector's work. However, the more data about outside weather conditions are available, the more accurate calculation might be done. In our further studies we suppose to take into consideration wind and precipitation dynamic parameters under different conditions.

The results of our calculation for the solar collector as a primary heat source are given in Table 4.

Table 4 – Solar radiation. Collector's efficiency at different time

Time	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00
Q, W/m^2	104.13	320.27	458.14	529.08	537.71	480.48	338.80	63.33
$Q_{\text{гк}}$, W/m^2	19.34	87.18	149.8	193.09	204.79	163.85	99.98	8.18
η, %	8.64	12.66	15.21	16.97	17.71	15.86	13.73	6.01

Thus, the collector's efficiency at the zenith on the winter solstice is around 18 %. We observe that the heat medium temperature decreases while the overall fuel and energy saving of the secondary heat source increases. However, the results obtained are reliable in the conditions with no external disturbance such as dust deposition, snow covering a solar collector, and cloudiness.

Conclusion

Implementing solar systems into the energy supply structure in Belarus climate depends directly on improving their operational efficiency. Although we have quite sufficient climate resources to develop solar energy industry, economically justified energy generation can be achieved through the combined use of several energy-efficient approaches.

Using solar thermal collectors as an alternative energy source operating according to certain meteorological factors allows us to increase their efficiency, maintain them in an environmentally friendly manner and find the most effective combinations of their application.

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APPROACHES TO ESTIMATE THE SOCIO-ECONOMIC RISKS CAUSED BY THE RIVER FLOOD

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Abstract
The issues of forecasting damage caused by flooding of anthropogenically transformed territories in a river floodplain of a plain type are considered based on the case of the floodplain of the Pripyat River. A method of spatial analysis of the level of the territory usage and the depth/duration of flooding is proposed, the results of which are applicable in preparation of maps of the socio-economic risks associated with flooding, and in planning anti-flood measures.

Keywords: river flood, anthropogenic transformed territories, socio-economic damage.

ПОДХОДЫ К ОЦЕНКЕ СОЦИАЛЬНО-ЭКОНОМИЧЕСКИХ РИСКОВ, ВЫЗВАННЫХ РЕЧНЫМ ПАВОДКОМ

А. А. Волчек, Д. А. Костюк, Д. О. Петров, Н. Н. Шешко

Реферат
Рассматриваются вопросы прогнозирования ущерба в результате затопления антропогенно-преобразованных территорий в пойме рек равнинного типа на примере поймы реки Припять. Предлагается метод пространственного анализа уровня использования территории и глубины/длительности затопления территории, результаты применения которого применимы при картировании связанных с наводнением социально-экономических рисков и планировании противопаводковых мероприятий.

Ключевые слова: речной паводок, антропогенно-преобразованные территории, социально-экономический ущерб.

Introduction

Methods of geographical analysis and forecasting have found wide application in almost all areas of the economic activity, and in particular in predicting the occurrence and development of dangerous hydrological phenomena (flooding of the territory) [3, 6]. Many scientists are developing methods and algorithms for calculating the boundaries and zones of flooding [8], and flood damage forecasting issues are particularly relevant for highly anthropogenic transformed territories [4, 7]. This also applies to flooding in the floodplains of the rivers.

Methods of geographical analysis and forecasting have found wide application in almost all areas of the economic activity, and in particular in predicting the occurrence and development of dangerous hydrological phenomena (flooding of the territory). Many scientists are developing methods and algorithms for calculating the boundaries and zones of flooding, and flood damage forecasting issues are particularly relevant for highly anthropogenic transformed territories [9]. This also applies to flooding in the floodplains of the rivers.

In particular, flooding is already a frequent guest in a number of river systems of the Baltic basin. In Belarus, the flood situation within the Pripyat River during the spring flood should be specifically mentioned: almost every year this territory and settlements in its floodplain are subjected to flooding typical for lowland rivers with predominantly snow feeding, resulting in significant economic damage [1, 2].

Flood prevention can be an effective defense mechanism by recognizing the need for information about the causes and consequences of floods and taking flood protection measures. An important element of this is the forecasting of the development of natural and climatic phenomena, their economic and social effect.

The degree of risk associated with such phenomena can generally be expressed as a combination of the probability of occurrence of damage and its consequences. Risk is most often expressed by multiplying the probability of occurrence of a negative event by the severity of its consequences. In one form or another, a similar equation is used to express flood risk in many sources [3, 4], but the specific variables vary significantly depending on the region and source data being assessed.

Estimating the socio-economic damage

Economic damage caused by hazardous hydrological phenomena can be estimated using the ArcGIS Spatial Analyst calculation algorithm package, designed to work with raster maps of various types of geographical phenomena [5]. First, it is necessary to prepare thematic layers of GIS (digital layers) of territories with different levels of economic efficiency, book value and social significance. Thus, it is possible to generalize the study area from a socio-economic point of view. In turn, the mentioned above approach requires a complete and detailed GIS with technical and technological parameters of technogenic objects, which is currently not possible for large areas due to the lack of such an integrated system, and the accuracy of the estimates will not increase significantly. This is due to the fact that enlargement and generalization when performing such estimates makes it possible to smooth out the forecast errors of the flood zone. To represent such an effect, one can conduct a mental experiment: the forecast of the flood zone was made with an accuracy of 100-500 m, while within the limits of the forecast accuracy there is an object with great economic efficiency, in which case the economic damage will be significantly overstated. The overestimation of economic damage will be proportional to the ratio of economic efficiency (or cost, or social significance) of the considered individual object to its average value over the territory of flooding.

The next issue that needs attention is the depth of the water within the flood zone. Depending on the depth of water, the magnitude of socio-economic damage per unit area is estimated. To take into account these features, weights can be used, obtained from preliminary physical, technical and economic analysis of the effect of the water depth of the territory in question on the amount of damage. At the same time, the application of expert estimates method for determining the weight coefficients is quite effective.

The duration of flooding of the territory can be taken into account in the same way as in the case of the depth of water in the territory in question [6], based on weighting factors. Thus, a quantitative risk assessment R can be represented as a product of combinations of the probabilities of flooding events and its duration by an assessment of the socio-economic significance of the j-th area of the territory:

$$R = E_j \cdot \left(p^h_{i,j} \cdot p^t_{i,j}\right) = \sum_{i=1}^{n}\left(p^h_{i,j} \cdot k^h_{i,j}\right) \cdot \left(p^t_{i,j} \cdot k^t_{i,j}\right) \cdot F_i \cdot e_j, \quad (1)$$

where E_j is the amount of damage to the j^{th} type of land, in monetary units;

$p^h_{i,j}$, $p^t_{i,j}$ – probabilistic estimates of the depth and duration of flooding of the jth fragment of the territory of the i^{th} area;

$k^h_{i,j}$, $k^t_{i,j}$ – respectively, weight coefficients taking into account the depth of the water standing and its duration for the i^{th} fragment of the j^{th} type of land, dimensionless;

F_i is the area of the i^{th} section formed by the intersection of the geometric polygon of the j^{th} type of land and the flooding polygon classified by depth and duration of the water standing, in the units of area;

e_j – specific efficiency (or cost, or social significance) of the j^{th} type of land, in monetary units per unit of area.

Weights can be determined through the signal functions as follows:

$$k^h = 0{,}5 \cdot \left(\frac{e^{2(h \cdot a_h + b_h)} - 1}{e^{2(h \cdot a_h + b_h)} + 1} + 1 \right) , \quad (2)$$

$$k^t = 0{,}5 \cdot t \cdot \left(\frac{e^{2(t \cdot a_t + b_t)} - 1}{e^{2(t \cdot a_t + b_t)} + 1} + 1 \right) , \quad (3)$$

where a_h, b_h, a_t, b_t are the parameters of the function determined based on the inflection points of the hyperbolic tangent (Fig. 1). In this case, the inflection points correspond to the first and second critical zones.

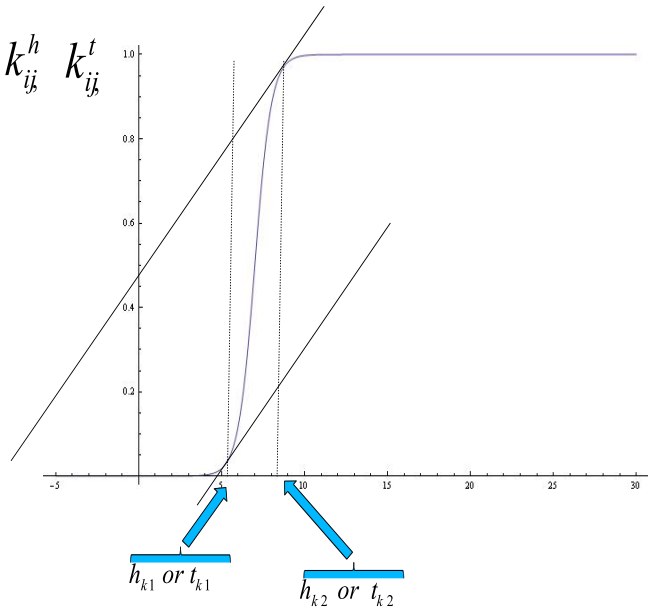

Figure 1 – The scheme for determining the parameters of the signal function

In the figure, one can see the signal function and two critical zones of the conditions for the formation of damages (and, accordingly, the risks of their occurrence) from flooding. The abscissa shows the parameters of the depth and duration of flooding, given by weight coefficients, the values of which depend on the critical zones k_1 and k_2, which, in turn, are determined by the physical and social conditions of damage formation. Thus, 3 zones of damage formation can be distinguished:

1. The first zone is taken for the depth/duration of flooding, when the amount of damage becomes calculable.
2. The second zone means that the damage increases linearly with the increase of the factor (depth or time of flooding);
3. The third zone corresponds to the depth/duration of flooding, the increase of which does not lead to an increase in damage, but is characterized by the areas taken out of circulation and the actual damage calculated for the second zone.

Using the example of determining the flooding time weight coefficient, we define the parameters of the function as follows

$$\begin{matrix} at\ h = h_{k1}, \frac{dk^h}{dh} \to 1 \\ at\ h = h_{k2}, \frac{dk^h}{dh} \to 1 \end{matrix} \to \begin{bmatrix} a_h \\ b_h \end{bmatrix}. \quad (4)$$

It should also be noted that there are differences in the equations for determining the weight coefficient of the depth of flooding and its duration. In the case of a relationship between the depth of flooding, when a certain level is exceeded, the damage stops growing almost completely. However, considering the time of flooding, from a certain moment only fixed costs can be considered as damage, the amount of which is directly proportional to the time of flooded territories exclusion from economic operation.

Risk visualization

It can be assumed that when representing a function in the form of a three-dimensional model, the line of intersection of the resulting surfaces corresponds to the most critical zone and maximum risks in terms of representing socio-economic consequences, thus forming the curve of the greatest damage in three-dimensional coordinates (Fig. 2).

Taking into account the equation of these functions intersection for local conditions of the flood formation, it is possible to obtain the personal weight coefficients of the damage risks.

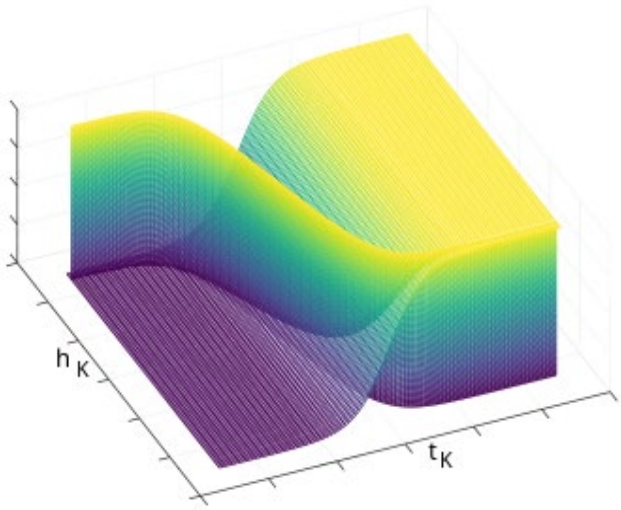

Figure 2 – A three-dimensional to find the line of intersection of the signal functions

The mouth of the Shchara River near a rural settlement was taken as a model site (Fig. 3). A spatial model of the distribution of the probabilities of occurrence of material damage was built using the predicted flooding of the territory and previously obtained weight coefficients (Fig. 3). Zones with a high level of amenities and a low degree of resistance to prolonged flooding are noticeably distinguished in this figure. The predicted value of damage as a result of flooding of the territory can be calculated based on this approach and using the cadastral database of land value and real estate. This, in turn, will make it possible to take into account such probable expenses in the preparation of both local budgets of the territories and the budget of the country as a whole.

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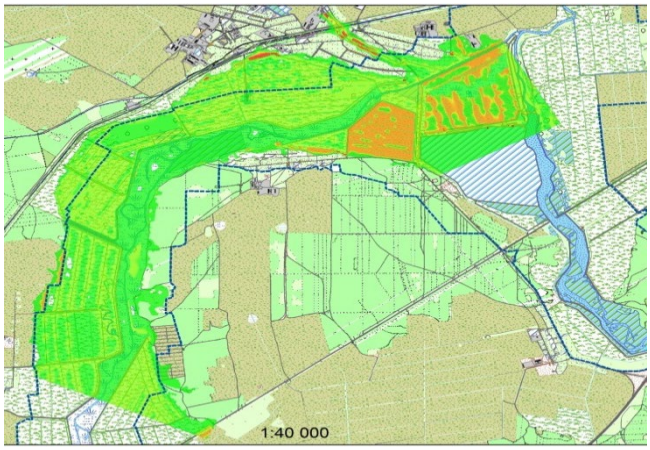

Figure 3 – Visual representation of the socio-economic risk

The approach based on the results of flood prediction, land segmentation based on its anthropogenic transformation, and GIS-based visualization provides the basis for further risk assessment and in planning the needed anti-flood measures and changes to the socio-economic activity on the territory.

Conclusion

Prevention or at least minimization of damage from natural disasters in modern conditions of high anthropogenic transformation is becoming increasingly important. In recent decades, there has been a steady trend towards an increase in the number of dangerous meteorological phenomena, which leads to an increase in socio-economic damage. The use of complex engineering measures, as a rule, reduces the damage caused by minor deviations of hydrological indicators from the average value [10]. A decrease in the calculated hydrological probabilities (less than 1%) leads to a significant increase in the cost of protective engineering and technical measures. Considering the problem from the point of view of the socio-economic damage probability makes the forecast of the allowable amount of damage with a given probability an urgent task. The approach presented in the paper, based on the identification of two critical levels of the impact of flooding, made it possible to establish the most unfavorable case of flood development. For these conditions, the boundary values of the depth and duration of flooding are determined. Using the established boundary conditions, a forecast of the socio-economic risks of flooding was developed for the model river section and the residential area adjacent to it.

The presented methodology for predicting socio-economic risks as a result of flooding of territories makes it possible to obtain quantitative estimates of probable material damage, which makes it possible to carry out budget planning on its basis, which ensures compensatory measures.

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SPATIAL AND TEMPORAL VARIABILITY OF THE SURFACE RIVER RUNOFF IN BELARUS

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Abstract

An assessment of changes in the surface river runoff of Belarus in modern conditions is given. Significant negative trends were found for the series of the percentage of surface runoff in the total volume of annual runoff for the period 1948–2017. The greatest decrease in surface runoff is observed in the south of Belarus. The degree of synchronicity of fluctuations of the long-term surface runoff of large rivers of Belarus is estimated. A modern map of the average annual modules of the surface river runoff distribution in Belarus has been obtained.

Keywords: surface runoff, underground runoff, hydrograph dissection, long-term variability, surface runoff modulus.

ПРОСТРАНСТВЕННО-ВРЕМЕННАЯ ИЗМЕНЧИВОСТЬ ПОВЕРХНОСТНОГО СТОКА РЕК БЕЛАРУСИ

А. А. Волчек, С. И. Парфомук, С. В. Сидак

Реферат

В работе дана оценка изменений поверхностного стока рек Беларуси в современных условиях. Для рядов доли поверхностного стока в общем объеме годового стока обнаружены значимые отрицательные тренды за период 1948–2017 гг. Наибольшее уменьшение поверхностного стока наблюдается на юге Беларуси. Выполнена оценка степени синхронности колебаний многолетнего поверхностного стока крупных рек Беларуси. Получена современная карта распределения среднемноголетних модулей поверхностного стока рек Беларуси.

Ключевые слова: поверхностный сток, подземный сток, расчленение гидрографа, многолетняя изменчивость, модуль поверхностного стока.

Introduction

Assessment of modern resources of the surface river runoff in connection with the ongoing global climatic changes is one of the urgent and complex tasks of hydrology. Today, scientific research on the dynamics of surface runoff in Belarus has not been carried out enough. However, the solution of this problem is important both from the scientific and practical point of view. Surface waters being one of the components of water resources are of great economic importance.

River runoff is combined of the surface and underground runoff. Surface runoff in the warm season is rarely observed in most of the territory of Belarus, which is a consequence of changes in the infiltration properties of the soil. During this period th surface runoff can be noted only after heavy rains. The problem in assessing surface runoff is as follows:

- this resource varies both in territory and in time;
- surface runoff, unlike underground, is characterized by extreme unevenness throughout the year.

The purpose of this work is to study the modern features of the spatial and temporal variability of the surface runoff resources of the rivers in Belarus through the analysis of long-term series of hydrological observations.

The realization of this goal consists in the consistent fulfillment of the following tasks:

- selection of a representative calculation period of hydrological observations to identify spatial-temporal patterns of surface runoff formation;
- reduction of river runoff data to a single multi-year period;
- substantiation of the methodology for assessing the surface runoff of the rivers in Belarus;
- quantitative assessment of the surface river runoff in Belarus;
- selection of the method of spatial interpolation of the studied characteristics of the river runoff;
- construction the map of the modules of the surface runoff of the rivers in Belarus;
- assessment of changes in the spatial-temporal transformation of the surface runoff of the rivers in Belarus.

Materials and methods

The observational data from the State Institution "Republican Center for Hydrometeorology, Control of Radioactive Contamination and Environmental Monitoring" of the Ministry of Natural Resources and Environmental Protection of the Republic of Belarus for the current hydrological stations for the period of instrumental observations published in the materials of state cadasters was used.

An important factor in the assessment of surface runoff is the choice of a representative period from the general data. The use of series of observations of the average annual, maximum and minimum river runoff rates for hydrological studies requires the selection of a calculation period for which the following conditions must be met:

- the average values of the series of observations correspond to the norm;
- the completed period of fluctuations in water content is traced;
- the length of the series is sufficient to assess the required empirical availability of water.

According to [1], the amount of observations of river runoff is considered representative for determining the average long–term value if the average square error of the calculated value of the hydrological characteristic does not exceed 10% for annual runoff and 20% for maximum and minimum runoff.

In this study, a method based on the use of "dynamic" estimates of hydrological parameters was used to assess the representative period [2]. Based on the results of the application of this method, as well as the study of the cyclicity of the long-term series of the runoff of the rivers of Belarus, the 70-year period of 1948-2017 was chosen as the calculation period for assessing the long-term variability of the surface runoff, and the period of 1953-2017 was chosen for constructing the map of the modules of the surface runoff [3].

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When working with spatial data, first of all it is necessary to understand how effective the monitoring network is [4]. In [5] the optimal number of hydrological observation stations for the values of the runoff of the rivers of Belarus was investigated. The study shows that the number of runoff monitoring stations is sufficient to solve various water management and hydrological problems. At the same time, the number of hydrological observation stations for annual runoff is minimal. Based on this, the construction of the map in this work was carried out using data on 120 hydrological stations evenly located on the territory of Belarus. The reduction of series with a short duration of observation periods to a multi-year period for calculating the values of surface runoff and constructing a map was carried out using the computer software complex "Hydrologist-2" [6].

Since measurements of surface runoff are not carried out by an instrumental method, the hydrograph dismemberment method is used to determine it. The use of this method makes it possible to isolate the underground component from the runoff hydrograph. The most difficult task is the dismemberment of runoff for periods of high water and large floods. In the literature, there are various approaches to the assessment of underground runoff in these phases of the water regime. The methods of dissection of the hydrograph are reflected in the works of B. V. Polyakov, B. I. Kudelin, K. V. Voskresensky, M. I. Lvovich, O. V. Popov [7-10].

In practice, when there is a lack of information about the relationship of river and groundwater, it is often assumed for lowland rivers that the amount of underground supply at the time of peak flood is equal to zero. Since the rivers of Belarus are characterized by a mixed type of nutrition, in this work, as the basis for the model for determining surface runoff, the method of dissection of hydrograph B.P. Polyakov is used, according to which, as the spring flood rises, underground nutrition sharply decreases and stops altogether when the flood peak passes. Then, when the flood subsides, the underground runoff gradually increases, which is due to the return of water by the floodplain of the river [11]. Annual values of surface runoff are calculated as the difference between annual and underground runoff:

$$Q_{suf_i} = \begin{cases} Q_i - \bar{Q}_{min}\ , & i < t_n \\ Q_i - \left(Q_{t_n} + \frac{(i-t_n)(Q_{t_{max}} - Q_{t_n})}{t_{max} - t_e}\right), & t_n \le i < t_{max} \\ Q_i - \left(Q_{t_{max}} + \frac{(i-t_{max})(Q_{t_e} - Q_{t_{max}})}{t_e - t_{max}}\right), & t_{max} \le i < t_e \\ Q_i - \bar{Q}_{min}\ , & i > t_e \end{cases} \quad (1)$$

where $i = \overline{1,n}$ – the number of the day in the year;

n – the number of days in the year;

t_n – the number of the day in the year corresponding to the beginning of the flood;

t_{max} – the number of the day in the year corresponding to the peak of the flood;

t_e – the number of the day in the year corresponding to the end of the flood;

Q_i,, m³/s – river runoff water consumption on the i-th day of the year,

$Q_{t_{max}}$, m³/s – water consumption on the day corresponding to the peak of the flood,

$\bar{Q}_{min}$, m³/s – arithmetic mean values of the average monthly minimum winter and summer-autumn water consumption.

The values of t_{max}, t_n and t_e can be obtained by the method described in detail in [12]. Figure 1 shows a graph of the dismemberment of the average long-term hydrograph of the Pripyat River at the Mozyr city constructed for the representative period according to the average daily river runoff.

Due to the high labor intensity and unavailability of observation data on the average daily runoff in some cases, without loss of accuracy of the results (based on the constructed long-term hydrographs on the average monthly runoff), it is permissible to use the average monthly runoff values to dissect the hydrograph of the river runoff in Belarus and the allocation of underground runoff:

$$Q_{ugr_k} = \begin{cases} Q_{ugr\ l.w._k}\ , & k \le 2 \\ \frac{1}{2} Q_{ugr\ l.w._2}\ , & k = 3 \\ 0, & k = 4 \\ \frac{1}{2} Q_{ugr\ l.w._6}\ , & k = 5 \\ Q_{ugr\ l.w._k}\ , & k \ge 6 \end{cases} \quad (2)$$

where k – number of the settlement calendar month,

$$Q_{ugr\ l.w._k} = \begin{cases} Q_k, & Q_k < \bar{Q}_{1,2,7-12} \\ \bar{Q}_{1,2,7-12}, & Q_k \ge \bar{Q}_{1,2,7-12} \end{cases},$$

$\bar{Q}_{1,2,7-12}$ – average monthly runoff for the months corresponding to the lower indices.

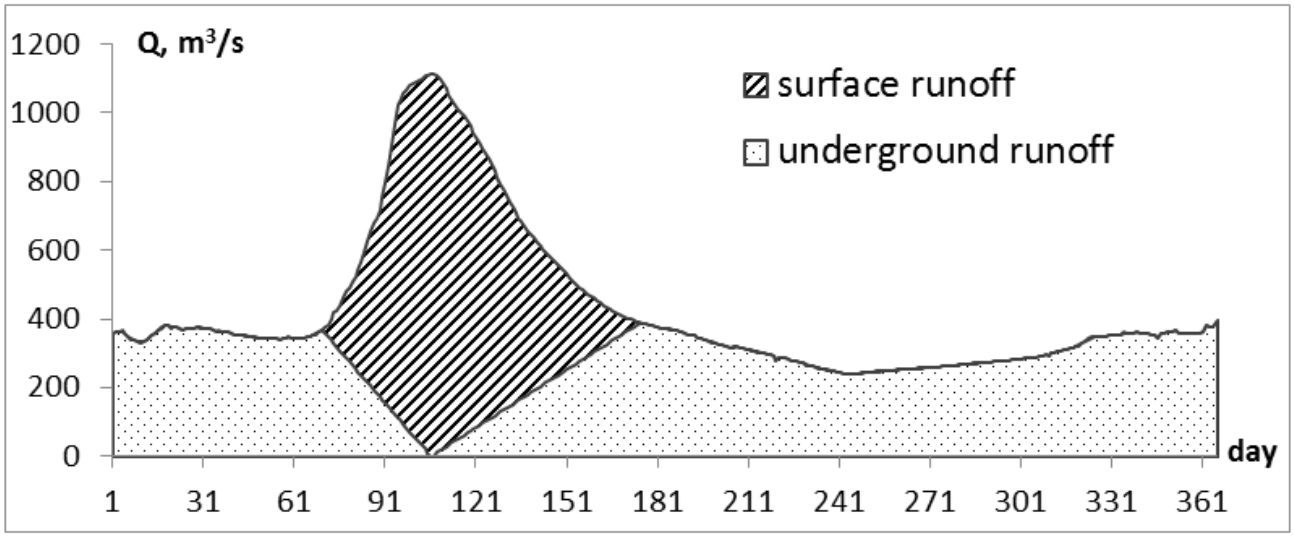
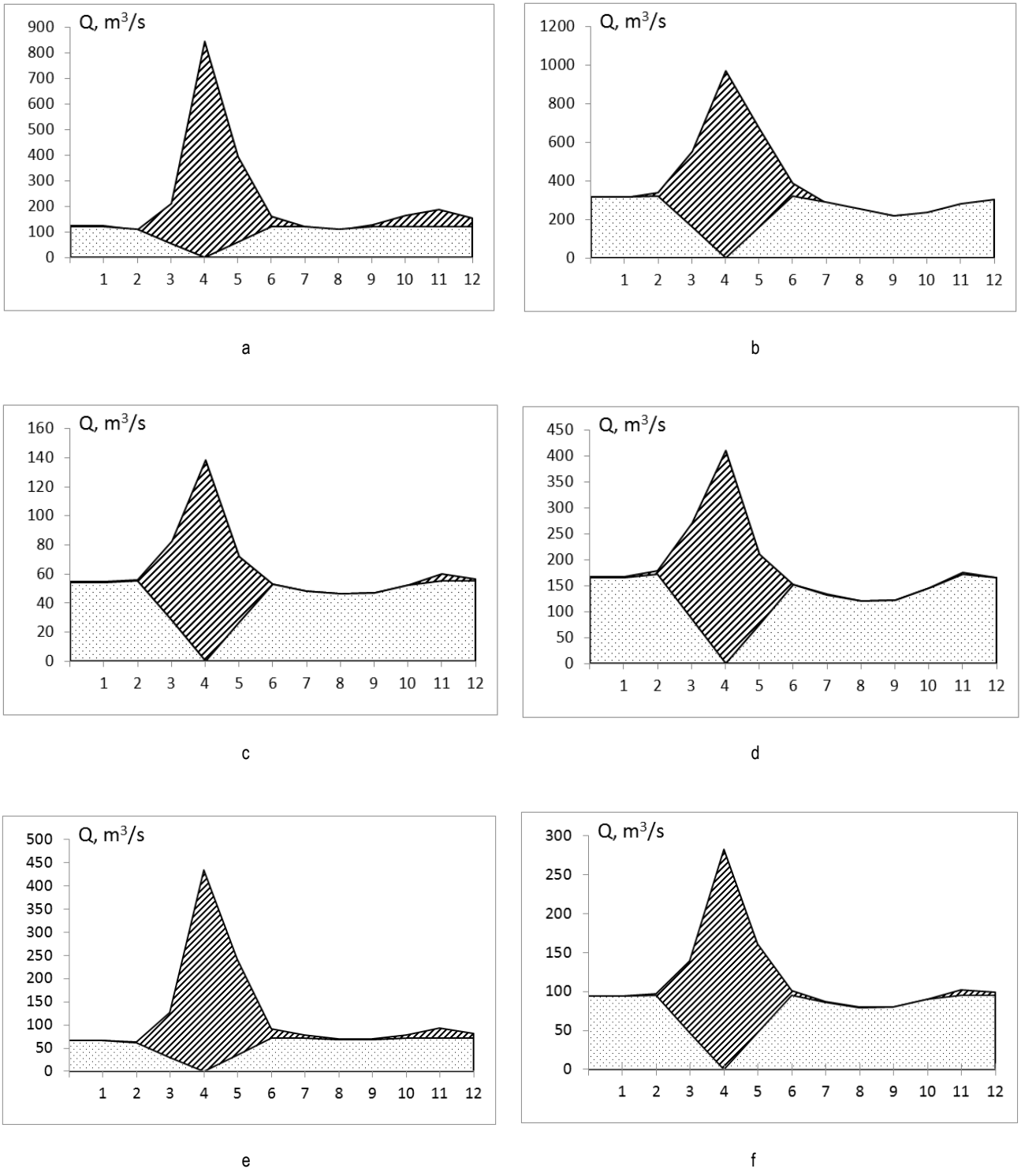


Figure 1 – The average long-term hydrograph of the Pripyat River at the Mozyr city built for the period 1948-2017 according to the average daily river runoff

Results and discussion

Long-term variability of surface runoff.

On the basis of model (2) the average long-term hydrographs are constructed for the average monthly runoff rates of river runoff, divided into underground and surface components. Figure 2 shows the obtained hydrographs for 6 hydrological stations of the largest rivers in Belarus.



a – the Western Dvina River at the Vitebsk city;
b – the Pripyat River at the Mozyr city;
c – the Vilia River at the Mikhalishki town;
d – the Neman River at the Grodno city;
e – the Dnieper River at the Orsha city,
f – the Berezina River at the Bobruisk city

Figure 2 – Average long–term hydrographs of river runoff

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Figure 2 shows that for all the considered sections the largest river runoff values are observed in April. The decline of the spring flood is especially prolonged for the Pripyat and Dnieper basins, gradually turning into summer floods. On the rest of the rivers under consideration, the rise and fall of the spring flood are proceeding at a faster pace. Since the main feature of modern changes in the water regime of the rivers of Belarus is the redistribution of runoff within the year, which occurs with a relative constancy of average annual water consumption, it is advisable to consider the percentage of surface runoff (d_{suf}, %) in the total annual runoff and the long-term variability of this indicator (Figure 3).

a – the Western Dvina River at the Vitebsk city;
b – the Pripyat River at the Mozyr city;
c – the Vilia River at the Mikhalishki town;
d – the Neman River at the Grodno city;
e – the Dnieper River at the Orsha city,
f – the Berezina River at the Bobruisk city

Figure 3 – Change in surface runoff in the total river runoff for the period 1948-2017

The analysis of linear trends in the series of the surface runoff percentage shows that in general there is a decrease in the values of the considered characteristics of the runoff. Linear negative trends are statistically significant at the 5% level.

For all the studied rivers, a synchronous course in long-term changes in the percentage of surface runoff in the total annual runoff is clearly traced, which is confirmed by positive significant correlation coefficients between these values (Table 1).

Table 1 – Correlation matrix of the surface runoff in the total annual runoff of the pairwise compared rivers of Belarus

	the Berezina River	the Dnieper River	the Pripyat River	the Neman River	the Vilia River
the Western Dvina River	0.61	0.72	0.48	0.54	0.54
the Berezina River		0.73	0.74	0.78	0.81
the Dnieper River			0.65	0.70	0.72
the Pripyat River				0.78	0.67
the Neman River					0.84

To assess the long-term variability of surface runoff, the periods differing in climatic conditions, but long enough to identify various trends, were analyzed: 1948, 1987, 1988, 2017 (taking into account the fact that 1988 corresponds to the beginning of an intensive increase in average annual air temperatures in Belarus).

Table 2 – The change (in %) of the average long-term values of indicators for the period 1988–2017 in relation to the period 1948–1987

	maximum runoff	minimum summer-autumn runoff	minimum winter runoff	percentage of surface runoff
the Western Dvina River	-21	4	46	-4
the Pripyat River	-33	12	23	-9
the Vilia River	-56	0	12	-11
the Neman River	-39	-5	21	-8
the Dnieper River	-30	28	47	-7
the Berezina River	-51	8	23	-10

It can be seen from Table 2 that the percentage of surface runoff for the period 1988-2017 for all the considered rivers has been decreased by 4–11%. The main reason for the decrease in the surface runoff of the rivers in Belarus in the last 30-year period is climate change. This is explained by the fact that due to the increase in winter temperatures, accompanied by winter thaws, increased infiltration of melt water into the soil in winter and spring, the underground component of runoff has significantly increased. A significant decrease in flood runoff in all catchments of Belarus is compensated by increased runoff (in most cases underground) in winter.

The assessment of the effect of changes in the maximum and minimum runoff on the dynamics of surface river runoff was carried out in two stages. At the first stage, paired regression relationships were revealed between changes in the two periods under consideration of surface runoff ($\Delta Q_{suf}, \%$) and maximum runoff ($\Delta Q_{max}, \%$), surface runoff and minimum summer-autumn runoff ($\Delta Q_{min\,s.a.}, \%$), surface runoff and minimum winter runoff ($\Delta Q_{min\,w.}, \%$). The results obtained at the first stage allow us to conclude that the effect of changes in the maximum and minimum winter runoff rates of river runoff on surface runoff is most significant (r=0.92 and r=0.86, respectively). It is worth noting that the decrease in the surface runoff of the rivers of Belarus was decisively influenced by a decrease in the maximum runoff. Based on this, at the second stage, in order to identify the cumulative relationship between the dynamics of surface runoff, the maximum water runoff of spring flood and the minimum winter runoff of river runoff, the following relationship was considered: $\Delta Q_{suf} = f(\Delta Q_{max}, \Delta Q_{min\,w.})$. The analytical expression of this relationship for the territory of Belarus is given below:

$$\Delta Q_{suf} = 0.12\Delta Q_{max} + 0.06\Delta Q_{min\,w.} - 5.05. \quad (3)$$

This relationship has a high correlation coefficient r=0.94. Using the model (3) it is possible to obtain predictive estimates of changes in surface runoff depending on various options for changing the maximum and minimum runoff (Table 3).

Table 3 – Forecast estimates of changes (in %) in the percentage of surface runoff depending on changes in the maximum water consumption of the spring flood and minimum winter river runoff

ΔQ_{max}, % \ $\Delta Q_{min\,w.}$, %	-10	0	10	20	30	40	50
10	-4.4	-3.85	-3.3	-2.75	-2.2	-1.65	-1.1
0	-5.6	-5.05	-4.5	-3.95	-3.4	-2.85	-2.3
-10	-6.8	-6.25	-5.7	-5.15	-4.6	-4.05	-3.5
-20	-8	-7.45	-6.9	-6.35	-5.8	-5.25	-4.7
-30	-9.2	-8.65	-8.1	-7.55	-7	-6.45	-5.9
-40	-10.4	-9.85	-9.3	-8.75	-8.2	-7.65	-7.1
-50	-11.6	-11.05	-10.5	-9.95	-9.4	-8.85	-8.3

Despite the presence of a general trend towards a decrease in surface runoff for the period 1988–2017 in relation to the period 1948–1987, when considering the variability of surface runoff over ten-year periods, an increase in surface runoff is observed for most of the studied strata over the last two decades of the study period (1998–2007, 2008–2017). This circumstance indicates the need for further study of the dynamics of surface runoff, the proportion of spring flooding, the maximum costs of spring flooding, the magnitude of rain floods in order to ensure the safety of the population and sustainable economic development.

Spatial structure of surface runoff.

Due to the fact that the surface runoff, which represents the water resources of the land, is an integral value, and measurements are carried out discretely, to represent its spatial structure, a runoff module is used, which is numerically equal to the runoff rate per unit area, which makes it possible to obtain comparable water characteristics for different river catchments. This makes it possible to represent surface runoff in the form of maps based on the principle of climatic runoff and obtain hydrological characteristics at those points where there are no observations.

The surface runoff map used today for the territory of Belarus (built in 2000 [13]) has lost its relevance to one degree or another for a number of reasons. Firstly, they do not meet the requirements of regulatory documents, in particular the TCP, according to which the determination of calculated hydrological characteristics should be based on data from long-term hydro meteorological observations with a single calculation period, while regular observations of recent years are mandatory [1]. This will allow taking into account the processes of global climate warming and anthropogenic impacts that have intensified in recent decades, which undoubtedly left its mark on the formation of the runoff of rivers in Belarus. Secondly, the development of spatial interpolation methods and computer technologies make it possible to objectively construct maps of the surface modules of the runoff of rivers in Belarus. In this regard, the issue of constructing a modern map of the surface runoff module of the rivers of Belarus becomes very relevant.

The construction of a map of the surface runoff of the rivers of Belarus was carried out using the ArcGIS software. The ArcGIS software package allows you to visualize large amounts of statistical information that has a geographical reference, create and edit maps of different scales [14]. The family of geoinformation software products of ArcGIS

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offers a wide range of tools for spatial modeling, which is carried out using a special geostatistical analysis module (Geostatistical Analyst).

The choice of a suitable interpolation method when constructing the map at the first stage was carried out experimentally. For this purpose, in this study, various deterministic and geostatistical methods were used to obtain the spatial distribution of modules of surface river runoff: the Inverse Distance Weighing method (IDW), Global Polynomial Interpolation (GPI), the Radial Basis Function method (RBF) and Ordinary Kriging (OK).

The results of interpolation by the IDW method showed that the isolines have a broken character in places, there are a large number of local closed areas on the surface and the law of geographical zonality is incorrectly expressed. Interpolation by the GPI method was carried out using polynomials of 2-6 degrees. With this method of interpolation, smoothed isolines were obtained that meet the requirements for compliance with the principle of geographical zonality when constructing runoff maps, however, the values of the runoff modulus went beyond the extreme reference points, in some cases even went into negative values, which is unacceptable when constructing runoff modulus distribution maps.

Three of the five basic functions used in RBF interpolation are: fully regularized spline (CRS), multi-square function (MQ), thin-film spline (TPS). When interpolated by BRF (TPS), the values of the runoff modulus went beyond the extreme reference points, and the use of the BRF(CRS) method led to the presence of a large number of closed local areas in the north-west of Belarus. The isolines obtained by BRF (MQ) and OK have a smooth shape, without a set of local regions, so further research was carried out using these two interpolation methods.

To evaluate and compare the characteristics of the two selected interpolation methods, the paper uses cross-validation by calculating several statistical measurements (root-mean-square error, average absolute error as a percentage, systematic error and coefficient of determination [15]. As a result of the analysis of cross-validation and the results of calculations of indicators for assessing the accuracy of the RBF (MQ) and OK interpolation methods, RBF(MQ) was chosen as an interpolation method for constructing a map of the modules of the surface runoff of the rivers of Belarus. The map constructed using the chosen interpolation method is shown in Figure 4.

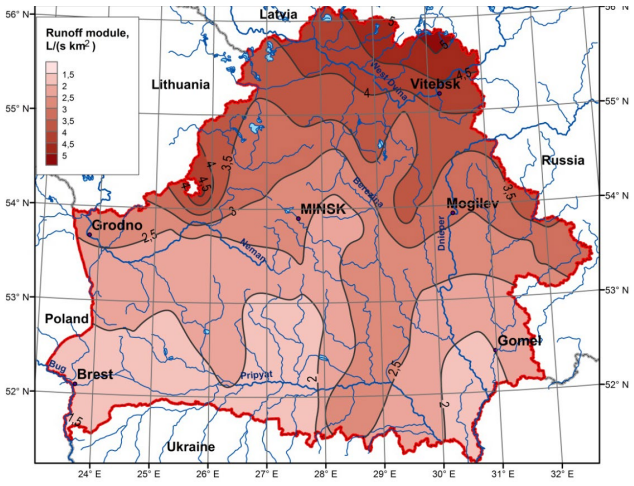

Figure 4 – Map of the surface runoff modules of rivers in Belarus for the period 1953–2017

The analysis of the constructed map allows us to conclude that the regularities of the formation of the surface runoff of the rivers of Belarus are subject to latitudinal zonality, which is determined by climatic factors. Some deviations of runoff isolines from latitudinal directions are caused by the hydrological structure of river basins. The minimum values of runoff in the south of Belarus are caused by reduced precipitation in this area compared to the northern part of the country and increased temperature in this region.

Conclusion

A characteristic trend of the long-term variability of the surface river runoff in Belarus has been a significant (by tens of percent) decrease in the amount of surface runoff. The greatest decrease in runoff is observed in the basins of the Pripyat and Berezina rivers. As a result of the performed studies a modern map of the average annual modules distribution of the surface river runoff in Belarus has been obtained. The updated data on the runoff distribution can be transformed into modern global hydrological maps. The use of mapping results can determine the planning of economic activities, the development of engineering applications that ensure the conservation and rational use of water resources, as well as their sustainable management.

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ASSESSMENT OF THE KRASNAYA SLOBODA FISH FARM IMPACT ON THE MOROCH RIVER RUNOFF

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Abstract

A comprehensive assessment of the impact of the Krasnaya Sloboda fish farm on the hydrological regime of the Moroch River in the calculated areas was carried out. The following methods were used in the work: field research, desk data processing, geographical analysis, statistical analysis, regression analysis, water balance calculations. The analysis of the hydrological regime of the calculated sections of the river used for the needs of the fish farm made it possible to determine the minimum average monthly water consumption of 95% probability of excess and ecological runoff, taking into account the intra-annual distribution of runoff. For the central section of the Krasnaya Sloboda fish farm, the permissible volume of withdrawal of water resources from the Moroch River has been determined.

Keywords: fish farm, reconnaissance survey, ecological runoff, water consumption, mathematical model, water content of the year.

ОЦЕНКА ВЛИЯНИЯ РЫБХОЗА «КРАСНАЯ СЛОБОДА» НА СТОК РЕКИ МОРОЧЬ

А. А. Волчек, С. И. Парфомук, Н. Н. Шешко, Н. Н. Шпендик, Д. Н. Дашкевич, С. В. Сидак, М. Ф. Кухаревич

Реферат

Выполнена комплексная оценка воздействия рыбхоза «Красная Слобода» на гидрологический режим р. Морочь в расчетных участках. В работе использовались следующие методы: полевые исследования, камеральная обработка данных, географический анализ, статистический анализ, регрессионный анализ, водобалансовые расчеты. Проведенный анализ гидрологического режима расчетных участков реки, используемых для нужд рыбхоза, позволил определить минимальный среднемесячный расход воды 95 % вероятности превышения и экологический сток с учетом внутригодового распределения стока. Для центрального участка рыбхоза «Красная Слобода» определен допустимый объем изъятия водных ресурсов из р. Морочь.

Ключевые слова: рыбоводное хозяйство, рекогносцировочное обследование, экологический сток, расход воды, математическая модель, водность года.

Introduction

Fishing is a unique type of production and plays an important role in the food complex of the Republic of Belarus, which provides the population with high-quality food. It is directly related to the use of water resources and places very high demands on their regime, quantitative and qualitative state. For the successful reproduction and normal development of fish, clean water with a sufficient amount of dissolved oxygen and the absence of harmful impurities, appropriate temperature and provision of feed are necessary. Water quality standards for fishery facilities are stricter than for drinking water sources.

For fish, the most important conditions are temperature, transparency, gas regime, content of nutrients. The connection of hydrobionts with the elements of the external environment is interdependent, and a change in one system of connections inevitably causes a change in the other. Therefore, considering the influence of individual components of the hydrochemical regime on the vital activity of hydrobionts, it is necessary to bear in mind the conditionality of such separation, because in nature all the relations of the organism and the environment are interconnected. The most favorable value for most fish is the hydrogen index (pH), which is close to neutral. With significant shifts to the acidic or alkaline side, the oxygen threshold increases, the intensity of fish respiration weakens, and the water itself can become toxic to fish [1, 2].

The purpose of this work is to assess the impact of the Krasnaya Sloboda fish farm on the Moroch River runoff.

Materials and methods

The Moroch is a 150 km long river in the Minsk region, a right tributary of the Sluch River. The catchment area is 2030 km^2. The average annual water consumption at the mouth is 8.7 m^3/s. The average slope of the water surface is 0.5%. The forest cover of the catchment area is 29%. The spring flood period accounts for 63% of the annual runoff. The maximum flood level is at the end of March, the average height above the mean level is 2.4 m. It freezes in mid-December, opens in mid-March. The spring ice drift lasts 5 days.

In this work, the data of hydrometric observations on the Moroch River for the period from 1954 to 2018, i.e. 65 years, which is sufficient to obtain objective statistical hydrological characteristics, are used. The missing data in the series of observations were restored with the use of data from observations of analogous points, taking into account the presence of synchronicity in the fluctuations of the river flow of the calculated gate and the lines of analogs, as well as taking into account the methods of bringing the series of hydrological characteristics to a multi-year period in the presence of hydrological observations for 6 years or more.

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To determine the water flow rates of different availability in a separate alignment, it is necessary to solve two separate tasks:

- arrange a temporary water measuring post and measure the main characteristics of the flow;
- determine the water content of the year of the studied watercourse at the current time.

According to the results of standard hydrometric work, the marks of the characteristic points of the channel are determined, on the basis of which the transverse profile of the channel is constructed, and the cross-sectional areas (ω), wetted perimeter (χ) and hydraulic radius (R) for different filling depths are calculated according to the following formulas:

$$\omega = \frac{1}{2}\sum_{i=1}^{n}\left(x_i\left(y_{i+1} - y_{i-1}\right)\right), \quad (1)$$

$$\chi = \sum_{i=1}^{n-1}\sqrt{\left(x_i - x_{i+1}\right)^2 + \left(y_i - y_{i+1}\right)^2} \quad (2)$$

where x_i and y_i – the coordinates of the i–th point of the polygon in question (Fig. 1), m;

n – the number of points of the polygon.

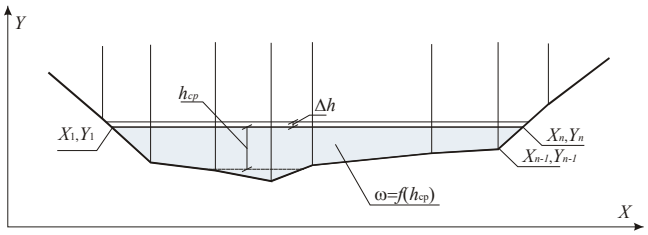


Figure 1 – Algorithm for calculating the proportions of forest cover, waterlogging and waterlogging of catchments

Thus, given the increment of depth Δh, the dependence of the cross-sectional area ω and the average depth h_{cp} is constructed. The increment of depth is taken depending on the severity of the relief of the bottom of the watercourse, but it is recommended to take the number of iterations $\tau > 25$, then $\Delta h = \frac{Y_{max} - Y_{min}}{\tau}$. Similarly the dependence of the wetted perimeter χ and the hydraulic radius R is determined.

Using the obtained arrays $\left[\omega, h_{cp}\right]$ and $\left[R, h_{cp}\right]$, the parameters of the regression model of the form [3] are evaluated

$$z = \alpha \cdot h_{cp}^{\ 2} + \beta \cdot h_{cp} + \varphi, \quad (3)$$

where z – the predicted geometric parameter of the channel;

α, β, φ – the constants of the regression equation.

To determine the water content of the current year, an analog river is selected, which has a long series of observations of the hydrological regime. As the preliminary analysis showed, the water content of the year with a high accuracy of approximation (r> 0.75) is determined by the months preceding the calculated one. When determining the parameters of the distribution function (three-parameter gamma distribution), the maximum likelihood method is used, for which there is a system of equations.

The method of determination developed by us is described in detail in [4, 5]. Ecological runoff is the amount of water that must remain in the river to ensure the conditions for the existence of hydrobionts while maintaining its necessary quality. In this case, floodplain ecosystems are preserved, and the river remains an element of the landscape. Thus, the ecological runoff ensures the quantitative and qualitative condition of the water body in the most low-water period of the year.

In general, environmental (minimum permissible) the drain should take into account the following factors [6]:

- the volume necessary for the normal development of hydrobionts. In this case, it is required to maintain water flow rates in the range of 0.25 – 0.6 m / s (0.25 m / s is the lower limit of the speed regime at which the rapid development of phytoplankton begins), with a flow depth of at least 0.1 – 3 m. An important period from the point of view of environmental functions is the inter–temperate periods of summer and winter. However, with an average thickness of ice formation from 17 to 45 cm, the death of ichthyofauna can be observed;
- the river performs its natural functions. The river network transports substances and energy, thus redistributing them in time and space;
- intra-annual variability of runoff. The presence of the variability of the river flow during the year supports the natural cyclicity in the development of various biological species;
- variability of runoff by year. As well as intra-annual variability, fluctuations in the volume of runoff over the years make it possible to enrich the floodplain part of the watercourse with nutrients. At the same time, flooding destroys hydrophobic plants inhabiting the floodplain during a low-water period.

In Belarus, the amount of ecological runoff is taken as 75% of the minimum monthly runoff of 95% security. But this approach does not fully meet the above requirements, namely: it does not provide intra-annual variability of runoff, does not take into account long-term cycles of water content and in most cases the minimum water flow velocity is not achieved.

The method of increasing security implies the allocation of the lower and upper limits of the flow change, which is practically found on a real river [7]. The essence of the method is to establish a lower limit of the environmentally acceptable runoff at the level of monthly expenses for a year of 99% security, since these conditions are marginal from the point of view of environmental management.

The consumption of 50% of security is accepted as the upper limit. Under these conditions, a normal mode of exchange of matter and energy is formed within the river-floodplain geosystem. The greatest productivity of river and floodplain ecosystems is observed with a security in the range of 40...60%.

The determination of the parameters of the ecological runoff distribution function is based on the transfer of the security of the average annual runoff to the predetermined security of the ecological runoff. Namely, it is assumed that the ecological runoff of 95% security corresponds to the average annual runoff of 99% security, and the ecological runoff of 25% security is assumed to be equal to the runoff of 50% security. Having two points of the curve of the distribution function of a random variable, you can select its parameters. However, the application of this approach limits the range of applied theoretical distribution curves (only two parametric distribution functions are applicable). In addition, the application of the transition is seen as quite subjective and cannot always be used as a project or directive. The application of this approach is most effective for large rivers. In the conditions of Belarus, where the compilation of the water balance is mainly aimed at small or medium-sized rivers, the use of this method is not always effective and reasonable [6].

The existing approaches to determining the ecological flow regulate only the minimum value of the river flow. At the same time, there is no definition of ecological runoff for various security conditions. The most effective way to determine the ecological runoff, taking into account the intra-annual distribution, is a way to increase security. Therefore, it is used in this work.

Results and discussion

To quantify the impact of the Krasnaya Sloboda fish farm on the flow of the Moroch River in June 2021, we performed hydrometric measurements of water flow in the channels located above and below the fish farm. The upper section is located on the northern outskirts of the agricultural town of Semezhevo, which is located in the south of the Kopylsky district of the Minsk region (Fig. 2).

Throughout the considered section of the river, the riverbed has a relatively rectilinear shape. Its width on the section of the target was 18 meters. The left and right banks with a height of about 1 m have a significant slope. The coastline is represented by sandstone, overlain by dense grassy vegetation with places of bushes. The bottom within the target is sandy-gravelly. The trunk is completely covered with aquatic vegetation (Fig. 3).

Figure 2 – Map-layout of the upper section

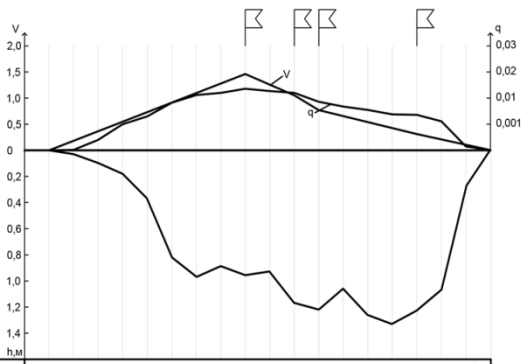
Based on the results of depth measurements in the upper alignment, a transverse profile of the Moroch river was constructed (Fig. 4) and the main characteristics were determined at the time of the survey: water flow Q = 1.08 m^3/s; cross-sectional area F = 13.83 m^2; river width along the water edge B = 17.4 m; average flow depth h_{cp} = 0.79 m; average water flow velocity V_{cp} = 0.78 m/s; maximum velocity V_{max} = 0.142 m/s.

The lower section is located near the intersection of the Moroch River and the H-9601 road on the stretch of road between the villages of Bolshoy and Maly Rozhan, which are located in the north-western part of the Soligorsky district of the Minsk region (Fig. 5).

The riverbed has a rectilinear character. Despite the width of 16 meters, the river in this place is quite shallow. The coast is low (does not exceed 1 m) in places steep sandy. The coastline and floodplain are covered with grassy vegetation. The bottom of the river is sandy. Near the shores, at some distance from the target, aquatic vegetation was present on the right bank, creating stagnant areas near the shores (Fig.6).

Figure 3 – Research area in the upper section

Q,m^3/s	1,08
F,m^2	13,83
B,m	17,4
hcp,m	0,79
Vcp,m/s	0,78
Vmax, m/s	0,142



No. of verticals		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
Distance from the constant start, m	0,5	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	17,9
Depth, m	0	0,02	0,1	0,16	0,38	0,83	0,97	0,91	0,86	0,94	1,18	1,2	1,13	1,22	1,26	1,21	1,08	0,3	0
Velocity, m/s	0	0,02	0,04	0,06	0,08	0,1	0,115	0,13	0,142	0,135	0,101	0,072	0,06	0,045	0,03	0,0298	0,01	0,005	0
Elementary water consumption, m^2/s	0	0,0002	0,004	0,0096	0,03	0,083	0,112	0,12	0,136	0,127	0,12	0,086	0,068	0,055	0,038	0,036	0,011	0,0015	0

Figure 4 – Transverse profile of the Moroch River in the upper section

Figure 5 – Map-layout of the lower section

Figure 6 – Research area in the lower section

Based on the results of depth measurements in the upper alignment, a transverse profile of the Moroch river was constructed (Fig. 7) and the main characteristics were determined at the time of the survey: water flow Q = 1.42 m^3/s; cross-sectional area F = 8.685 m^2; river width along the water edge B=16.4 m; average flow depth h_{cp}= 0.53 m; average water flow velocity V_{cp}=0.16 m/s; maximum velocity V_{max}= 0.234 m/s.

A comparative analysis of the studied sections showed their significant difference. So the section of the river in the lower alignment requires cleaning of the riverbed. Of the quantitative characteristics, attention is drawn to the increase in water runoff in the lower alignment ΔQ = 0.34 m^3/s. This is caused by additional discharge of water from the surface of fish ponds.

Based on the results of processing hydrometric measurement data according to the method described above, mathematical models (flow rates/levels/velocities) and curves of the relationship between the velocity/flow rate and the water level in the formation of the Moroch River were obtained according to the method [8, 9]. As a feature, it should be noted that the use of communication curves is permissible only within the established range. The use of extrapolation is acceptable, but it can lead to significant deviations and errors.

For the upper section:

$$V = -0{,}0618{h_{\text{cp}}}^3 + 0{,}1111{h_{\text{cp}}}^2 + 0{,}0484h_{\text{cp}}$$
$$Q = 2{,}1764{h_{\text{cp}}}^3 - 0{,}4465{h_{\text{cp}}}^2 + 0{,}1859h_{\text{cp}}$$

For the lower section:

$$V = 0{,}0561{h_{\text{cp}}}^3 - 0{,}1163{h_{\text{cp}}}^2 + 0{,}3547h_{\text{cp}}$$
$$Q = 0{,}6323{h_{\text{cp}}}^3 + 4{,}6266{h_{\text{cp}}}^2 - 0{,}0510h_{\text{cp}}$$

The data obtained during the calculation of the ecological flow of rivers allowed us to determine the values of the permissible withdrawal of surface water from the river, taking into account evaporation losses from the water mirror and filtration from reservoirs. The results of calculations, provided that the ecological runoff is preserved in the rivers under consideration, taking into account the intra-annual distribution for various probabilities of excess (security), are given below.

The analysis of the hydrological characteristics of the Moroch River was carried out on the estimated section of the river below the Krasnaya Sloboda fish farm. Data on the quantitative characteristics of the flow of the Moracha River by month and by year are presented in Table 1.

The characteristics of the minimum flow are calculated for the hydrological justification of various water management and water protection projects, namely: the design of hydroelectric power plants for energy generation, water supply of cities, rural settlements, water transport, fisheries. In the practice of water management design, the main application is found in the values of the minimum runoff of security in the range of 75–99%, characterizing years with low−water intervals of relatively rare repeatability. When assessing the worst conditions for the formation of water quality, a minimum flow of 95% security is usually used (average repeatability 1 time in 20 years), which is a rather arbitrary condition requiring differentiation depending on the severity of negative environmental and sanitary consequences. Table 2 shows the results of calculating the minimum average monthly water consumption of 95% of the probability of excess (security), taking into account the intra-annual distribution of runoff.

Taking into account the results of field studies and using the security transfer method, we carried out hydrological calculations to determine the ecological flow of the Moroch River, taking into account the intra–annual distribution of runoff for various probabilities of excess (security), the results of which are shown in Tables 3-4.

The results of calculations for the Moroch River showed the possibility of permissible withdrawal of surface water per year from 20.26 million m^3 for ecological runoff 95% probability of excess to 83.12 million m^3 for ecological runoff 5% probability of excess. The maximum allowable withdrawal of surface water from the river, taking into account the preservation of the lowest critical value of ecological runoff, cannot exceed 93.60 million m^3. The largest withdrawal from the Moroch River is permissible in the spring months – in total from 14.86 million m^3 (95% security) to 50.64 million m^3 (5% of security), and the smallest – in summer (from June to August) – from 0.38 to 7.17 million m^3, respectively. At the same time, in low-water years (in July there is a 95% probability of excess for runoff and in August there is a 75% probability of excess for runoff), withdrawal is not allowed, since the runoff in the river during these months corresponds to ecological runoff.

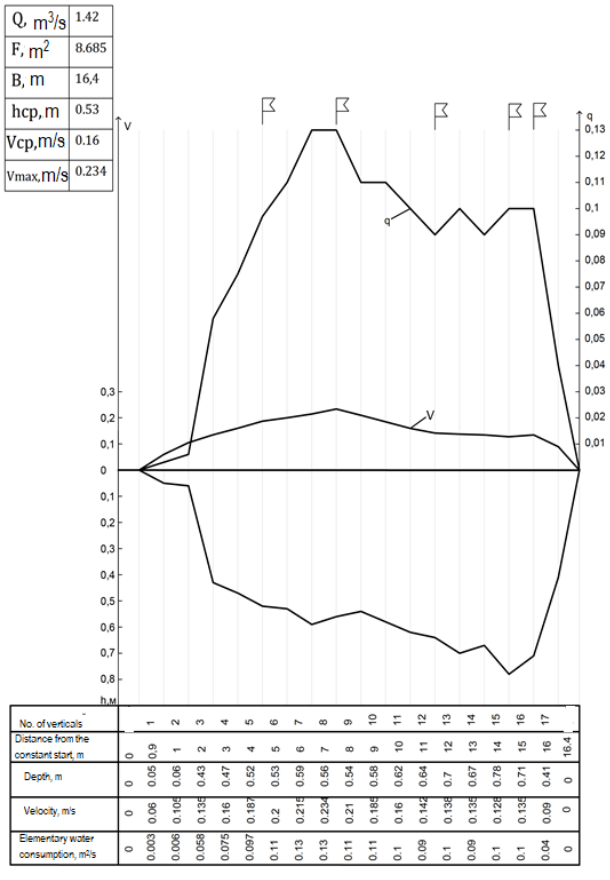


Figure 7 – Transverse profile of the Moroch River in the lower section

Table 1 – Intra-annual distribution of the flow of the Moroch River in the average water content year

Interval												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Runoff, m^3/c												
3.36	4.70	17.2	22.7	4.75	3.07	2.59	2.53	2.68	3.33	5.10	4.81	6.42
Coefficient of variation, *Cv*												
0.71	1.02	0.75	0.95	0.63	0.70	0.68	1.07	0.82	0.53	0.61	0.60	0.30
Coefficient of asymmetry, *Cs*												
1.44	1.42	0.52	1.57	1.78	2.31	2.17	4.93	2.19	1.17	1.52	1.47	0.87
Autocorrelation coefficient, *r*(1)												
0.01	0.14	0.09	0.20	0.05	0.01	-0.16	-0.20	0.06	-0.15	0.00	0.03	0.25

Table 2 – Minimum average monthly water consumption of 95% security, taking into account the intra-annual distribution of the flow of the Moroch River, million m^3

Interval												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
4.78	3.46	28.9	41.53	10.01	4.89	2.72	3.59	3.02	4.12	6.88	7.52	121.4

Table 3 – Ecological runoff taking into account intra-annual distribution, million m^3

Interval												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
95 % probability of excess (security)												
3.86	2.79	23.3	33.50	8.07	3.95	2.19	2.90	2.44	3.32	5.55	6.06	97.97
75 % probability of excess (security)												
6.41	3.82	35.0	38.34	8.51	7.31	4.21	3.01	3.70	6.07	9.28	12.27	137.9
50% probability of excess (security)												
7.45	4.44	40.7	44.54	9.89	8.49	4.89	3.49	4.29	7.05	10.78	14.26	160.3
5% probability of excess (security))												
11.31	6.74	61.8	67.62	15.01	12.89	7.42	5.30	6.52	10.70	16.37	21.65	243.3

Table 4 – The values of permissible withdrawal of surface water from the Moroch River, taking into account the conservation of ecological runoff, million m^3

Interval												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
95 % probability of excess (security)												
0.91	0.65	5.56	7.85	1.45	0.30	0.00	0.08	0.19	0.59	1.25	1.43	20.26
75% probability of excess (security)												
1.27	0.75	7.01	7.52	1.22	0.82	0.17	0.00	0.35	1.01	1.78	2.45	24.35
50% probability of excess (security)												
1.55	0.92	8.54	9.19	1.59	1.14	0.35	0.12	0.51	1.28	2.19	2.98	30.35
5% probability of excess (security)												
4.00	2.38	21.9	23.85	4.85	3.94	1.96	1.27	1.92	3.60	5.74	7.68	83.12

Conclusion

A comprehensive assessment of the impact of the Krasnaya Sloboda fish farm, located in the Moroch River basin, on the hydrological regime of the river was carried out to improve the efficiency of water resources management, taking into account the ecological functioning of water bodies, during which the following tasks were solved:

– an analysis of the hydrological regime of the calculated sections of rivers used for the needs of fish farms located in the Moroch River basin, consisting of an analysis of available hydrological information, a representative period for calculating hydrological characteristics was established, which is 65 years and was adopted from 1954 to 2018, the main hydrological characteristics were determined, including the average annual values of runoff, coefficients of variation, asymmetries, autocorrelations;
– full-scale studies of river sections were carried out, during which the gates were laid above and below the water intake area for the needs of the fish farm. Transverse profiles are constructed. Hydrological characteristics have been calculated for the gates, which include the distribution of local longitudinal averaged water flow velocities and water flow rates in the cross sections of watercourses. The conducted field studies made it possible to determine the water consumption in the studied areas above and below the fish farms during the research period;

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- hydrological calculations were performed to determine the minimum average monthly water consumption of 95% probability of excess (security) and ecological runoff, taking into account the intra-annual distribution of runoff of various security;
- mathematical models have been developed for the areas located below and above the fish farm in the form of mathematical models that allow, depending on the average depth of water in the alignment, to determine the flow rates and water flow rates;
- operational hydraulic calculations in order to assess the impact of water intakes by the fish farm on changes in the hydrological regime of water bodies (water depths, flow rates and water flow rates) are carried out on the basis of developed mathematical models as the difference in design parameters for the laid lines below and above the fish farms;
- the mathematical dependences for the depth, flow velocity and water flow rates in the studied areas below the fish farms corresponding to the ecological runoff were determined using the results of hydrological calculations and mathematical models of water bodies;
- the values of permissible withdrawal of surface water from the river used for the needs of fish farms have been determined, taking into account evaporation losses from the water mirror and filtration from reservoirs and ponds, while ensuring the conditions for preserving ecological runoff in rivers, which will allow determining the most effective filling regime for fish ponds.

The results obtained are relevant for the near future (10 years), however, they may require some adjustments in the future due to projected climate changes. Forecast estimates of changes in the flow of the Moroch River for the period up to 2035 are characterized by a slight change in the flow on average per year, but there is a high probability of its unevenness and multidirection in seasons and months. The runoff can change especially significantly in the summer months. The increase in the unevenness of the intra-annual distribution of runoff and the increase in flood risks caused by sharp thaws in winter, the earlier onset of spring floods and an increase in the intensity of rain floods can lead to an increase in the risks of extreme events, including the occurrence of low-water periods, the likelihood of long low-water periods increases. During low-water periods, there may be a significant decrease in the flow of small rivers, deterioration of the ecological state and recreational potential of rivers and adjacent territories, changes in the hydrogeological regime of groundwater, depletion of soil cover in the floodplain, etc.

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RIVERS' HYDROLOGICAL CHARACTERISTICS OF THE NATIONAL PARK «BIALOWIEZA FOREST»

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Abstract
The article presents analysis of modern hydrological characteristics of the of Bialowieza Forest rivers' during the period of instrumental observations and provides a water regime's forecast assessment of the research territory. The database of Bialowieza Forest rivers' hydrological characteristics was updated with the help of GIS.

Keywords: river, flow, hydrology, database, Bialowieza Forest.

ГИДРОЛОГИЧЕСКИЕ ХАРАКТЕРИСТИКИ РЕК НАЦИОНАЛЬНОГО ПАРКА «БЕЛОВЕЖСКАЯ ПУЩА»

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Реферат
В статье представлен анализ современных гидрологических характеристик рек Беловежской пущи за период инструментальных наблюдений и дана прогнозная оценка водного режима исследуемой территории. База данных гидрологических характеристик рек Беловежской пущи была обновлена с помощью ГИС.

Ключевые слова: река, сток, гидрология, база данных, Беловежская пуща.

Introduction

The National park «Bialowieza Forest» is located in the eastern part of the Visla's river basin, on the catchment area of the rivers Narev and Lesnaya (Left and Right). The divide between the Baltic and Black Seas runs near park's northern and northeastern borders. The tributaries of the river Neman – rivers Svisloch and Ross – originate not far from the northern vicinity of the forest; the source of Yaselda, a tributary of the river Pripyat that flows into the river Dnieper, is located at the north-eastern forest's vicinity. There is a watershed between the basins of two tributaries of the river Bug – the Left Lesnaya and the Mukhavets – in the south-eastern limits of the forest [1, 2].

The river Narev that originates in the swamps of the tract «Dikoe» plays an extremely important role in regulating of the hydrological regime in the northern part of the forest. In the southern part of the National park, the main waterways are the rivers Right Lesnaya and Left Lesnaya. The river Right Lesnaya originates in Poland, flows in a south-easterly direction through the southern part of the National park and merges with the river Left Lesnaya on its' border, forming the Lesnaya River, which flows into the river Zapadny Bug north of city Brest. The source of the river Left Lesnaya is located on the territory of the National park («Shereshevskoe forestry»). The river Left Lesnaya flows in a south-easterly direction, then turns to the southwest and represents the south-eastern border of the National park by itself. The remaining rivers originate mainly in the territory of the National park and flow into the rivers Narev, Left Lesnaya and Right Lesnaya.

There are no natural lakes on the territory of the National park. As a result of hydro-reclamation works carried out in the second half of the twentieth century, several fairly large artificial reservoirs were created: Lyadskoe, Khmelevskoe, Sipurka, Pererovnitsa and Colonna.

Water landscapes significantly affect the functioning of the geosystem of Bialowieza Forest, as well as the maintenance of the natural water and energy balance depends on them. Water landscapes include swampy massifs, swampy forests and meadows, which affect the formation of runoff of water objects located on the forest's territory.

Rational management of water resources can be implemented only in case of existence of complete, unified, reliable and timely information about conditionы and trends of changes in water ecosystems or their individual components. Geographic information systems (GIS) are the systems that provide all levels of water resources management for determining the strategy of environmental management and making operational decisions [3, 4].

The purpose of current research is to determine the main hydrological characteristics of the rivers on the territory of National park «Bialowieza Forest» within the borders of the Republic of Belarus.

Materials and methods

The methodological basis of the research was the scientific provisions on the stochastic nature of river flow, which made it possible to apply statistical methods of time series analysis. The methods of water and heat energy balance, mathematical modeling were used. A system analysis of the accumulated information and a comparative geographical method made it possible to synthesize and objectively evaluate the patterns of spatial and temporal fluctuations of the water resources on the territory of the National park «Bialowieza Forest».

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A large number of small rivers and streams flow through the territory of Bialowieza Forest, but regular hydrological observations are not enough for an objective assessment of water resources. Therefore, we used the data of hydrological observations not only on rivers, located on the territory of the National park, but also in the immediate vicinity, on which hydrometric observations are conducted or were conducted, such as: the river Zelvyanka in the observation point of the village Peski, the river Yaselda in the observation point of the village Horev, the river Rudavka in the observation point of the village Rudnya, the river Ross in the observation point of the village Studenets, the river Narev in the observation point of the village Nemerzha, the river Lesnaya in the observation point of the village Zamosty. The following hydrological data on water consumption were used for research: average annual, average monthly, maximum spring floods, maximum rain floods, summer-autumn and winter low water by observation points for the period from 1946 to 2018 inclusive.

The missing data in the series of observations were restored using the observation data of analog observation points, taking into account the presence of synchronicity in the fluctuations of the observation point and of the point-analog using the software package «Hydrologist – 2» [5, 6].

For these rivers, according to TCP 45-3.04-168-2009, calculated hydrological characteristics were determined using analytical distribution functions of annual exceedance probabilities, in particular the three-parameter gamma distribution. At the initial stage, the homogeneity of the series of hydrological observations was assessed on the basis of genetic and statistical analyses of the initial observation data [7, 8].

According to the series of hydrological observations, the following estimates of the parameters of the analytical distribution curves were determined by the highest likelihood method: the average long-term value $\bar{Q}$, the variation factor C_v and the ratio of the asymmetry factor to the variation factor C_s/C_v. Mathematical models in the form of linear trends were used to assess trends in flow fluctuations. The quantitative indicators of these changes were estimated by a gradient that is numerically equal to the regression coefficient (a) multiplied by 10 years, i.e. α=a×10 years [9].

For rivers were no hydrological observations, regional methods for calculating hydrological characteristics were used, based on the results of generalization of hydrometeorological observations in the research area, taking into account the influence of local factors [7, 8].

The use of regional methods for determining the main hydrological characteristics provides for the determination of a number of hydrographic characteristics of catchments: catchment area, km^2; length of the river, km; average height of the catchment, m; average slope of the riverbed, %; lake cover, forest cover and swampiness of the catchment, %, which were determined using GIS technologies.

One of the regulatory documents when creating a GIS hydrographic network is the Directive of the European Parliament and of the Council establishing a framework for Community action in the field of water policy, which was adopted in 2000. This document regulates approaches in the policy of protection, use and management of water resources and is intended to harmonize and unify the approaches of the EU and other European countries to water resources management and protection. The main objects of any GIS are maps, geographical data and tables.

The framework requires European countries to provide a significant amount of information in the form of maps (more than 13 layers and 49 data tables). The best form of providing most of the required information is the form of thematic GIS layers. This is due to the fact that most of the data should be presented in a spatial context. The implementation of the framework requires the comparison of geographical data (coordinates of locations) both for the purpose of preparing water management plans in the basins, and for the purpose of preparing reports of Basin administrations. In the first case, GIS technology is necessary for the development of various information layers (for example, the characteristics of basins, the chemical and ecological state of surface and groundwater).

The GIS of the hydrographic network of the territory of the National park «Bialowieza Forest» is based on existing cartographic materials. All digital data was recorded in the GIS database in geographical coordinates. The geodetic mapping system was used by Pulkovo 1942. This method of recording made it possible to easily transform data into a new system of plane coordinates, which was necessary for spatial analysis. The flat coordinates of Pulkovo 1942 GK Zona 5N were used with the purpose to form a general map of the entire natural-territorial complex Bialowieza Forest.

GIS of the hydrographic network of the natural-territorial complex Bialowieza Forest was created as a result of processing graphic materials, and GIS contains the following main layers:

- linear layer of rivers;
- linear channel layer;
- polygonal layer of reservoirs;
- polygonal layer of catchments.

As additional layers, GIS contains:

- polygonal and raster layers of swamps;
- polygonal layer and raster layers of forest cover;
- raster layer of reservoirs;
- linear layer of the border of the National park «Bialowieza Forest»;
- chiseled layers of the location of the points of the sources and estuaries;
- rasters of digital terrain models, topographic plans and satellite images;
- tables.

The linear layer of rivers includes 117 objects with a total length of more than 942 km, of which 53 objects are represented by rivers, and the rest are tributaries, meanders and other objects. As attribute information, this layer contains information about the name of the water body, its encoding, and geometric parameters. Additional connected attribute information contains information about the average slope along the length of the object.

The linear channel layer contains 2,270 objects with a total length of 2,168 km. The channel layer contains information about the encoding of objects, as well as information about geometric parameters.

The polygonal layer of reservoirs is represented by 49 objects with a total area of 11.6 km^2. The layer contains information about the type of water body, its encoding and geometric parameters. Of the 49 objects, 46 objects are encoded. As an addition, the polygon layer is duplicated as a bitmap image.

The polygonal layer of catchments includes 49 objects. As attribute information, there are names of catchments, their geometric dimensions, information about the degree of lake cover, forest cover and swampiness of the catchment. As a connected additional information, the layer contains information about the areas of forests, reservoirs and swamps for each catchment.

Polygonal and raster layers of swamps and forest vegetation provide visual information about the degree of forest cover and swampiness of the National park «Bialowieza Forest» and adjacent territories.

The linear layer of the border of the National park «Bialowieza Forest» is demonstrative and contains only information about its length, which is 568 km.

The point layers of the sources and estuaries of rivers display, respectively, the location of the sources and estuaries of 53 and 49 rivers. The layers contain information about belonging to the river and coordinates in the form of latitude and longitude. The river source layer contains information about the height of the river source point as additional connected information.

The raster of the digital relief model presents visual and digital information about the heights of the territory of the National park «Bialowieza Forest» and adjacent territories for 2006 – 2008 in the form of a set of pixels with a dimension of 12.5x12.5 m.

Topographic plans and satellite images carry only visual information about the territory of the National park «Bialowieza Forest» and adjacent territories.

The tables are presented with attribute information about the height of the sources of rivers, the average slope of rivers, the areas occupied by forest vegetation, swamps and reservoirs. These tables act as additional connected information for some layers.

The ArcGIS tools are used to calculate the proportions of forested, watered, and swampy catchments. The calculation algorithm is common for all 3 parameters and is shown in Figure 1.

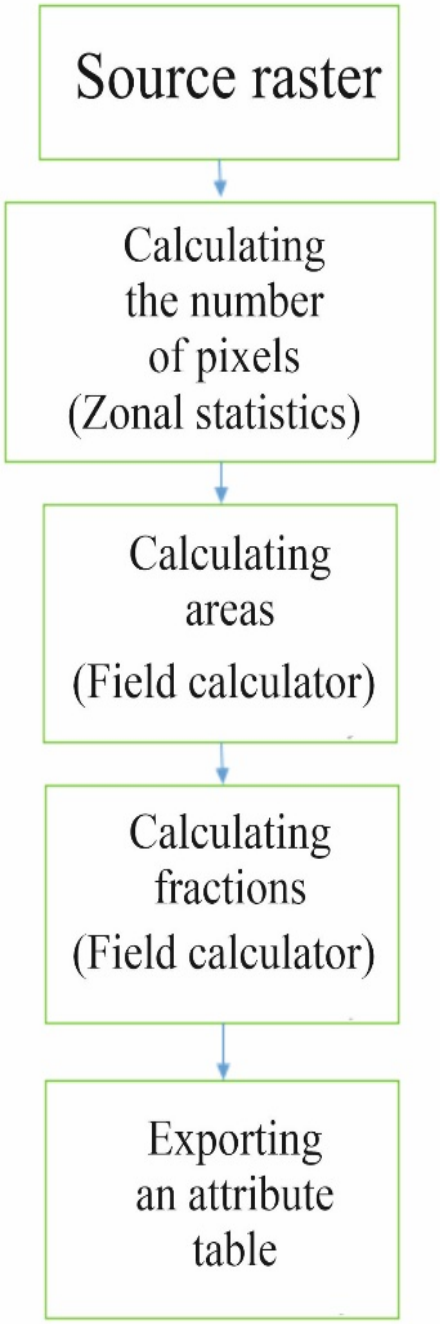

Figure 1 – Algorithm for calculating the proportions of forest cover, waterlogging and waterlogging of catchments

As initial rasters, previously created rasters of forest vegetation, reservoirs and swamps within the catchments of rivers of the National park «Bialowieza Forest» are used (Figure 2).

The *Zonal Statistics as a Table* tool was used to calculate the number of pixels of forests, swamps and reservoirs within catchments. River catchments act as a working area.

After creating tables with the calculated number of pixels of swamps, reservoirs and forests, the areas within the catchments were calculated. Knowing the pixel size – 5x5 m using the *Field Calculator tool*, the areas occupied by these parameters were calculated.

Knowing the size of the catchment areas, using the *Field Calculator tool*, the degrees of forest cover, waterlogging and swampiness of the catchment areas of water objects were calculated.

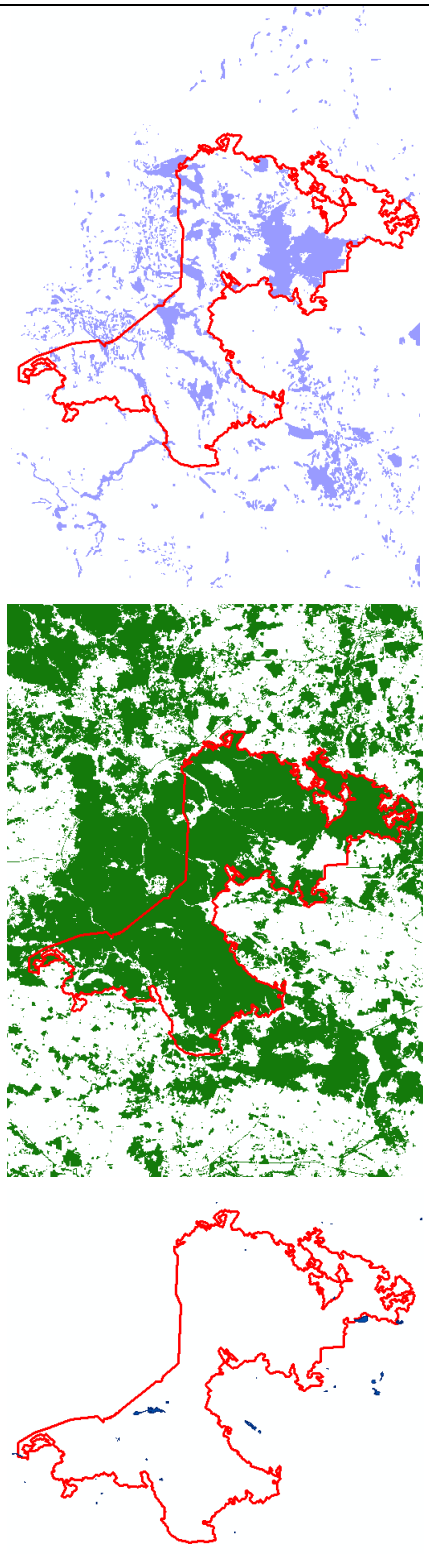

Figure 2 – Rasters of swamps, forest vegetation and reservoirs of the National park «Bialowieza Forest»

Results and discussion

The chronological course of maximum spring flood runoff, maximum rain flood runoff, minimum summer-autumn runoff, minimum winter runoff for the rivers Yaselda, Rudovka, Ross, Narev, Lesnaya, Zelvyanka, where regular hydrological observations are conducted, as well as their trends are presented in Figure 3.

The chronological course of annual runoff is represented in Figure 4.

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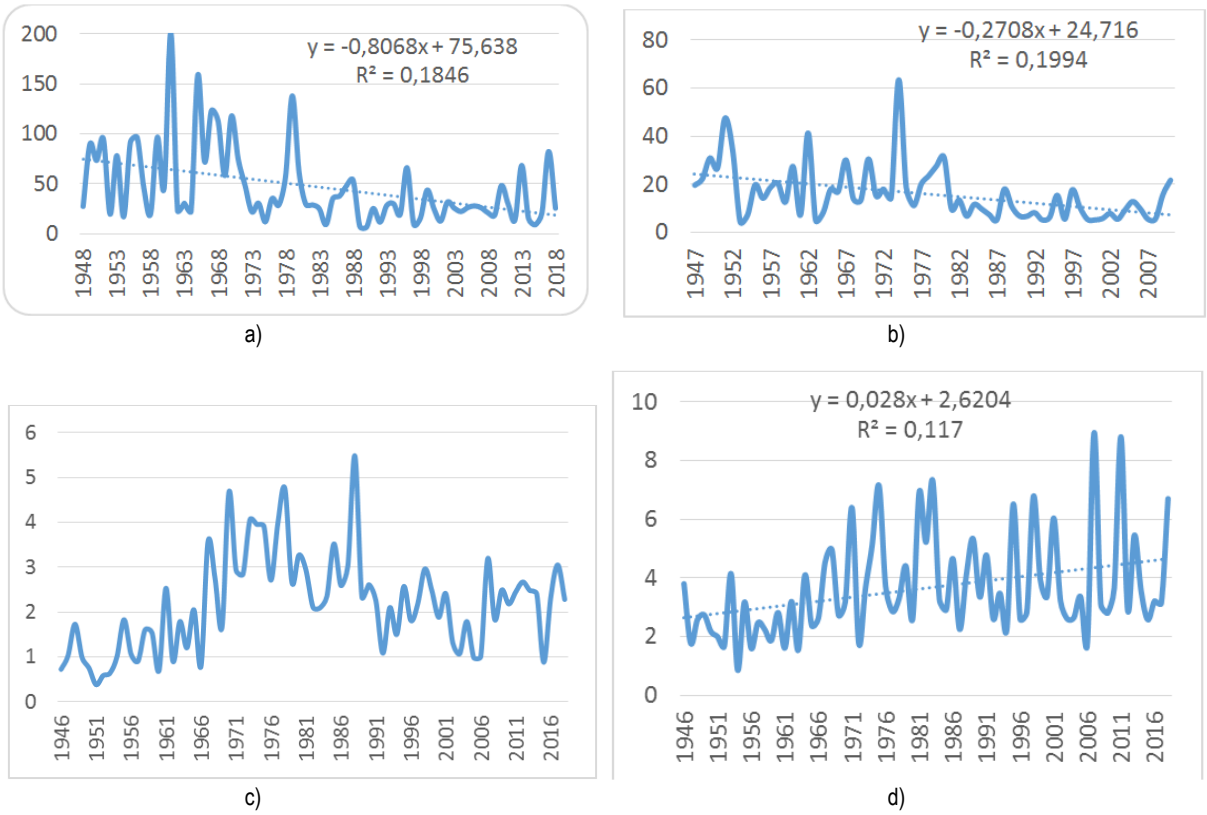

a) maximum spring flood runoff; b) maximum runoff of rain floods; c) minimum summer-autumn runoff; d) minimum winter runoff

Figure 3 – Chronological course of various types of runoff of the Lesnaya river in the observation point of the village Zamosty

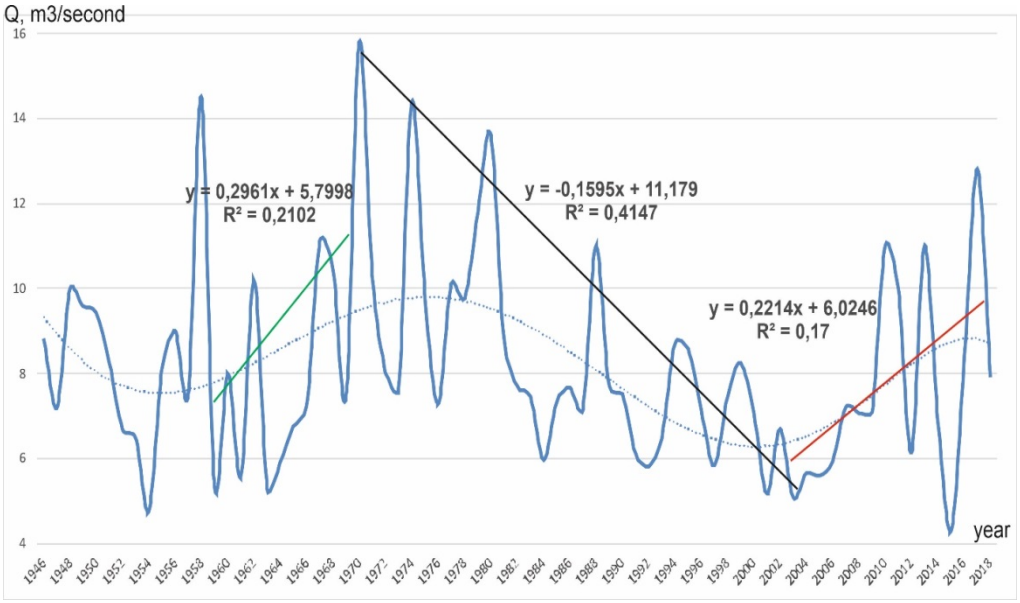

Figure 4 – Chronological course of annual runoff of the Lesnaya river in the observation point of the village Zamosty

The analysis of the obtained results showed that for all rivers, there isa decrease in the flow of maximum spring flood runoff (power trend – 19,5%) and maximum runoff of rain floods (power trend – 20,8%) and an increase in the flow of minimum winter runoff (power trend – 12,2%). Minimum summer-autumn runoff has the behavior of a time series the same as annual runoff.

The consumption in winter has increased, due to milder winters, the presence of frequent thaws and sufficient humidification of the territory. Firstly, it increased due to a decrease in the accumulation of groundwater in the ice in the aeration zone during the migration of unfrozen moisture to the freezing front. Secondly, the losses of underground river supply to the formation of ice formations have decreased: river ice, ice, seasonal underground ice. Thirdly, with a decrease in the thickness of the ice in the rivers, the carrying capacity of the channels increases. Fourth, with a decrease in soil freezing, their air permeability increases. With a freer penetration of air into the aeration zone over groundwater in winter, a lower pressure is not created than in the atmosphere, and groundwater is freely discharged into rivers.

Table 1 shows the average long-term values of annual runoff water consumption, maximum spring flood runoff, maximum rain flood runoff, minimum summer-autumn runoff, minimum winter runoff for the rivers Yaselda, Rudavka, Ross, Narev, Lesnaya, Zelvyanka for the estimated

period from 1946 to 2018, as well as factors of variation and parameters of linear trends of flow changes.

Using the three-parameter gamma distribution method, the annual water consumption characteristic of a very high-water year (5% security) and a very low-water year (95% security), as well as for the maximum water consumption of the spring flood, the maximum water consumption of rain floods, the minimum expenses of summer-autumn and winter autumn were determined (Table 2).

The calculation of the average monthly water consumption of the Bialowieza Forest's rivers on which regular hydrometric observations of a very high-water year (P=5%), an average water content year (P=50%) and a very low-water year (P=95%) are conducted is presented in Table 3.

For rivers where regular hydrological observations are not conducted, distribution parameters and calculated values were determined using a set of methods, namely: water balance; hydrological analogy; averaging in a homogeneous area; construction of contour maps, etc. [7, 8].

The calculation of the average annual water consumption of the rivers of the National park «Bialowieza Forest», as well as the annual expenses of very high-water and very low-water years are presented in Table 4.

The calculation of the average monthly water consumption of the rivers of Belovezhskaya Pushcha on which there are no regular hydrometric observations for the security of 5, 50, 95% is presented in Table 5.

Table 1 – Main hydrological characteristics of the rivers of the National park «Bialowieza Forest»

River	Observation point	Runoff type	Norm, m^3/sec	Factor		Gradient, m^3/sec 10 years
				variation	correlation	
Zelvyanka	Peski	Annual	9.18	0.23	0.01	-0.09
		Spring flood	62.5	0.90	0.02	-12.83
		Rain flood	14.3	0.52	0.16	-0.31
		Summer-autumn	3.28	0.44	0.33	0.01
		Winter	4.26	0.33	0.22	0.21
Lesnaya	Zamosty	Annual	8.16	0.29	0.20	-0.17
		Spring flood	48.4	0.82	0.20	-8.85
		Rain flood	15.7	0.72	0.24	-2.42
		Summer-autumn	2.18	0.50	0.49	0.13
		Winter	3.66	0.47	-0.02	0.28
Narev	Nemerzha	Annual	1.33	0.51	0.14	-0.04
		Spring flood	12.4	1.02	-0.04	-2.60
		Rain flood	2.64	0.64	0.23	-0.08
		Summer-autumn	0.17	0.83	0.11	-0.02
		Winter	0.33	0.72	0.07	0.02
Ross	Studenets	Annual	4.91	0.18	0.09	-0.06
		Spring flood	36.9	1.20	-0.13	-9.79
		Rain flood	6.00	0.40	0.13	0.10
		Summer-autumn	2.82	0.23	0.38	-0.05
		Winter	3.22	0.27	0.25	0.13
Rudavka	Rudnya	Annual	0.645	0.35	0.18	-0.01
		Spring flood	4.53	0.49	0.18	-0.55
		Rain flood	2.07	0.73	0.12	-0.25
		Summer-autumn	0.100	0.87	0.10	0.01
		Winter	0.174	0.70	-0.01	0.02
Yaselda	Horev	Annual	3.15	0.34	0.12	-0.10
		Spring flood	11.8	0.53	0.13	-1.47
		Rain flood	5.23	0.28	0.19	-0.06
		Summer-autumn	0.755	0.52	0.48	-0.01
		Winter	1.75	0.50	0.53	0.27

Table 2 – Water consumption of rivers of the National park «Bialowieza Forest» in very high and very low-water years, m^3/sec

Year dryness	Runoff type				
	Annual	Spring flood	Summer-autumn	Winter	Rain flood
river Zelvyanka – Peski					
P=5 %	13.3	187	6.06	7.27	33.6
P=95 %	7.06	21.3	1.31	1.98	7.87
river Lesnaya – Zamosty					
P=5 %	12.8	127	3.9	7.18	37.3
P=95 %	5.21	10.5	0.663	1.53	4.63
river Narev – Nemerzha					
P=5 %	2.52	23.9	0.522	0.98	7.74
P=95 %	0.716	1.98	0.011	0.088	0.613
river Ross – Studenets					
P=5 %	5.95	74.4	3.79	4.97	8.7
P=95 %	4.10	2.92	1.83	2.65	4.65
river Rudavka – Rudnya					
P=5 %	1.35	9.69	0.37	0.599	6.54
P=95 %	0.37	2.57	0.00	0.024	0.623
river Yaselda – Horev					
P=5 %	4.74	20.8	2.02	3.64	10.5
P=95 %	2.35	6.27	0.481	1.00	3.31

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Table 3 – Annual distribution of the runoff of the Bialowieza Forest's rivers for years of different security (in % of the annual runoff)

Year dryness, %	Spring				Summer-autumn							Winter			
	III	IV	V	Σ	VI	VII	VIII	IX	X	XI	Σ	XII	I	II	Σ
river Zelvyanka – Peski															
5	5.78	24.9	9.25	40	5.59	7.46	4.45	5.48	6.58	8.16	37.7	6.56	5.36	10.4	22.3
50	20.2	12.1	7.43	39.8	7.13	5.7	4.7	5.75	6.46	7.88	37.6	7.39	9.21	5.99	22.6
95	18.1	13.2	10.1	41.4	6.94	5.76	4.92	5.26	6.58	7.81	37.3	9.12	6.54	5.7	21.4
river Lesnaya – Zamosty															
5	18.7	8.95	5.39	33.1	8.43	5.65	3.89	4.77	8.43	11.1	42.3	5.31	7.32	12	24.7
50	20	14.4	8.29	42.7	7.67	5.07	3.32	3.87	5.01	6.25	31.2	8.48	11.6	6.04	26.1
95	23.3	16.3	10.9	50.5	4.89	3.32	2.46	2.8	4.11	6.03	23.6	10.4	7.11	8.35	25.9
river Narev – Nemerzha															
5	10.6	20	4.02	34.6	2.77	6.9	4.53	4.48	11.1	15	44.7	3.55	10.6	6.52	20.7
50	26.8	19.7	9	55.5	4.33	2.9	1.51	1.56	2.73	4.73	17.8	8.26	13.6	4.82	26.7
95	36.2	24.6	11.6	72.4	1.6	0.75	0.42	0.46	0.81	1.35	5.4	4.9	10.1	7.19	22.2
river Ross – Studenets															
5	14.2	9.3	6.76	30.2	6.69	7.9	5.83	8.09	7.04	7.53	43.1	8.82	7.85	10	26.7
50	12.4	10.2	8.23	30.8	7.68	6.96	5.91	6.71	7.58	8.34	43.2	8.68	7.62	9.7	26
95	11.8	9.83	8.3	29.9	7.36	5.51	6.25	6.04	7.98	9.59	42.7	10.5	8.81	8.04	27.3
river Rudavka – Rudnya															
5	12.7	6.97	3.81	23.4	3.08	6.32	10.7	4.93	9.24	15.9	50.2	7.58	14.1	4.7	26.4
50	8.33	32.7	18.4	59.4	6.81	2.39	1.41	2.2	3.59	5.72	22.1	5.47	9.76	3.19	18.4
95	24.4	49.3	11.3	85	1.36	0.59	0.28	0.26	0.59	1.22	4.29	5.83	2.7	2.18	10.7
river Yaselda – Horev															
5	4.99	7.05	3.53	15.6	10.5	8.42	6.17	7.33	10.1	12	54.5	9.65	12.7	7.48	29.9
50	8.78	17.1	12.1	38.1	6.9	5.24	4.37	4.99	6.22	7.32	35	8.61	11.5	6.8	26.9
95	21.5	14.9	11.8	48.2	5.46	3.52	2.82	3.26	4.75	6.02	25.9	8.52	10.7	6.72	25.9

Table 4 – Characteristics of the Bialowieza Forest's rivers

River	Catchment			Runoff norm, м³/с	Water runoff dryness, %	
	square, km²	degree of forest cover, %	swampiness, %		P=5 %	P=95 %
Belaya	273.3	23.1	2.1	1.10	1.91	0.507
Berezovka	24.7	21.2	–	0.077	0.126	0.039
Vishnya	43.4	77.7	3.0	0.126	0.231	0.051
Gvozna	94.0	93.1	24.1	0.384	0.647	0.185
Gitka	13.3	99.5	1.8	0.038	0.065	0.018
Guricinka	9.6	56.3	2.7	0.039	0.061	0.021
Drunyuvka	40.4	69.1	14.8	0.143	0.241	0.069
Yelenka	12.3	95.3	14.6	0.042	0.071	0.021
Zlota	6.4	40.3	4.0	0.018	0.031	0.009
Zubrica	14.6	91.5	10.3	0.044	0.076	0.021
Kalinovets	7.2	99.3	5.3	0.021	0.037	0.009
Kolonna	93.8	52.0	15.4	0.478	0.771	0.247
Krapivnica	39.1	43.4	2.8	0.137	0.227	0.068
Kulevka	9.9	96.6	18.8	0.034	0.058	0.017
Left Lesnaya	435.0	54.3	6.0	1.48	2.61	0.646
Right Lesnaya	409.6	63.2	8.0	1.57	2.74	0.705
Lomovka	17.3	57.8	1.6	0.061	0.099	0.031
Loshanka	35.9	19.4	0.0	0.126	0,207	0,064
Luzhaika	47,4	19,4	17,1	0,113	0,206	0,046
Lutovka	82,5	92,0	7,3	0,316	0,542	0,147
Medyanka	57,8	60,1	17,6	0,276	0,469	0,130
Muravka	5,8	31,9	4,3	0,018	0,031	0,008
Narevka	468,5	60,1	8,7	1,98	3,33	0,959
Nemerzhanka	34,8	98,2	25,3	0,116	0,198	0,055
Ol'hovka	16,6	30,1	77,3	0,068	0,114	0,033
Orluvka	18,7	98,8	24,2	0,066	0,110	0,033
Perevoloka	33,2	96,6	17,0	0,098	0,167	0,047
Peredelka	17,8	17,8		0,056	0,093	0,028
Pesec	9,0	95,7	4,4	0,035	0,059	0,017
Plyuskovka	96,8	97,2	22,1	0,332	0,595	0,137
Poboika	13,5	91,4	11,4	0,047	0,079	0,023
Polichna	126,7	66,9	4,0	0,528	0,898	0,249
Poperechnaya	57,1	8,8	0,4	0,186	0,332	0,078
Pchelka	37,9	64,9	15,8	0,152	0,247	0,076
Sipurka	67,3	27,9	2,0	0,193	0,327	0,091
Solomenka	84,8	91,9	23,2	0,193	0,327	0,091
Stanock	19,2	94,3	5,4	0,056	0,098	0,025
Tochnica	38,3	20,5	0,2	0,133	0,240	0,056
Tushemlyanka	26,8	64,9	27,9	0,095	0,159	0,046
Horovka	21,0	50,9	1,0	0,074	0,116	0,039
Schiba	124,7	44,3	2,9	0,652	1,03	0,353
Yamenka	40,3	98,4	16,0	0,119	0,203	0,056
Yatvez'	55,0	29,1		0,186	0,305	0,098

Table 5 – Annual distribution of the runoff of the Bialowieza Forest's rivers for years of different dryness (in % of the annual runoff)

Year dryness. %	Spring				Summer-autumn							Winter			
	III	IV	V	Σ	VI	VII	VIII	IX	X	XI	Σ	XII	I	II	Σ
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
river Guricinka															
5	23.4	7.4	4.2	35	8.7	4.9	6.1	3.7	8.4	12.8	44.6	11	5.5	3.9	20.4
50	30.5	9.7	5.5	45.7	6.6	3.8	4.7	2.8	6.5	9.8	34.2	10.8	5.4	3.9	20.1
95	39.5	12.5	7.1	59.1	4.3	2.4	3	1.8	4.2	6.3	22	10.2	5.1	3.6	18.9
river Pesec															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	35.5	14.4	6.1	56	5.4	3.2	1.9	0.8	3.3	6.4	21	14	5.7	3.3	23
river Schiba															
5	23	7.9	4.2	35.1	8.72	4.88	6.07	3.7	8.38	12.8	44.5	11	5.5	3.91	20.4
50	30	10.2	5.5	45.7	6.63	3.82	4.72	2.83	6.46	9.76	34.2	10.8	5.42	3.92	20.1
95	38.8	12.9	7.2	58.9	4.33	2.44	3.03	1.84	4.2	6.29	22.1	10.2	5.14	3.65	19
river Medyanka															
5	42	10.7	3.7	56.4	2.59	1.86	5.45	6.71	4.79	6.8	28.2	4.96	2.34	8.11	15.4
50	40.3	20.1	8.84	69.3	3.92	2.32	1.7	1.99	3.2	5.29	18.4	5.42	3.11	3.77	12.3
95	49.8	27.6	8.59	86	1.61	0.91	0.70	0.79	1.11	1.81	6.94	3.9	1.91	1.3	7.11
river Perevoloka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Solomenka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Tochnica															
5	22.2	9.37	4.1	34	10.5	6.2	3.83	1.8	6.53	12.5	41.4	13.6	5.83	3.55	22.9
50	30.5	12.9	5.56	49	6.9	4.07	2.52	1.23	4.3	8.25	27.3	14	6.07	3.63	23.7
95	41.1	17.3	7.43	65.9	3.17	1.93	1.2	0.58	1.97	3.85	12.7	12.7	5.45	3.28	21.5
river Polichna															
5	22.5	9.24	3.94	35.3	10.7	6.28	3.73	1.64	6.59	12.6	41.5	13.8	5.73	3.35	22.8
50	31	12.7	5.36	49.1	6.98	4.09	2.42	1.13	4.3	8.21	27.1	14.3	6.01	3.45	23.8
95	41.8	17.1	7.17	66.1	3.11	1.91	1.12	0.52	1.91	3.73	12.3	13	5.41	3.14	21.6
river Sipurka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Right Lesnaya															
5	21.8	9.55	4.32	32.2	10.2	6.09	3.98	2.02	6.46	12.4	41.2	13.3	5.98	3.82	23.1
50	29.9	13.1	5.85	48.9	6.79	4.03	2.64	1.38	4.3	8.3	27.4	13.6	6.14	3.89	23.7
95	40.2	17.5	7.79	65.5	3.24	1.97	1.31	0.67	2.04	4.01	13.2	12.3	5.5	3.48	21.3
river Belaya															
5	22.2	9.4	4.14	33.7	10.4	6.18	3.86	1.84	6.52	12.5	41.3	13.5	5.86	3.6	23
50	30.4	12.9	5.63	49	6.88	4.06	2.54	1.26	4.3	8.26	27.3	14	6.08	3.68	23.7
95	40.9	17.3	7.51	65.8	3.18	1.94	1.22	0.60	1.98	3.88	12.8	12.6	5.46	3.32	21.4
river Left Lesnaya															
5	21.9	9.53	4.29	32.4	10.2	6.1	3.96	1.99	6.47	12.4	41.2	13.3	5.96	3.79	23.1
50	30	13.1	5.82	48.9	6.8	4.03	2.63	1.36	4.3	8.3	27.4	13.7	6.13	3.86	23.7
95	40.3	17.5	7.75	65.5	3.23	1.97	1.3	0.66	2.03	3.99	13.2	12.4	5.5	3.46	21.3
river Krapivnica															
5	23.4	7.4	4.2	35	8.7	4.9	6.1	3.7	8.4	12.8	44.6	11	5.5	3.9	20.4
50	30.5	9.7	5.5	45.7	6.6	3.8	4.7	2.8	6.5	9.8	34.2	10.8	5.4	3.9	20.1
95	39.5	12.5	7.1	59.1	4.3	2.4	3	1.8	4.2	6.3	22	10.2	5.1	3.6	18.9
river Kolonna															
5	22.5	9.24	3.95	35.3	10.6	6.27	3.74	1.65	6.58	12.6	41.5	13.7	5.74	3.37	22.8
50	30.9	12.8	5.37	49.1	6.97	4.09	2.43	1.14	4.3	8.21	27.1	14.3	6.02	3.46	23.8
95	41.8	17.2	7.19	66.1	3.12	1.91	1.13	0.52	1.92	3.74	12.3	13	5.41	3.15	21.6
river Poboika															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Pchelka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Lomovka															
5	23.4	7.4	4.2	35	8.7	4.9	6.1	3.7	8.4	12.8	44.6	11	5.5	3.9	20.4
50	30.5	9.7	5.5	45.7	6.6	3.8	4.7	2.8	6.5	9.8	34.2	10.8	5.4	3.9	20.1
95	39.5	12.5	7.1	59.1	4.3	2.4	3	1.8	4.2	6.3	22	10.2	5.1	3.6	18.9

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1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
river Kulevka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Drunyuvka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Horovka															
5	23.4	7.4	4.2	35	8.7	4.9	6.1	3.7	8.4	12.8	44.6	11	5.5	3.9	20.4
50	30.5	9.7	5.5	45.7	6.6	3.8	4.7	2.8	6.5	9.8	34.2	10.8	5.4	3.9	20.1
95	39.5	12.5	7.1	59.1	4.3	2.4	3	1.8	4.2	6.3	22	10.2	5.1	3.6	18.9
river Tushemlyanka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Nemerzhanka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Orluvka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Gvozna															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Zlota															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Lutovka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Yelenka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Poperechnaya															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Narevka															
5	22.2	9.38	4.12	33.9	10.4	6.19	3.85	1.82	6.53	12.5	41.3	13.5	5.85	3.57	23
50	30.5	12.9	5.59	49	6.89	4.06	2.53	1.25	4.3	8.25	27.3	14	6.07	3.66	23.7
95	41	17.3	7.46	65.8	3.17	1.94	1.21	0.59	1.97	3.86	12.7	12.7	5.45	3.3	21.4
river Yamenka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Poperechnaya															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Muravka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Zubrica															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Gitka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Luzhaika															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
river Kalinovets															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Plyuskovka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Stanock															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Vishnya															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Yatvez'															
5	23.4	7.4	4.2	35	8.7	4.9	6.1	3.7	8.4	12.8	44.6	11	5.5	3.9	20.4
50	30.5	9.7	5.5	45.7	6.6	3.8	4.7	2.8	6.5	9.8	34.2	10.8	5.4	3.9	20.1
95	39.5	12.5	7.1	59.1	4.3	2.4	3	1.8	4.2	6.3	22	10.2	5.1	3.6	18.9
river Loshanka															
5	23.4	7.4	4.2	35	8.7	4.9	6.1	3.7	8.4	12.8	44.6	11	5.5	3.9	20.4
50	30.5	9.7	5.5	45.7	6.6	3.8	4.7	2.8	6.5	9.8	34.2	10.8	5.4	3.9	20.1
95	39.5	12.5	7.1	59.1	4.3	2.4	3	1.8	4.2	6.3	22	10.2	5.1	3.6	18.9
river Berezovka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6
river Peredelka															
5	22.6	9.2	3.9	35.7	10.7	6.3	3.7	1.6	6.6	12.6	41.5	13.8	5.7	3.3	22.8
50	31.1	12.7	5.3	49.1	7	4.1	2.4	1.1	4.3	8.2	27.1	14.4	6	3.4	23.8
95	42	17.1	7.1	66.2	3.1	1.9	1.1	0.5	1.9	3.7	12.2	13.1	5.4	3.1	21.6

Conclusion

The analysis of the database of hydrological observations of the flow of the Bialowieza Forest's rivers for various types (average annual, average monthly, spring floods, rain floods, summer-autumn and winter low water) for the current closed hydrometric posts for the period of instrumental observations up to and including 2018. In the course of the conducted studies, the missed water flow rates were restored, the series of observations were brought to a single calculation period from 1946 to 2018, and an assessment for uniformity was performed. The formed hydrological base allows solving a number of hydrological, ecological and water management tasks for the rivers of the National park «Bialowieza Forest».

During the research, hydrographic information on the rivers of the National park «Bialowieza Forest» was updated using GIS technologies, including the catchment area, river length, catchment slope, forest cover and swampiness of the territory in absolute and relative terms, and other parameters. This made it possible to estimate the flow of rivers for different water years.

The analysis of river flow fluctuations during the period of instrumental observations showed a slight change in the decrease in the average annual river flow. At the same time, there is a decrease in spring flood runoff and an increase in winter runoff on all rivers. The average long-term runoff of rain floods tends to some slight decrease, and the runoff of the summer–autumn fall, on the contrary, to a slight increase for most of the rivers studied.

Gratitudes

This research was completed within the scope of the task ZT.2.5. «Development of analyze and forecast changes in the water regime of the territory of National park «Bialowieza Forest» and recommendations for its maintenance» of the State Scientific and Technical Program «Green technologies of resource management and environmental safety» Subprogram «Sustainable nature management and innovative technologies for processing, protection and reproduction of natural resources».

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ORGANIZATIONAL AND ECONOMIC SUPPORT FOR THE APPLICATION OF STATE SUPPORT MEASURES FOR INVESTMENT PROJECTS IN THE REGION

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Abstract

The article discusses the issues of increasing the validity of the application of measures of state support for investment projects by management bodies. The importance of making decisions on the provision of benefits in the implementation of investment projects, taking into account the criterion of social responsibility of the initiator of the project, is substantiated. The characteristics of the organizational and economic mechanism of regulation of investment activity are given, the organizational and economic components are disclosed and directions for improving the mechanism are proposed, taking into account the priority of social and environmental factors within the framework of sustainable regional development. It is proposed to supplement the structure of the sections of the business plan with indicators of social responsibility for the project. Practical recommendations on the application of state support measures to stimulate the implementation of socially responsible investment projects are given.

Keywords: investment project, investment activity, business plan, social responsibility of business, state support, organizational and economic mechanism of regulation of investment activity.

ОРГАНИЗАЦИОННО-ЭКОНОМИЧЕСКОЕ ОБЕСПЕЧЕНИЕ ПРИМЕНЕНИЯ МЕР ГОСУДАРСТВЕННОЙ ПОДДЕРЖКИ ИНВЕСТИЦИОННЫХ ПРОЕКТОВ В РЕГИОНЕ

Е. О. Дружинина

Реферат

В статье рассмотрены вопросы повышения обоснованности применения мер государственной поддержки инвестиционных проектов органами управления. Обоснована важность принятия решений по предоставлению льгот при реализации инвестиционных проектов с учетом критерия социальной ответственности инициатора проекта. Дана характеристика организационно-экономического механизма регулирования инвестиционной деятельности, раскрыты организационная и экономическая составляющие и предложены направления совершенствования механизма с учетом приоритета социального и экологического факторов в рамках устойчивого регионального развития. Предложено дополнить структуру разделов бизнес-плана показателями социальной ответственности по проекту. Приведены практические рекомендации по применению мер государственной поддержки, позволяющие стимулировать реализацию социально-ответственных инвестиционных проектов.

Ключевые слова: инвестиционный проект, инвестиционная деятельность, бизнес-план, социальная ответственность бизнеса, государственная поддержка, организационно-экономический механизм регулирования инвестиционной деятельности.

Introduction

Improving the competitiveness of the regional economy is the main complex task. Ultimately, the result of the work of the entire economic system of the country depends on it. Investment activity is an important component of the development of any economic system, an indicator of the state of the country's economy. Fluctuations in investment investments are considered as an indicator of changes in aggregate demand and, in the future, the volume of national and regional production, as well as the level of employment of the population.

Currently, the National Strategy of Sustainable Socio & Economic Development of the Republic of Belarus until 2030 is being implemented in the Republic of Belarus. The Belarusian model of sustainable development takes into account the sustainable development goals developed by the UN, national interests and peculiarities of the Belarusian economy. The main characteristics of the model include: strong effective state power, participation of civil society in solving problems of sustainable development, effective state and public support for socially vulnerable groups of the population, environmentally sound state policy and others [1].

Regional concepts of sustainable development have been adopted at the regional level, aimed at achieving a reasonable balance in solving social, economic and environmental problems of the region, meeting people's needs for material and spiritual well-being, a favorable state of nature, based on mechanisms for implementing these requirements and monitoring their implementation.

The implementation of investment activities in the region is the most important condition for the implementation of strategic and tactical tasks of social and economic development, the implementation of innovative, agro-industrial, environmental policy.

Investment activity is a set of practical actions of legal entities, individuals, and the state to attract and invest funds and other valuables in investment objects in order to achieve a significant result (making a profit, income, solving a social problem, etc.). The choice of an object for investment is made by the investor based on the effectiveness of the project. However, the development of science, culture, the creation of other socially significant objects, environmental protection can not always bring income, and are more often unprofitable. Therefore, the intrusion of the state into the investment sphere is a normal world practice aimed at harmonizing the investment process and solving priority tasks related to the development of society.

In addition, investments in the development of production, the introduction of new technologies are accompanied by risks of impact not only on the economic, but also social, and environmental spheres in the implementation of investment activities. The duration of the environmental crisis and its impact on the quality of life of society are inextricably linked with the economic activities of the subjects and cause increased attention to preventive measures that provide for the integration of social, environmental and economic factors when making investment decisions.

Thus, the State is obliged, on the one hand, to support investments by providing various support measures, and on the other, to direct investment activities to the implementation of measures included in the state's economic, scientific, technical, social and environmental policy.

Based on the highlighted problem, it is possible to formulate the **objectives of this study**, which are to provide an integrated approach to the application by management bodies of measures to support investment projects of economic entities in the region with the help of an organizational and economic mechanism for regulating investment activities in the region based on the principles of corporate social responsibility.

Corporate social responsibility CSR (or business social responsibility) is a voluntary contribution of business to the development of society in the social, economic and environmental spheres, directly related to the main activity of the company and going beyond the minimum defined by law.

Based on this, the *social responsibility of the initiator of an investment project (SRIP)* is a planned voluntary contribution, laid down in the indicators of the investment project, to the development of society in the social, economic and environmental spheres, directly related to the main activity of the company and going beyond the minimum defined by law.

Theoretical and practical aspects of state support in the implementation of investment projects

State support is provided to economic entities for the implementation of investment projects – financial and other assistance in accordance with the legislation, in the form of budget subsidies and other financial assistance, budget loans and loans, tax and tariff benefits, external government loans, guarantees of the Government of the Republic of Belarus on loans and loans and other preferences. Financing of investment projects is carried out at the expense of budgets of all levels, extra-budgetary funds, as well as other sources. Reasonable and responsible allocation of budgetary funds and extra-budgetary funds is the task of the State. When allocating funds, various approaches and regulatory and instructional materials are used, including separately for different levels of decision-making. Financial and other support for investment projects is provided through the application of various measures and instruments for regulating investment activities. In order to increase the validity of the application of state support measures for investment projects, information on their social orientation is needed, which will allow more efficient allocation of funds allocated for their financing.

The results of the socio-economic assessment of investment projects are used to increase the validity of the use of instruments for regulating investment activities, as well as state support measures aimed at activating the activities of socially responsible business entities, reducing or preventing the destructive impact of investment projects on the socio-ecosystem of the project area and adjacent regions.

This task is solved with the help of an **organizational and economic mechanism for regulating investment activity** in the region, which is a set of forms, methods, tools and levers of influence on investment activity, interconnected into a single mechanism that allows determining the volume, structure, directions and implementation of investments that ensure the implementation of regional goals and objectives of socio-economic development of the region.

Let's consider specific measures, methods and tools of the mechanism of regulation of investment activity. To ensure the socio-economic and environmental security of the region, it is important to use organizational measures to facilitate the implementation of projects that meet the goals of socio-economic development of the regions. These are socially significant projects, innovative and infrastructure projects, environmentally efficient, which, in fact, are implemented according to the principles of social responsibility. For such assistance, the interaction of regional government bodies and investors is necessary. Subjects are regional management bodies that perform the functions of a regulator, initiators of investment projects (commercial and non–profit organizations, individual investors). The object is commercial investment projects proposed for implementation in the region.

Different levels of management systems combine administrative and economic methods of regulation. Administrative (direct) methods involve a direct impact on the subjects of investment activity: prohibitions, restrictions, permits, regulations established by legislative and regulatory acts.

The direct participation of the state in investment activities includes the adoption of state investment programs and their financing at the expense of the republican budget, the provision of centralized investment resources from the republican budget to finance investment projects, the state comprehensive examination of investment projects and others.

Economic (indirect) methods involve influencing the subjects of investment activity by stimulating investment decisions both in the interests of the subjects themselves and in the interests of society as a whole. The creation of favorable conditions for the development of investment activities includes the provision of state support to investors, the definition of conditions for the ownership, use and disposal of land, subsoil, water and forests, the privatization of state-owned facilities, and others.

The instruments to be improved for the purposes of regional regulation according to the principles of social responsibility are: competitive selection of investment projects, state support, state participation, state financing based on a socially responsible approach. Accordingly, it is necessary to form information support for the assessment of the social responsibility of the initiators of the project; improving the procedure for selecting investment projects to provide state support, taking into account an additional criterion that takes into account the contribution to the development of the region's economy; establishing the relationship between regulatory instruments and indicators of social responsibility of the project; justification of project financing at the expense of budgetary and extra-budgetary funds in the context of the implementation of the concept of sustainable socio-economic development of regions.

In order to activate the activities of socially responsible business entities, to prevent the destructive impact of investment projects on the socio-economic system of the region, it is necessary to improve the organizational and economic mechanism for regulating investment activities in terms of supplementing the project selection procedure with measures to assess the social responsibility of the initiator of the investment project (SRIP). The *economic component* of the organizational and economic mechanism for regulating investment activity includes the proposed methodological approach to assessing the social responsibility of the initiator of the investment project, which determined the content of the developed methods for assessing the level of SRIP and assessing the economic effect of SRIP (information support) [2]. The *organizational component* of the mechanism is represented by the development of practical recommendations on the reasonable allocation by management bodies of financial support for socially responsible investors based on the SRIP criterion. In contrast to existing approaches, not only socio-economic indicators of the project's effectiveness are evaluated, but also the voluntary contribution of the investor to the social and environmental spheres of the region's development.

To analyze the compliance of the project data of investment proposals with the principles of CSR and to ensure the implementation of socially responsible investment, it is necessary to supplement the information and analytical support for the development and evaluation of business plans for investment projects with an independent section "Indicators of social responsibility for the project", including the main calculation indicators reflecting the contribution of the initiator of the project to the development of the region.

The implementation of an investment project (related to the creation of a new production facility by placing it on the premises of a decommissioned facility, on existing vacant areas, during new construction, technical re-equipment, reconstruction) requires the preparation of permits, justifying and evaluating documentation, the formation of which begins at the pre-investment stage. The set of documents contains fundamental information, confirmed by studies, justifications, calculations, allowing you to make a decision on the feasibility of implementing an investment project, taking into account internal and external effects and consequences.

Project support of the investment process in construction, taking into account the current legislation in the Republic of Belarus and foreign practice, as a rule, consists of the main stages:

A) Pre–investment stage: stage 1 – submission of a petition (declaration) of intent to the local executive authority by the customer (investor) in accordance with the established procedure. Obtaining a decision of the local executive authority; stage 2 – development of a justification for investments in construction. Receipt from the relevant executive authority of a decision on preliminary approval of the location of the object (act of site selection) (Table 1).

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Table 1 – The main content of the pre-investment stage of the implementation of investment projects

Stages	Content	Intelligence
Submission by the customer to the local executive authority of a petition of intent	Contains preliminary information: formation of an investment plan, determination of investment objectives, purpose, capacity and location of the construction object; possible impact of the planned activity on the environment; assessment of investment opportunities and achievement of the planned technical and economic indicators	*Declaration of intent* Investor, location, technical and technological data of the construction object, number of employees, need for raw materials, water, land, energy resources, etc.
Development, coordination, examination and approval of the justification of investments in the construction of the facility	Implementation of alternative studies, calculations of investment efficiency, determination of social, environmental and other consequences of the construction and operation of the facility, assessment of investment opportunities and achievement of the planned technical and economic indicators; preliminary approval of the location of the land plot; obtaining an expert opinion on the justification of investments	*Justification of investments in the construction of the facility* Investment objectives; general characteristics, purpose, capacity, location of the facility; basic technological solutions; provision of resources (material, labor, etc.); architectural and planning concept; environmental impact assessment; social development; project budget; investment efficiency
Section of the feasibility study	Assessment of the technical feasibility and economic feasibility of the project; environmental impact assessment	During the construction of industrial facilities, it is part of the justification of investments in construction
Development, approval, examination and approval of the *business plan* of the investment project	Development in cases of justification: the possibility of attracting investments in fixed assets, external loans, loans; the expediency of providing state support measures; for the purposes of: detailed verification of feasibility and economic efficiency; short- and medium-term planning; search for an investor	*Business plan* Summary, description of the industry, products, production, marketing, organizational, financial plan; risk analysis, sensitivity and sustainability of the project; calculation tables; other aspects
Defining a project management scheme	Reflection of the most key events of the project, their planned parameters and management decisions (actions) to achieve them	*Project management plan* Register of project stakeholders; organizational structure of project management; project implementation schedule; project cost plan (budget); resource plan; project quality management plan; project risk management plan; project supply management plan; project implementation control plan; project communications management plan; project change management plan; other aspects
Development of a design assignment	The basis for the design; permits for design and construction, transferred to the project organization-contractor for the development of project documentation; information about construction; technology requirements	*Design assignment* Basic data and design requirements (depending on the complexity, type and purpose of the projected object), information about the land plot and planning restrictions; basic technical and economic indicators based on economic calculations performed in the business plan

Source: compiled by the author.

The basic information provided in the declaration of intent, justification of investments in the construction of facilities, on social aspects include the approximate number of workers and employees, sources of satisfaction of labor needs, provision of workers and their families with housing and communal and social facilities, etc., on environmental aspects – the approximate demand of the construction object for water resources (volume, quantity, source of water supply), energy resources (electricity, heat, steam, fuel), land resources (with appropriate justification of the approximate size of the land plot and the terms of its use), etc.

B) Investment stage: stage 1 – justification of investment in construction; stage 2 – architectural project; stage 3 – construction project. This stage includes the development, coordination, examination and approval of project documentation, the implementation on its basis of the allotment of land for construction, the development of architectural and construction projects, the examination of project documentation; construction and installation works, commissioning, commissioning of the facility.

Thus, the information provided in the pre-project documentation contains a fairly high level of generalization of data, mainly includes permits and supporting documentation for the implementation of the project, which does not allow for a comprehensive economic assessment of the socio-environmental parameters of the investment project. More detailed information is reflected in the business plan developed to assess the necessity, commercial efficiency, financial feasibility and contribution to the economy of the region of investments in the construction, reconstruction of the construction object.

To date, the pre-project documentation and business plan contain a significant amount of data, including, among other things, information about the social and environmental effects and consequences of the project. But this is not enough to assess the social responsibility of the initiator of the project (SRIP). Rather, the information is presented only from the qualitative side, mainly without a monetary assessment of social and environmental consequences, without comparing project indicators with the average values in the region, comparing with international standards and determining a voluntary contribution to the development of the region in excess of legislative norms. To determine the initiator's active or passive position in solving social and environmental problems, it is necessary to provide a more detailed explanation of income and expenses in addition to the one that is currently reflected in the business plan: expenses for environmental protection measures, environmental training of personnel, expenses for the formation of a social package for employees and others. At the same time, the absence, on the one hand, of established requirements, and on the other hand, of the initiators' interest in disclosing additional information about the social and environmental impact of the project, including both regulated and initiative components, does not allow for a comprehensive economic assessment of the social and environmental parameters of the investment project and to determine the social responsibility of the initiator of the project.

In this regard, it is proposed by processing the information provided in the pre-project documentation, business plan and other sources to form new data sets that, in our opinion, allow us to evaluate the SRIP.

The distinctive features of this approach are:

1) inclusion of comparative indicators: for social and economic indicators in comparison with the average values for the main types of economic activity in the region, and for environmental indicators also by comparing the values actually achieved with environmental impact standards (maximum permissible emission of harmful substances, maximum permissible discharge of harmful substances);
2) in contrast to the environmental impact assessment based on determining the impact in natural terms, it is proposed to assess the social and environmental component using a cost-based approach, which allows you to assess the contribution to the development of the region (or harm) in monetary terms.

The assessment of social responsibility is a characteristic in which the initiator (investor) of an investment project is interested, which counts on state support, as well as regional authorities that distribute financial resources to stimulate investment in the region. Therefore, we consider it most reasonable to allocate the indicators proposed by the author to a separate, initiative, section of the business plan, the information of which is not currently reflected in other sections according to the rules for developing business plans for investment projects [3].

To assess the social responsibility of the initiator of an investment project when developing a business plan, it is proposed to accumulate in a separate section of the business plan "Indicators of social responsibility for the project" the main calculated indicators determined on the basis of the application of the methods proposed by the author for diagnosing the potential impact on the socio-ecosystem of the region and calculating the effect of socially responsible investment [4]. Interrelated indicators are used, revealing social, environmental and economic benefits and losses from the position of influence on the socio-ecosystem of the region, necessary to assess compliance with the requirements of social responsibility standards. The initiator of the project calculates indicators in the context of economic, social and environmental components.

The main purpose of this section is to provide investors and other interested parties with the necessary information about the potential impact of an investment project on the socio–ecosystem of the territory of its implementation and the planned effect of socially responsible investment. The preparation of the section is carried out by the initiator of the investment project.

The significance of the section is: to identify both positive and negative consequences for the region induced by the implementation of an investment project that comprehensively characterizes its economic, social and environmental aspects; to determine the financial value of potential losses from the implementation of a business project for the socio-ecosystem of the region or, conversely, a contribution to improving the welfare of society and the development of the region, including the number in excess of the legally established requirements. This section includes aspects that allow:

- to improve the structure of the investment project during its preparation by the initiator and developer, to identify and solve problems in a timely manner, to avoid the appearance of adverse socio-environmental impacts, to respond to future events;
- to increase the interest of investors and initiators of the project in the implementation of the principles of social responsibility;
- increase the investment attractiveness of the project;
- to provide in the business plan the necessary income and expenses for compensation of socio-environmental losses, that is, to make an adjustment to the calculation of the overall effectiveness of the investment project;
- to form the non-financial aspect of the CSR of the proposed project in the context of key stakeholders;
- to conduct an examination of the social responsibility of investment projects to justify the decision on the application of regulatory measures aimed at preventing, reducing and compensating for socio-environmental losses and improving the quality of the environment and living standards, stimulating and supporting investment projects of a socially responsible orientation.

Conclusions

Investments are one of the factors of economic progress at the macro-, meso- and micro- levels. The state is interested in investing in a prosperous and stable society, environmental protection, the institutional implementation of which can serve as a strategy of socially responsible investment in the development and implementation of business projects by economic entities of the region. A successful policy for the development of investment activity largely depends on the continuous improvement of its regulatory instruments, which takes into account the main trends of modern economic growth. When implementing versatile design solutions, the improvement of the system of stimulating socially responsible investments and preventing possible adverse consequences of the implementation of investment decisions for the environment and society becomes relevant. This leads to the need to improve the instruments for regulating investment activities available to management bodies, the most important of which are the financing of investment projects, the selection of which is based on criteria consistent with the priorities of socio-economic development. In the context of the implementation of the strategy of regional sustainable development, the application of the provisions of socially responsible investment will allow taking into account the social and environmental factors in the evaluation and selection of investment projects.

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THEORETICAL APPROACHES TO THE STUDY OF REGIONAL COMPETITIVENESS

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Abstract

Theoretical approaches to revealing the content of the region's competitiveness are outlined, summarized and analyzed. Interpretations of the concept of competitiveness of the region by groups are ordered. The signs of the competitiveness of the region as a system are given. The author's interpretation of the concept of regional competitiveness is proposed.

Keywords: competitiveness, region, competitive advantages, competition, enterprise competitiveness, population competitiveness.

ТЕОРЕТИЧЕСКИЕ ПОДХОДЫ К ИЗУЧЕНИЮ РЕГИОНАЛЬНОЙ КОНКУРЕНТОСПОСОБНОСТИ

Н. Н. Флячинская

Реферат

Изложены, обобщены и проанализированы теоретические подходы к раскрытию содержания конкурентоспособности региона. Упорядочены трактовки понятия конкурентоспособность региона по группам. Приведены признаки конкурентоспособности региона как системы. Предложена авторская трактовка понятия региональной конкурентоспособности.

Ключевые слова: конкурентоспособность, регион, конкурентные преимущества, конкуренция, конкурентоспособность предприятия, конкурентоспособность населения.

Introduction

Against the background of increasing interdependence and interconnectedness among economic processes, an important step in the hierarchy is the competitiveness of the region. The regions, being independent market entities, directly implement the goals and objectives aimed at meeting the socio-economic needs of the population.

The growing competition of regions for investments, which is observed at the present stage of economic development, creates ever higher requirements for meeting the growing needs of the population, identifying the essence and competitiveness of the region [1]. Note that the competitiveness of the region in the form of an economic process is understood as a set of complex, unrelated processes that are influenced by various conditions:

- factors of production;
- conditions for the implementation of activities;
- factors of demand for goods of the main industries of the region;
- political;
- socio-cultural;
- organizational and legal, etc.

Due to new economic trends, the competition of regions becomes a theoretical and practical problem, regardless of regional development.

Theoretical approaches to the competitiveness of the region

Even a cursory analysis showed that territorial competitiveness remains one of the most debatable categories in economics. The world has not even developed a single definition or at least an understanding of the essence of this phenomenon, there are no general criteria for evaluating it.

The results of comparing various definitions of the concept of «competitiveness of the region» made it possible to notice that the authors in the formulations most often identify the criteria that are the basis of this category, for example:

- realization of the economic potential of the region;
- organization of favorable conditions for creating business entities and maintaining competitive positions in the market;
- growth of gross regional product per capita;
- production of goods and services resistant to internal and external competition;
- creation of investment attractiveness of the region;
- high standard of living in the region;
- use of innovations in the business life of the region.

According to these criteria, the opinions of scientists and economists are considered, which can be divided into four groups. For example, adherents of the first approach associate the competitiveness of the region with the opposition to competition in the commodity markets. However, here you can see the subject of competition – the enterprise. However, the high level of competitiveness of the entire region is not always confirmed by the achievement of the competitiveness of enterprises in the market.

The second approach links competitiveness with the ability of the economy to improve the welfare of the region's population. Here the subject of competition is the population. It can also be considered that the supposed opinion that the region is able to achieve competitiveness only by improving the standard of living of the population is limited.

Representatives of the third approach under the regional competitiveness understand the possibility of identifying, creating, using competitive advantages to improve competitive positions between competing regions. In our opinion, this approach is closest to reality. Under the competitiveness of the region, we mean the ability to withstand competition from other regions in the struggle for resources that are required for the development of the territory and the solution of socio-economic problems on this basis. A more detailed example of the definition of the concept of "competitiveness of the region" is presented in Table 1.

According to the fourth approach, competition between regions includes not only an economic component, but also a political, environmental, social, cultural and legislative one. At the same time, the different interests of the regions, together with their potentials and capabilities, lead to certain achievements in certain areas.

Regional competitiveness is the only type of competition in which the imitation of experience and the use of the results of other regions is convenient and desirable. Since the competitiveness of the region is not built on the deterioration of the rating positions of the competing regions, but involves the improvement of a wide range of indicators of the region and their retention. To some extent, it can be argued that this competition is common for all participants, with the aim of achieving individual success, which is fundamentally different from other subject competitiveness (goods, enterprises, countries).

Table 1 – The essence of the concept of «competitiveness of the region»

The essence of the economic category	Author
Competitiveness as the ability to withstand competition in product markets (competitiveness of enterprises)	
Competitiveness of the region – the ability of the region to sell its own products that meet international standards based on the results of a diagnostic assessment	R. Mason [2]
The competitiveness of the region lies in the ability of the region to produce goods and provide services that meet the requirements in foreign markets, as well as maintain a high level of income of the population	D. N. Kolkin [3]
The competitiveness of the region lies in the efficiency of the use of regional products, firstly, labor and capital, in comparison with other regions, in their dynamics, in the amount of gross regional product per capita	M. Porter [4]
Competitiveness – the ability of a region to compete with similar regions in a particular (domestic or foreign) market	R. A. Fatkhutdinov [5]
Competitiveness as the ability to improve the quality of life of the population (competitiveness of the population)	
The competitiveness of the region lies in the ability of regional bodies to improve the standard of living of the population by attracting investment in the business environment, developing more promising sectors of the economy, infrastructure and small business	M. V. Vinokurov [6]
The competitiveness of the region is the role and place of the region, depending on the ability of other regions of Russia to maintain a high standard of living for the population and develop the existing economic potential (in production, finance, labor, investment, innovation, raw materials and other components)	A. Vorotnikov [7]
Regional competitiveness is the ability to offer attractive conditions and a sustainable environment for the operation of enterprises and the life of the population	EU Directorate-General for Regional Policy [8]
Regional competitiveness can be measured on the basis of a number of indicators of socio-economic development that reflect the development of the region in dynamics; thus, it is possible to assess the change in regional competitiveness	B. Catalin [9]
Competitiveness as the ability to find, create, use competitive advantages	
The competitiveness of a region primarily means the presence and implementation of the competitive potential of this region. However, competitive opportunities are multifaceted and are formed as different signs of the region's ability to participate in competitive relations through interaction with other countries. Competitiveness in the above words is due to the following features: the competitive advantages of the region in various industries and sectors of the economy, the social sphere, climatic conditions, geographical location, the availability of natural resources, the intellectual level of development of the population	V. I. Vidyapin, M. V. Stepanov [1]
Competitiveness of the region – the ability to find, create, use competitive advantages to maintain or improve the position among the regions	N. Ya. Kalyuzhnov [10]
The competitiveness of the region can be realized only by managing the competitive advantages of participants in the market activity of the region (enterprises, organizations)	M. N. Nagorskaya [11]
The competitiveness of the region is aimed at ensuring a higher level of economic and social life in the region. It represents the successful implementation of a complex of competitive advantages in the process of tough struggle (competition) for resources (human, financial, natural, etc.)	E. N. Tikhomirov [12]
Comprehensive interpretation of the region's competitiveness	
The competitiveness of the region includes three main areas: – the need of the population to achieve a high standard of living (competitiveness in the labor market); – the efficiency of the functioning of the economic mechanism of the region (competitiveness in the commodity market); – investment attractiveness (competitiveness in the capital market)	V. N. Parakhina [13]
Competitiveness of the region – the ability of the region to attract investments, labor resources, create goods and services that can compete in domestic and foreign markets, by using existing opportunities, ensuring a high quality of life for the population and creating potential for future generations	I. N. Rusak [14]
The competitiveness of the region is a set of economic relations associated with the sustainable development of the region, reflecting the efficiency of using the current and prospective competitive advantages of the region to ensure a high standard of living for the population	A. A. Shashko [15]
Competitiveness of the region – the ability of the region, taking into account the existing innovative and investment potential of the region, to ensure a high level and quality of life for the population, the production of competitive products (works, services), attracting investments, creating sustainable and long-term advantages in all areas of activity and creating potential for new generations	O. P. Sovetnikova [16]

The results of the analysis of literary sources allow us to draw some conclusions, namely:

1. Among scientists dealing with the problems of the competitiveness of the region, there is no unity in the interpretation and content of this category.
2. Interpreting the concept of regional competitiveness, almost all authors focus on the presence of competitive advantages, however, there are disagreements about the understanding of their list and priority.
3. Some authors closely link the concepts of «regional competitiveness» and «industry competitiveness», which is incorrect, since the competitiveness of the industry at the regional level is only an integral element of the region's competitiveness.
4. When interpreting the category «competitiveness of the region», some authors give a meaningful description, others – a functional one.

We define the competitiveness of a region as a systemic concept that reflects the competitive advantages of a particular region over others in terms of a set of parameters (economic, financial, production, market, investment, innovation, etc.), which are combined in a certain way and form a priority uniqueness and consolidate positions in a certain area. and in a period of time and under a certain influence of the operating environment.

The study of the essence of the region's competitiveness is necessary for a meaningful understanding of the mechanisms of formation of competitiveness processes. In addition, the disclosure of the objective content and essence of theoretical concepts makes it possible to scientifically substantiate and effectively solve the problems of competitiveness.

The study can be built through system analysis, since competitiveness can be represented as a system with relevant elements: structure, hierarchy, communication, multi-level, etc. Such an analysis is characterized

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by considering the relevant elements in a certain order, which are dictated by a causal relationship and lead to a systemic result. At the same time, a logical chain is observed: the goal – the means to achieve the goals – the necessary resources.

The results of the study, the study of theory and practice on the problem make it possible to identify the main properties of the category «competitiveness of the region», namely:

- comparability: the competitiveness of the territory in relation to real competitors is determined and studied;
- spatiality: the competitiveness of a region is determined within a certain market, a specific field of activity, since under equal conditions a region can be identified as competitive in one market and non-competitive in another;
- dynamism: the concept of competitiveness is limited in time, since a region can be competitive in one period and lose these positions in another period, so the competitiveness of a region cannot be a constant value;
- subjectivity: involves the selection of a list and a set of parameters that form the competitiveness of the region;
- attributiveness: determination of a unique feature that primarily forms the competitive advantage of the region;
- integrality: the assessment of the competitiveness of the region cannot be carried out according to one criterion, but is necessarily based on the use of an integral indicator that accumulates the most representative indicators;
- taking into account internal and external conditions of functioning: when assessing or forecasting the competitiveness of a region, it is necessary to take into account all the factors that have or may have an impact on its formation;
- relevance: means that the competitive position of the region can only be determined within the framework of the relevant operating environment;
- consistency: implies taking into account the entire set of parameters and conditions that make up the competitiveness of the region, the relationship between them and their mutual influence.

The selection and systematization of criteria can be carried out on the basis of the methodology of system analysis, which determine the essence of the category «competitiveness of the region». It is characterized by the orderliness and logic of the study of the difficulties that arise in the system, when considering an object. The competitiveness of the region not only carries the properties of the economic system, but is also an independent and integral system with the appropriate properties and purpose. This category allows the region to compete effectively to achieve economic, social, environmental and other goals.

The competitiveness of a region as a system has all the features of a system, which include:

- purposefulness – the competitiveness of the region has its own goals, objectives, their predecessors and a vision of obtaining results. The behavior of the system is subject to control;
- complexity – a set of elements, components that are intertwined with influencing factors and create patterns of external and internal relationships. Moreover, this sign directly depends on constant external factors, such as the economic development of the country, the territorial location of the region, the presence of historically developed industries, and more;
- divisibility of the system presupposes the existence of subsystems of territorial competitiveness, identified according to individual characteristics. For example, on a territorial basis, a system of districts, social groupings is distinguished; by the nature of the goals – economic, social, environmental, institutional and others;
- integrity means the presence of integral, emergent qualities that are in the system as a whole and are absent in its individual elements or subsystems;
- the diversity of the system is associated with its various autonomous elements of regional competitiveness;
- structuredness is determined by the presence of stable links between the elements of the system and their distribution by hierarchy levels;
- the hierarchy arises on the basis of decomposition, representing a relatively constant order of spatio-temporal relations between its elements and the external environment.

Conclusion

Based on the study and analysis of literary sources and taking into account the above characteristics, the interpretation of the category «competitiveness of the region» has been clarified as: a systemic concept that reflects the competitive advantages of a particular region over others in terms of a set of parameters (economic, financial, production, market, investment, innovation, etc.), which are combined in a certain way and form a priority uniqueness and consolidate positions in a certain area and in a period of time and under a certain influence of the functioning environment.

The proposed definition differs from the existing ones, is characterized by complexity and takes into account spatial, temporal, subject, attributive, relative and other properties.

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ASSESSMENT OF LIFE CYCLE COSTS OF PUBLIC BUILDINGS OF SOCIO-CULTURAL PURPOSE

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Abstract

The paper presents the results of calculating the life cycle costs for eleven public buildings of social and cultural purposes: kindergartens, schools, clinics. A brief analysis of the obtained data is carried out, the structure of life cycle costs is considered, conclusions are drawn that reveal the specifics of estimating the costs of public buildings for social and cultural purposes. The importance and significance of assessing the costs of the life cycle of public buildings at the pre-project stage, the stage of design, construction and operation is revealed.

Keywords: life cycle costs, public buildings for housing and civil purposes, features of assessing the life cycle costs of public buildings.

ОЦЕНКА ЗАТРАТ ЖИЗНЕННОГО ЦИКЛА ОБЩЕСТВЕННЫХ ЗДАНИЙ СОЦИАЛЬНО-КУЛЬТУРНОГО НАЗНАЧЕНИЯ

О. С. Голубова

Реферат

В работе приведены результаты расчета затрат жизненного цикла по одиннадцати общественным зданиям социально-культурного назначения: детским садам, школам, поликлиникам. Выполнен краткий анализ полученных данных, рассмотрена структура затрат жизненного цикла, сделаны выводы, раскрывающие специфику оценки затрат общественных зданий социально-культурного назначения. Раскрыта важность и значимость оценки затрат жизненного цикла общественных зданий на предпроектной стадии, стадии проектирования, строительства и эксплуатации.

Ключевые слова: затраты жизненного цикла, общественные здания жилищно-гражданского назначения, особенности оценки затрат жизненного цикла общественных зданий.

Introduction

One of the key priorities of the state policy is the creation of comfortable conditions for life, work and human development. Social and cultural facilities are a natural and indispensable component of a comfortable living environment. The social sphere includes preschool and educational institutions, clinics and other infrastructure facilities that ensure social stability, health, education and comprehensive development of the individual.

According to the Program for the Socio-Economic Development of the Republic of Belarus for 2021-2025, approved by Decree of the President of the Republic of Belarus dated July 29, 2021 No. 292, by the end of 2025, it is planned to build at least 90 institutions of preschool education, including in the cities of Minsk, Soligorsk, Brest, Baranovichi, Zhabinka, Orsha, Rechitsa, Shklov, in Minsk, Dzerzhinsky and Pukhovichi regions. And in 2026-2030, it is planned to create an electronic database on preschool education institutions. The plans provide for the construction (reconstruction) of at least 45 educational institutions, including in the cities of Minsk, Gomel, Bobruisk, Stolbtsy, Fanipol, Molodechno, Baranovichi, Kobrin, Stolin. In addition, the construction of primary health care facilities should ensure that medical services are within walking distance.

However, construction (reconstruction) must be carried out economically rationally, reasonably. At the same time, the rationality of spending funds should be ensured not only and not so much in terms of construction costs, as in terms of operating costs. To develop an economic justification tool for rational spending on construction, taking into account the entire set of costs associated with the construction, operation, repairs, modernization and demolition of this building, a methodology was developed and the life cycle costs of public buildings for social and cultural purposes were calculated.

Main part

For each property, there are one-time costs for its construction, costs for operation and maintenance, major repairs and, ultimately, demolition. The essence of the assessment of the life cycle of a building is that in order to make a decision on the choice of materials, products, structures, installed equipment and justify the technical and economic indicators of the designed object, it is necessary to compare one-time and periodic costs for the construction, operation and demolition of the building [1].

The life cycle of an object, as a period of time of its existence, is defined in a narrow and expanded sense. In a narrow sense, the life cycle of a real estate object includes three main phases: formation, operation and demolition [2]. In a broader sense, the life cycle of a real estate object consists of the stage of formation of an idea for the development of the territory (pre-project stage), design of a real estate object, construction, operation and liquidation of the object [3].

The first attempt to connect the life cycle of products with factorized demand is S. Hirsch [4]. Then, in 1966, R. Vernon put forward the theory of the International Product Life Cycle Theory in marketing. The advantage of this approach is that it describes not the production of a single item, but the period of product circulation on the market [5].

At present, many works of foreign authors are devoted to the methodology for estimating the costs of the life cycle of products in various industries and areas of application, including, back in the late 1980s, a review work by D. Gairdner, which contained 130 references and qualified LCA not as a theory, but as concept [6].

In the Republic of Belarus, a lot of work was also carried out to assess the costs of the life cycle of residential buildings, which made it possible to form a methodology for estimating the costs of the life cycle of residential buildings [7]. Based on this methodology, an assessment was made of the life cycle costs of public buildings for social and cultural purposes: 5 kindergartens (for 200 and 230 places), 3 schools (for 501, 765, 1020 school places) and 3 polyclinics (for 650 and 850 visits). per shift).

All calculations were carried out based on the construction conditions of the facility for 1 year, and the service life of 50 years. Calculations were made in Belarusian rubles in prices as of 01/01/2022.

The basis for the calculations was the design data for the facilities, information from the conclusions of the State Construction Expertise, the estimated cost of construction, design technical and economic indicators of operating costs, prices and tariffs set by energy supply organizations. The results of calculating the life cycle costs for 11 public buildings of social and cultural purpose are shown in Figure 1.

Kindergartens have the lowest life cycle costs. Also, these objects were distinguished by a high degree of typing, so the calculations showed a greater convergence of values. The life cycle costs for the three schools have a much wider range of values both in terms of area and cost. However, the specific indicators of life cycle costs per 1 m^2 of the total area of the building, which reflects the diameter of the spheres in Figure 1, are the lowest of all three groups of objects. The widest range of scatter of life cycle cost values is found in polyclinic buildings. At the same time, it is clearly seen that for objects with a smaller total area, the unit costs per 1 m2 of the total area are higher.

In general, it can be noted that there is a direct relationship between the total area of buildings and life cycle costs.

The structure of life cycle costs for kindergartens, schools and clinics is shown in Figure 2.

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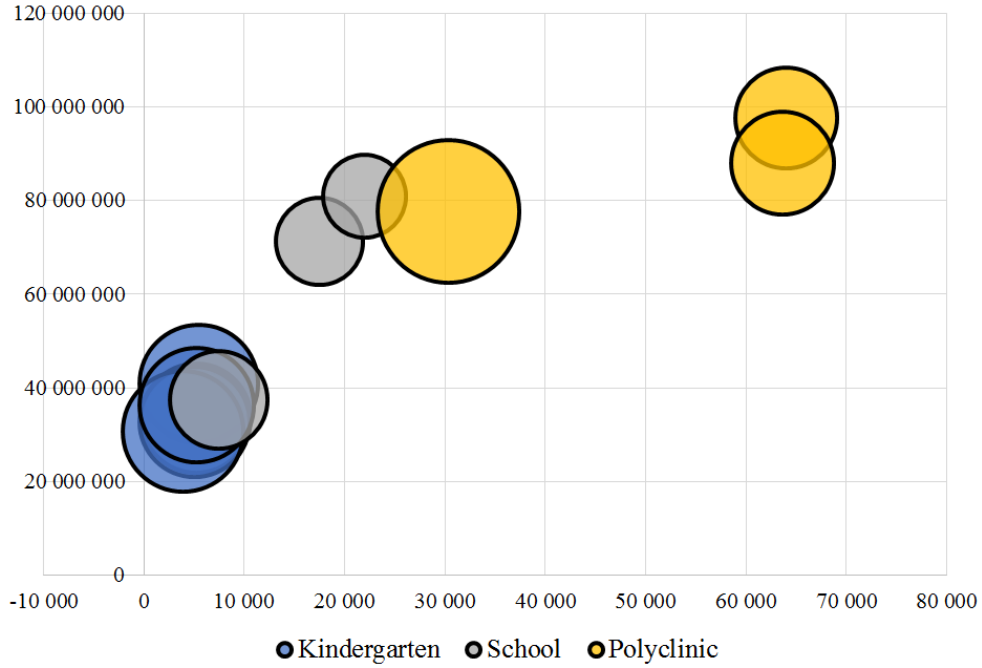

Figure 1 – Life cycle costs depending on the total area of buildings, total Belarusian rubles as of 01.01.2022

Source: Author's own calculations based on data from construction projects

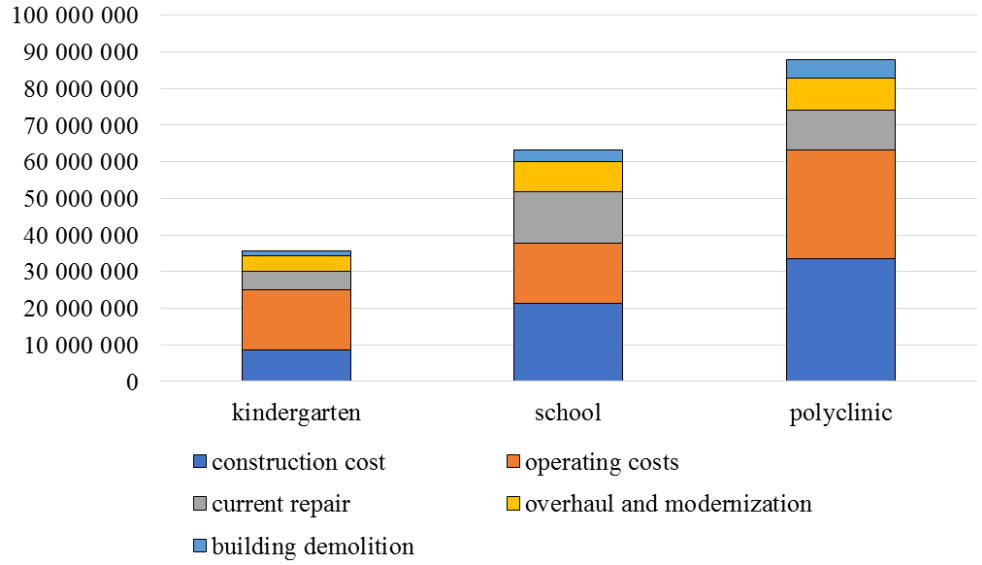

Figure 2 – The cost structure of the life cycle of public buildings for social and cultural purposes

Source: Author's own calculations based on data from construction projects

An analysis of the life cycle costs of public buildings for social and cultural purposes led to the conclusion that from the total value of the life cycle costs:

one-time costs for the construction of social and cultural facilities range from 20.68 % to 48.88 %;

operating costs from 24.75 % to 52.31 %;

current repair costs from 12.06 % to 25.65 %;

overhaul and modernization costs from 7.94 % to 14.86 %;

demolition costs from 3.10 % to 7.33 %.

In general, the costs related to construction activities (construction, maintenance and overhaul, modernization, demolition) range from 75.25 % to 47.69 % of the life cycle costs of public buildings.

The assessment of the life cycle costs of public buildings for social and cultural purposes, carried out for such facilities as kindergartens, schools, clinics, allows us to conclude that methodically the cost assessment for social and cultural facilities is identical to the assessment of residential buildings. The stages of the life cycle, the list of costs, the calculation algorithm reflects the specifics of the creation and operation of real estate objects.

The identified features of estimating the costs of public buildings for social and cultural purposes include the following provisions:

– objects of public buildings (kindergartens, schools, clinics) are overwhelmingly created at the expense of the budget, with state regulation of prices for construction, maintenance, operation, repair and modernization;
– objects of public buildings (kindergartens, schools, clinics) are overwhelmingly created according to standard and reusable designs, which facilitates the calculation of life cycle costs;
– in the structure of one-time costs for the construction of social facilities, the share of costs for technological equipment is quite large, compared with residential buildings. When assessing the life cycle costs of public buildings for social and cultural purposes, the cost of

technological equipment was not taken into account in the calculations, since these costs relate to the production and economic activities of the organization, and not the maintenance and service of buildings and structures;
- to assess the rationality of costs, the Standards for the marginal cost of construction of social and cultural facilities as of January 1, 2021, established by the Decree of the Ministry of Architecture and Construction of the Republic of Belarus No. 69 dated July 21, 2021, are used;
- tariffs for payment for heat and electric energy for social and cultural facilities are set by structural divisions of the Ministry of Energy of the Republic of Belarus in the context of regions. For budgetary organizations, tariffs are set at a level lower than for commercial organizations, but higher than for paying utility bills by the population;
- current repair of premises in schools is carried out annually, before the start of the school year. At the same time, the implementation of repair work is partially financed from the funds of the boards of trustees, sponsorship;
- overhaul and modernization of facilities, as a rule, is carried out for individual elements of the building (arrangement of a barrier-free environment, access control systems, modernization of eating places and food preparation, etc.). Comprehensive modernization of buildings is actually carried out after a 45-50-year service life, that is, when the building is close to the end of the standard service life;
- assessment of the life cycle costs of public buildings for social and cultural purposes can be performed both per unit of the total area of the facility and per unit of capacity. The specific indicator, which provides a comparison of indicators of the cost of construction, operating costs and the cost of capital (current) repairs, modernization, reconstruction and demolition of facilities, are indicators of the number of places (for schools, kindergartens) or the number of visits (for clinics, sports and recreation centers). centers). Specific indicators of costs per consumer unit of facility capacity to the greatest extent reflect the functional relationship between consumer goods, which are provided by the operation of these facilities, and payment for their construction and operation.

Conclusion

In general, the use of the methodology for assessing the life cycle costs in relation to the objects of public buildings for social and cultural purposes at the pre-project stage, design and construction stages allows:
- based on a comparative analysis of projects, choose the option whose life cycle costs are lower, and, accordingly, in the aggregate will provide savings in the budget, or another customer financing the construction and operation of the facility;
- stimulate the construction of energy-saving and, in general, resource-saving buildings and structures that reduce operating costs;
- to form a database of standard construction projects that provide minimum life cycle costs for the required space-planning indicators;
- evaluate the effect of scale of construction, justifying the increase in life cycle costs with an increase in space-planning indicators, capacity, throughput of the construction object;
- given that public buildings for social and cultural purposes are massively built according to standard designs, life cycle cost assessment allows you to get a multiplier effect from optimizing the technical and economic parameters of the building.

All this together shows the importance and significance of life cycle cost assessment at the design stage, the need to monitor and control the actual costs of building operation throughout its entire life cycle.

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IMPROVING THE SYSTEM OF GROUPING DIRECT AND INDIRECT COSTS OF THE ESTIMATED COST OF CONSTRUCTION IN THE REPUBLIC OF KAZAKHSTAN

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Abstract

The article describes the system of estimated standards that exists in the EAEU countries. The author proposes new approaches to the grouping of items of direct and indirect costs included in the estimated cost of construction. The elements of costs, cost items, articles of estimated cost, which together form the estimated cost of construction at the present time, are singled out. A new system for grouping cost elements of the estimated cost of construction has been proposed and the economic essence of these changes has been disclosed. The new structure of cost items of the estimated cost and the corresponding methodological recommendations for the calculation of direct and indirect cost items of the estimated cost for the construction of buildings and structures are proposed for implementation in the Republic of Kazakhstan.

Keywords: estimated standards, estimated cost of construction, elements and cost items, direct and indirect costs.

СОВЕРШЕНСТВОВАНИЕ СИСТЕМЫ ГРУППИРОВКИ ПРЯМЫХ И КОСВЕННЫХ ЗАТРАТ СМЕТНОЙ СТОИМОСТИ СТРОИТЕЛЬСТВА В РЕСПУБЛИКЕ КАЗАХСТАН

А. А. Хасан

Реферат

В статье описана система сметных нормативов, существующая в странах ЕАЭС. Автором предложены новые подходы к группировке статей прямых и косвенных затрат, включаемых в сметную стоимость строительства. Выделены элементы затрат, стати затрат, статьи сметной стоимости, которые в совокупности формируют сметную стоимость строительства в настоящее время. Предложена новая система группировки элементов затрат сметной стоимости строительства и раскрыта экономическая сущность этих изменений Новая структура статей затрат сметной стоимости и соответствующие ей методические рекомендации по расчету статей прямых и косвенных затрат сметной стоимости на строительство зданий и сооружений предложены к внедрению в Республике Казахстан.

Ключевые слова: сметные нормативы, сметная стоимость строительства, элементы и статьи затрат, прямые и косвенные затраты.

Introduction

The procedure for the formation of the estimated cost of construction, which has developed in the EAEU countries, was formed back in Soviet times. The estimated cost of construction is the amount of money required for the construction of an object, the amount of which is determined on the basis of design materials using estimated standards, which are a single estimated and regulatory framework.

As in all other types of economic activity, the procedure for forming the cost of construction provides for the allocation of direct and indirect costs. A significant difference in pricing in construction is that the estimated cost of construction is calculated by the design organization on the basis of a system of estimated standards and is used by the customer and contractor to assess the volume of investments, during procurement procedures, and to pay for the work performed. Taking into account the fact that the estimated cost of construction is the main tool for managing all the cost characteristics of construction, it can be said that the procedure for the formation of cost items and items of the estimated cost of construction is of paramount importance for improving the system of estimated rationing.

Main part

In all EAEU countries, estimated standards are a set of regulatory documents on pricing in construction, which are the basis for determining the estimated cost, which includes:

- regulatory documents, guidelines, instructions and recommendations for determining the cost of construction of facilities, determining the cost of other works and costs associated with construction (the cost of design work, engineering surveys, engineering services);
- estimated norms for work in construction, established on the accepted meter of volumes of construction work (direct costs);
- estimated norms for certain expenses and costs in construction, expressed as a percentage of the accepted accrual base (indirect costs);
- aggregated estimated norms and corresponding aggregated cost indicators for assessing the cost of construction in the early stages of project consideration;
- estimated prices for construction resources included in direct costs;
- estimated prices for the transportation of goods for construction;
- prices for design and survey work for construction;
- prices for the construction of buildings and structures, formed on the basis of aggregated estimated standards and / or cost indicators of analogous objects.

Estimated norms play a decisive role in the system of estimated standards. They form the cost of direct and indirect costs, form the basis of the estimated cost of construction.

At present, in the field of pricing in construction, upon detailed consideration in the EAEU countries, a number of problems have emerged, the key of which is the outdated base of estimated norms and the discrepancy between the estimated cost of construction and the market value emerging in construction. As a result, the contractor performs some work with excess profits, while others at a loss. At the same time, as noted by K.A. Guriev, V.S. Gladkikh «The effectiveness of the process of estimating the estimated cost of construction and installation works directly depends on the elements that form this cost» [1].

O.A. Gorelova, referring to the State Program of the Russian Federation «Development of Industry and Increasing its Competitiveness" (approved by Decree of the Government of the Russian Federation of April 15, 2014) No. 328 notes that "... the formation of a single economic and technological space within the Eurasian Union predetermines new conditions for the development of construction organizations, especially in the face of fierce competition for consumers and resources» [2].

That is, improving the system of grouping direct and indirect costs of the estimated cost of construction should be an effective tool to ensure transparency of competition and management of construction costs.

The problems of obsolescence of estimated norms, their inconsistency with actual costs, are considered by such authors as E.A. Gukov [3], G.A. Vlasova, N.V. Knyazeva, T.A. Shindin [4], M.Yu. Somov [5], D.V. Chipurnov [6] O.S. Golubova [7]. All authors, speaking about the improvement of approaches to the formation of the estimated cost of construction, emphasize the need to use the resource pricing method, update prices, and prices for resources, practically do not mention that

the pricing system in construction should be transparent, focused on increasing the competitiveness of construction organizations, create conditions for a comparative analysis of the advantages of technologies and methods of production, take into account the key areas of price competition: the efficiency of the use of labor resources, machines and mechanisms, materials, production management and the rate of commercial profit. A complex multi-item system of estimated rationing and pricing in construction blurs these areas of competition, forming an approach to a banal price reduction without substantiating why this price is reduced, what factors of production ensure its reduction.

The system of estimated rationing developed by the author for the Republic of Kazakhstan is based on a new approach to the formation of estimated norms, which makes it possible to assess the impact of each type of resource used in construction on the final cost of construction work, increase the efficiency of planning in construction, and ensure the reliability of construction cost estimates in design and estimate documentation.

In the Republic of Kazakhstan, as in many post-Soviet countries, the Soviet system of regulatory documents was adopted as the basis for estimates in construction, based on which in 2001 an estimate and regulatory framework was created using the base-index method. However, as time has shown, the application of this method does not meet the requirements of either state authorities, or organizations - customers in construction activities, or contractors.

A distinctive feature of building economic relations in the Republic of Kazakhstan is that estimated norms are not mandatory for all business entities operating in construction. They are obligatory only for construction organizations that carry out the construction of facilities financed in full or in part with the involvement of budget funds and sources equivalent to it. In addition, all construction organizations operating in construction in the Republic of Kazakhstan are private commercial organizations aimed at making a profit from construction activities. Therefore, it is especially important for them not only to calculate the price for state control of the reasonableness of spending funds, but to ensure effective cost management that will allow them to plan their activities, to assess the impact of each type of resource on business results.

An innovation of the methodological approach to the estimated rationing in the Republic of Kazakhstan is the transformation of direct and indirect cost items taken into account in the composition of the estimated norms, clearly shown in Figure 1.

In contrast to the currently existing approaches that have developed in the EAEU countries, the grouping of costs proposed by the author is based on the principle of combining elemental and aggregated costs, corresponds to the criterion of uniformity of cost elements in each article and corresponds to the traditional approach, which consists in the fact that the cost of construction includes the costs of labor resources, operation of machines and mechanisms and materials.

To identify differences, compare the existing and the systems proposed by the author, Figure 2 shows a grouping of costs that corresponds to the approach that has developed in the EAEU countries.

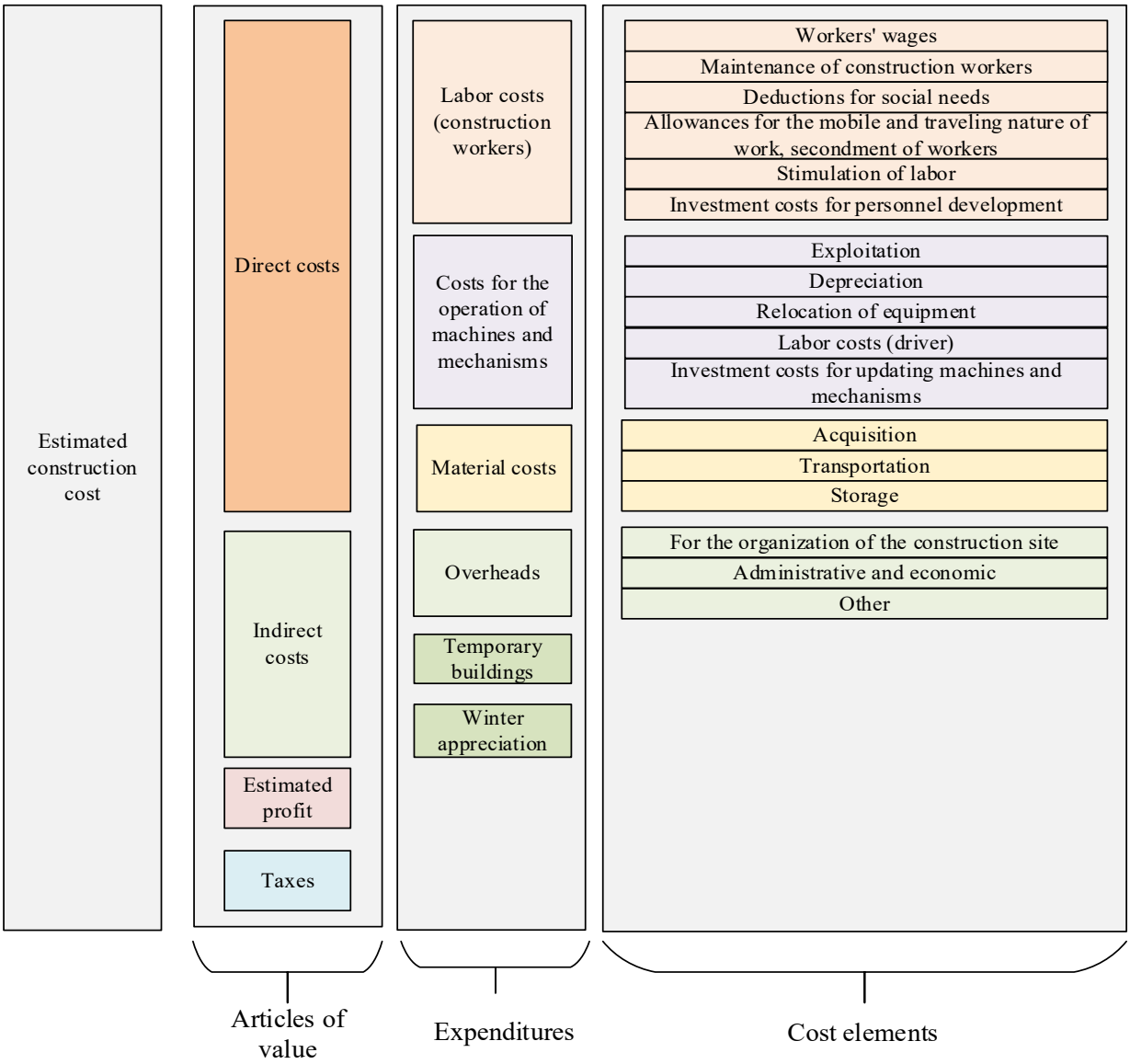

Figure 1 – New system for grouping cost elements of the estimated cost of construction

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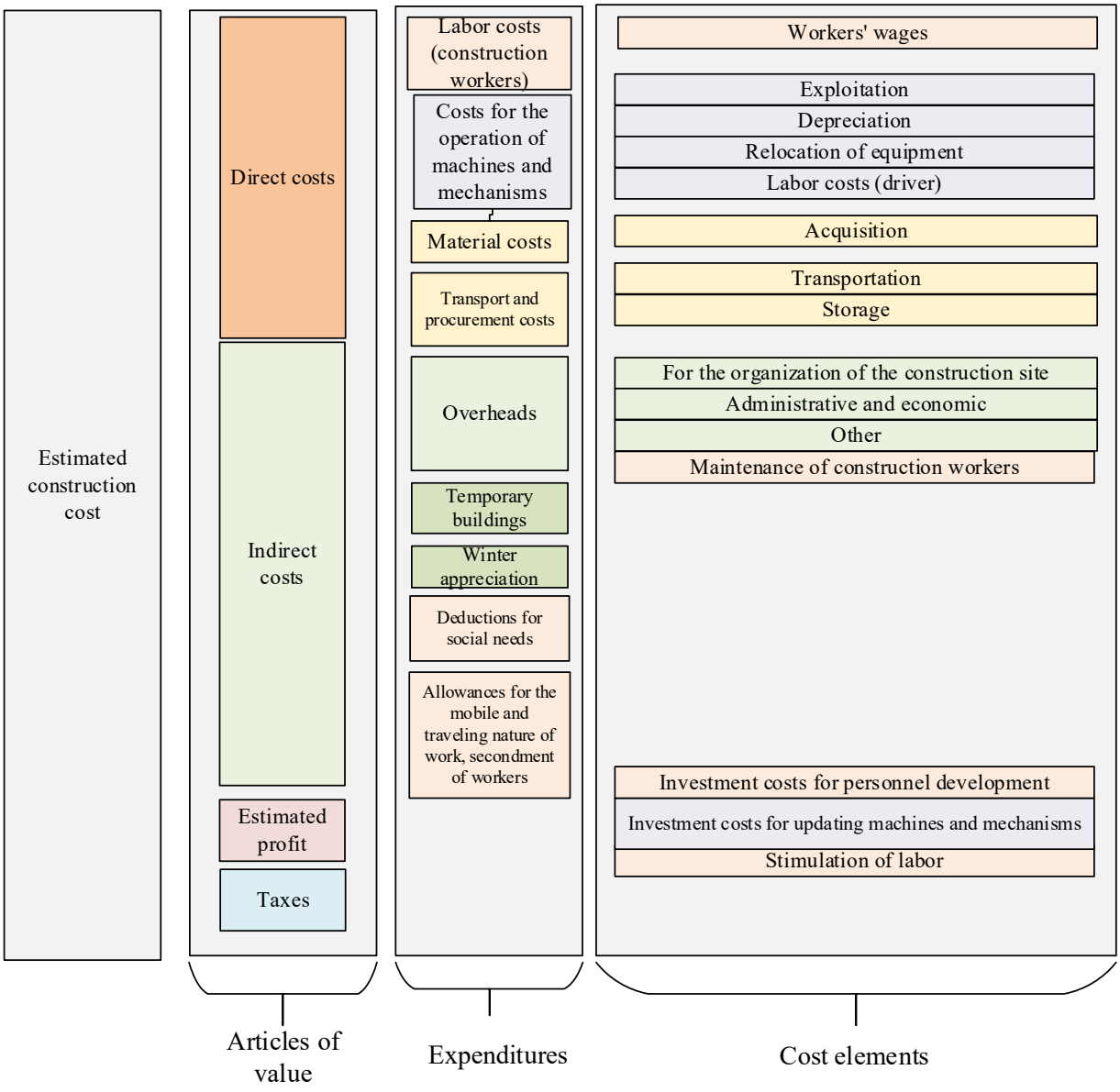

Figure 2 – The existing system in the EAEU countries for grouping cost elements of the estimated cost of construction

It should be noted that Figures 1 and 2 detail the elements of direct costs. Elements of indirect costs and estimated profit are represented by those components that are proposed to be regrouped. Articles, the composition of which does not change, are presented without details.

The new grouping of costs improved by the author takes into account:

1. Transformation of the article "Wages of workers" into the article "Costs of labor resources (construction workers)". It is proposed in this cost item to take into account not only the basic wages of workers, as it is taken into account in the Russian Federation, and the price of a man-hour wage, as in the Republic of Belarus, but the total amount of labor costs, including:

a) the average price of a man-hour of labor of workers;
b) the cost of servicing construction workers:
– severance pay (compensation) paid in the event of termination of the employment contract (contract);
– additional payment up to the average monthly earnings in case of temporary transfer to an easier, lower-paid job due to damage to health as a result of an accident at work or an occupational disease;
– other payments and additional payments stipulated by the legislation;
– the cost of providing sanitary and hygienic and cultural and living conditions at the construction site;
– health and safety costs;
– the costs associated with the training and retraining of personnel.
c) contributions for social needs (including contributions to the social protection fund);
d) allowances for the mobile and traveling nature of work, secondment of workers (if it is necessary to perform work outside the permanent place of residence of the worker);
e) stimulation of labor (bonus from profit);
f) investment costs for personnel development (training, personnel certification, trainings, seminars, social support from profits and additional payments provided for by the collective agreement).

The article “Costs for labor resources (construction workers)” provides for the full range of costs incurred by the organization in connection with the use of workers' labor. The value of this cost item reflects in value terms the cost of 1 man-hour of work of a construction worker. In addition, unlike the approaches existing in the EAEU countries, in the Republic of Kazakhstan this value is differentiated not only depending on the skill level (worker category), but also on the specialty (masons, assemblers, electricians, plumbers, etc.). This makes it possible to take into account the difference in wages existing in practice for workers of different professions and to ensure that the estimated and actual cost of workers' labor is consistent.

2. Transformation of the article “Expenses for the operation of machines and mechanisms”. Without changing the title of this article, it is proposed to include:

a) the cost of operating machines and mechanisms, taking into account the cost of fuels and other operating costs;
b) depreciation charges;
c) the cost of relocating machines and mechanisms from the base of mechanization to the construction site and back;
d) investment costs for updating machines and mechanisms.

The principal difference of the new approach is the inclusion in the price of a machine-hour of operation of construction machines and investment cost mechanisms that ensure the renewal of construction equipment, which makes it possible to take into account the profit from the operation of equipment in the price, assess the profitability of replacing one type of equipment with another, and also compare technologies that involve the use of various types of construction equipment.

3. Saving the item "Costs of materials", including:
a) the estimated cost of acquiring materials, products and structures at manufacturing enterprises, or from the first importers who imported materials, products or structures into the customs territory of the state, taking into account customs fees and duties;
b) the cost of transporting materials, products, structures from the place of production to the on-site warehouse;
c) the cost of storing materials, products and structures in the on-site warehouse.

This cost item in the system proposed by the author does not undergo any changes, compared with the current practice of grouping costs in budget documents.

4. Transformation of the item "Overhead costs", excluding the cost of servicing construction workers. In this form, overhead costs take into account only the costs of organizing work at the construction site, the administrative and economic costs of the construction organization and other overhead costs and reflect the costs of the organization associated with construction management, which allows comparing contractors by the amount of costs for performing these functions. It is this cost item that reflects the amount of money for which a construction organization is ready to organize construction production and manage construction.
5. Preservation of the economic essence and cost elements of such cost items as "costs for temporary buildings and structures" and "additional costs for work in winter" (winter appreciation). These cost items reflect the specifics of the construction site arrangement and the atmospheric and climatic conditions associated with construction, which are practically independent of the contractor.
6. Transformation of the item “Estimated profit”, which in the new approach reflects the commercial benefit of the organization from the construction of the facility, excluding the cost of updating construction equipment and labor costs financed from profit. This approach allows us to compare the effectiveness of construction activities with alternative options for investing capital, to assess the profitability of construction production for the owners of construction organizations.
7. Accounting in the estimated cost of construction of taxes, fees and deductions attributable to costs and paid from the proceeds. Taking into account that there are various taxes, fees and deductions in the EAEU countries, accounting for taxes in the estimated cost allows the customer to provide for the funds that will need to be paid to the contractor, and when choosing a work contractor on a competitive basis, take into account the impact of this cost item on the amounts, payable to the contractor for work performed.

Conclusion

Thus, the cost grouping system proposed by the author creates conditions for revising the structure of the estimated cost of construction, taking into account complex cost items in it, including the entire set of contractor's costs associated with the use of various types of resources: labor of workers, operation of machines and mechanisms, building materials, overhead costs for construction management, costs for temporary buildings and winter appreciation, the estimated profit of the contractor and his taxes. This approach is focused on improving the economic efficiency of construction by creating conditions for comparing and choosing construction technologies and work methods that reduce investment costs.

The methodological support proposed by the author for the development of estimated standards for direct and indirect costs for the performance of construction work is reflected in the guiding document in the construction of the Republic of Kazakhstan - 8.01-14-2022 "Calculation of estimated prices for construction resources".

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PRINCIPLES OF «SEAMLESS» TECHNOLOGIES IN TRANSPORT LOGISTICS

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Abstract

An urgent problem in transport and logistics systems for the delivery of goods is long delays in cargo at terminals. In modern conditions of digital transformation of business processes, the strategic task of the transport industry is the implementation of «seamless» technologies. The goal of «seamless» technologies is to achieve high performance of transport and logistics delivery schemes through optimization technological interaction. The implementation of «seamless» technologies in transport logistics is possible through process management based on the integration of information systems of participants in transport and technological delivery schemes in a single digital space. The ways of implementing the principles of «seamless» technologies based on the creation of digital platforms are considered.

Keywords: transport logistics, «seamless» technologies, electronic shipping document, multimodal transportation, digital platform, freight forwarder.

ПРИНЦИПЫ «БЕСШОВНЫХ» ТЕХНОЛОГИЙ В ТРАНСПОРТНОЙ ЛОГИСТИКЕ

Т. В. Пильгун

Реферат

Актуальной проблемой в транспортно-логистических системах доставки грузов являются продолжительные задержки грузов на терминалах. В современных условиях цифровой трансформации бизнес-процессов стратегическая задача транспортной отрасли – реализация «бесшовных» технологий. Цель «бесшовных» технологий – достижение высоких показателей транспортно-логистических схем доставки грузов за счет оптимизации технологического взаимодействия. Реализация «бесшовных» технологий в транспортной логистике возможна посредством управления процессами на основе интеграции информационных систем участников транспортно-технологических схем доставки в едином цифровом пространстве. Рассматриваются пути реализации принципов «бесшовных» технологий на основе создания цифровых платформ.

Ключевые слова: транспортная логистика, «бесшовные» технологии, электронный перевозочный документ, мультимодальные перевозки, цифровая платформа, экспедитор.

Introduction

Technological support of transportation processes has always been a condition for the effective organization of transportation in transport. Technological processes were given a lot of attention. And the more operations were included in the technological process, the more stringent requirements were imposed on the standards for their implementation. This is justified by the fact that the technological processes themselves must be coordinated with each other in terms of the time factor and prevent unproductive inter-technological downtime. Multi-operational technological processes are typical of such types of transport as railway and aviation. Less complex technological algorithms can be used in road transport.

In transport, the problem of reducing long delays of goods at cargo terminals is still relevant, including its handling from one mode of transport to another, documents reissuing and control procedures by government agencies, etc. It is known that downtime at terminals and transport hubs in some cases reach 50-60% of the total time of movement of cargo from shippers to consignees.

Informatization of technological processes and the creation of intelligent systems for information support of transportation processes was at once one of the most effective measures in transport services related to the movement of goods. Information technologies contributed to the improvement of technological processes, the development of manageability in transport and logistics systems. Currently, informatization is acquiring a new conceptual format - digitalization. One of the goals of the digitalization strategy of the transport industry is the implementation of «seamless» technologies, both in national and international traffic [1].

Main part. Principles of «seamless» technologies

The terms «seamless logistics», «seamless technologies» refer to logistics systems which are to conditionally designate the tasks of reducing, and ultimately, eliminating inter-operational and inter-technological downtime in the process of the movement of logistics flows. Theoretically, the terms are applicable to any industry, but more often they can be found in relation to the transport processes associated with transportation, without which no economic system can function. In modern economic systems, modern logistics solutions based on digital technologies come to the aid of the transport business. According to the author, «seamless logistics» may well be attributed to the list of logistics concepts such as JUST-IN-TIME, QUICK RESPONSE, KANBAN and others.

The essence of the concept of «seamless logistics» is the desire to optimize the technological interaction between all participants in the transport and technological scheme for the delivery of goods from the cargo owner to the consumer. The goal of such technological interaction should be the minimum and reasonable delivery time, reduction of transport costs, transparency of all business processes with the unconditional safety of the cargo and the safety of its transportation. Considering ways to achieve «seamlessness» in transport and logistics systems, attention is focused on technologies that were previously called end-to-end technologies, but today are «seamless», possibly implying a close logistical connection between them.

The organization of «seamlessness» is especially relevant and complex in multimodal transport and logistics systems, which involve the involvement of carriers of different modes of transport. In these cases, responsible planning of transport and logistics processes is of great importance. With the advent of informatization, for each type of transport, under the influence of objective and subjective factors, «their own» characteristic information technologies have been formed.

The modern period of economic development of the world is characterized by the development of the concept of the digital economy, which involves the digital transformation of business processes. It is expected that digital transformation will eventually change thinking patterns, management methods and work organization using digital technologies [2]. Digital transformation is a process that is associated with the digitization of the description of material resources, the creation of copies of them, the formation of network interaction platforms to obtain the desired result in the process of exposure or the use of automation tools. Digitized data is used to manage business processes, to develop mechanisms for working with digital technologies [3].

Thus, using the existing conceptual attitudes and expectations of scientists and practitioners from the digital economy, we can conclude that

the implementation of «seamless» technologies in transport logistics is possible through process management based on the integration of information systems of participants in transport and technological delivery schemes in a single digital space. The level of integration will determine the level of «seamlessness». An important indicator of digital interaction that can improve management efficiency in transport and logistics delivery systems, especially mixed ones, is the speed of interaction.

Interaction occurs between many entities providing services in the process of cargo flow: cargo owners, forwarders, brokers, stevedoring associations, carriers, operators of rolling stock and storage facilities, public authorities (customs, border, phytosanitary, veterinary and others). Currently, interaction (request for conditions, quotations, transfer of documents, negotiation of contracts, etc.) on various issues takes place by telephone, fax, and the Internet. Issues can take anywhere from an hour to several days to resolve. An increase in the speed of interaction can be facilitated by the creation of a single technological and digital space, or, in other words, a digital ecosystem of transport logistics. The digital ecosystem of transport logistics is a set of information systems and digital platforms that provide close information interaction and systemic exchange of electronic data between its main subjects within the boundaries of a single technological and information space, to solve the problems of effectively promoting material flow in logistics supply chains [4].

The principles of «seamless» technologies were laid down by the UN Convention on International Multimodal Transport of Goods (further – UN Convention), which is the main legislative document in the field of multimodal transport, signed in 1980. These principles include [5]:

close relationship of all participants in the process, especially when handling cargo by various modes of transport;

prompt transmission of information;

the minimum number of documents;

strict coordination of terminal technologies of different modes of transport.

The UN Convention has also proposed logistics solutions aimed at reducing downtime and speeding up the movement of goods in complex multimodal transport and logistics systems. The main achievements of the UN Convention are the introduction of the concept of «multimodal transportation operator» and the need to execute transportation under a single transport document (end-to-end document).

The functions of the operator of multimodal transportation, and they become transport or forwarding companies, are reduced to a centralized organization of the delivery of goods to the recipient. Also, the operator is fully responsible for the cargo after he accepts the cargo. A single transport document defines a multimodal bill of lading developed by the International Federation of Forwarding Associations (FIATA).

However, the multimodal bill of lading has not entered the practice as a single end-to end transportation document; each mode of transport involved in multimodal transportation has its own established bill of lading.

In the context of digital transformation, new ways are opened to improve the efficiency of intermodal logistics, and the decisions of the UN Convention may be more useful in a new digital format.

One of the ways to implement the principles of «seamless» technologies is to create a digital platform or an electronic platform, based on which a system of end-to-end exchange of electronic transportation documents will be formed, interactions between interested participants in various logistics services related to cargo and other related flows will be carried out. The creation and support of a digital platform should be carried out by system integrators capable of solving the tasks set by the delivery participants, whose information systems are integrated on the platform.

The best solution for organizing a high degree of «seamlessness» is the organization of delivery through the platform, and centralized management, especially in multimodal systems, should be carried out by operators or forwarders, who are considered aggregators in digital conditions.

In the field of using an electronic document in transport logistics, there are some developments. In rail transportation, the task of creating a single digital space, the transition to «paperless" technologies, the essence of which is the conversion of existing documents into digital events, a complete transition from information systems to information management ones, has long been set. Thus, the automated system «Electronic Transportation» has been introduced in Belarus – a centralized automated system for electronic registration and support of cargo transportation using an electronic digital signature.

All intra-republican rail transportation is carried out using a legally significant electronic transportation document signed with an electronic digital signature. In international traffic, the issues of «paperless» interaction in freight transportation are being successfully worked out with many neighboring railway administrations and customs representative.

In road transport, transportation using an electronic waybill is not widely practiced, only in some experimental cases, although the legal framework and the procedure for interaction have been developed and approved at the legislative level [6]. The problems of road carriers are seen in their conservatism. Basically, these are private companies that do not have corporate unity, as in railway transport. Motor transport organizations operate on market conditions, developing primarily customer services to increase their attractiveness, and the introduction of information technology is more often associated with the primary tasks of improving the efficiency of their own business processes.

Conclusion

Digital transformation are to implement the basic principles of «seamless logistics» in transport and logistics systems by transferring the details of a transportation document into digital events and accumulating them on a digital platform. The condition for «seamless» logistics is the creation of a digital platform, which should become the basis for the integration of information technologies of delivery participants, especially carriers.

At the same time, it is difficult to unite carriers of various modes of transport participating in transport and logistics delivery systems, due to the different level of development of informatization and readiness for integration, the unwillingness of participants to share their data on transportation, including tariffs. The way out to ensure a high level of «seamless» logistics is seen in the future creation of an expeditionary center based on a digital platform and digital technologies. At the same time, transport and logistics delivery schemes will be characterized by the presence of an aggregator for their rational organization and management of business processes, «seamless» or end-to-end technologies, as well as through tariffs.

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THE ROLE OF PROFESSIONAL ETHICS AND INTERNAL AUDIT IN THE DISCLOSURE OF INFORMATION ABOUT THE ENTERPRISE

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Abstract

The issue of disclosure continues to be a challenge for users of financial and non-financial reporting and the accounting standards community. Financial disclosure standards aim to improve the qualitative characteristics, comparability, verifiability, timeliness and understandability of financial statements. Enterprises that implement the principles of the ESG agenda face the problem of disclosing information about the results of socially responsible activities in non-financial reporting. Such reporting is optional and standardized. This is due to the voluntary nature of socially responsible activity. The quality of information disclosure is determined by professional ethical principles and internal audit.

Keywords: information disclosure, financial and non-financial reporting, professional ethics, internal audit, reporting veiling.

РОЛЬ ПРОФЕССИОНАЛЬНОЙ ЭТИКИ И ВНУТРЕННЕГО АУДИТА В РАСКРЫТИИ ИНФОРМАЦИИ О ПРЕДПРИЯТИИ

Н. В. Потапова, И. В. Приймачук

Реферат

Вопрос раскрытия информации продолжает оставаться проблемой для пользователей финансовой и нефинансовой отчетности и сообщества стандартов бухгалтерского учета. Стандарты раскрытия финансовой информации направлены на улучшение качественных характеристик, сопоставимости, проверяемости, своевременности и понятности финансовой отчетности. Предприятия, реализующие принципы ESG-повестки, сталкиваются с проблемой раскрытия информации о результатах социально ответственной деятельности в нефинансовой отчетности. Такая отчетность не является обязательной и стандартизированной. Это связано с добровольным характером социально-ответственной деятельности. Качество раскрытия информации определяется профессиональными этическими принципами и внутренним аудитом.

Ключевые слова: раскрытие информации, финансовая и нефинансовая отчетности, профессиональная этика, внутренний аудит, вуалирование отчетности.

Introduction

Disclosure based regulation sounds like an easy solution to a lot of problems. For disclosure to work as a governance tool, quite a number of elements (or incentives) need to be working together. The main tools are the development of documents and legislative norms and standards.

Some disclosures can be effectively provided directly in the financial statements, such as a provision for uncollectible receivables. Other disclosures may be provided either directly in the financial statements or in the notes. The possibility of using professional accounting judgments, the ambiguous interpretation of the application of information disclosure standards lead to the possibility of using financial reporting concealment tools.

The main part

The most pressing problems in the disclosure of information about the enterprise are the veiling of financial statements, incomparability and "green" distortion of non-financial reporting indicators. The most significant role in solving the problems of information disclosure belongs to the ethical principles in the field of accounting and the internal audit system in order to monitor their compliance.

The disclosure problem continues to pose a challenge to the accounting standard setting community.

The veiling of financial statements is a deliberate action or inaction with the aim of distorting financial statements or its individual indicators, which causes certain harm to users of statements [1].

The concept of sustainable development has become widespread in the practice of enterprises. ESG performance indicators are presented in various non-financial reports.

Non-financial reporting is reporting that simultaneously covers the economic, environmental and social aspects of the company's activities, disclosing information about its non-financial initiatives and contribution to the sustainable development of the surrounding world [2].

Due to the lack of mandatory standards for non-financial reporting, the data provided by companies to reporting users can vary significantly in content, which complicates the comparability and usefulness of these data. One of the urgent problems is to reduce the risks of the so-called "green" veiling ("green laundering") of non-financial reporting. At the same time, increasing the reliability of non-financial reporting indicators through standardization is also associated with certain business risks of disclosing information about the activities of an enterprise.

Issues of form and style, determining required disclosures, common challenges in preparing various disclosures, disclosures of financial and non-financial performance, and disclosure risks are pressing issues for the business community and professional accountants and auditors.

Financial data is reliable only because auditors check it first. They are the first line of defence for shareholders and serve one of the most valuable functions in a market economy. They provide assurances regarding the information on which almost all our economic decisions are based. If the information is wrong, then the economic decisions we make will also be wrong. In contrast to other professions the auditing profession bears a special burden of being objective and independent.

Raising the quality of the audit and improving the independence of the auditor will remain important challenges in the years to come.

One of the conditions for ensuring a quality audit is the observance of ethical principles. The backbone of an effective disclosure audit is an internal audit system.

The purpose of this study was to study the role and influence of the requirements of the professional ethics of the auditor and the internal audit system on the quality of disclosure of information about the activities of the enterprise.

Understanding the importance of information technology and quality information has already come. And today, the understanding that those who own the world, who have the latest, high-quality information - the needs of progress, no longer raises questions and doubts in anyone.

No public, social life and its scientific manifestations are possible without information, which acts as the locomotive of social, political, and technical progress. The demand for knowledge, the ability to analyze and compare all types of reporting are necessary for a modern leader at any level to make informed and competent decisions.

Any information is important to correlate with the target content in relation to the user. Users make management decisions based on statistical, social, non-financial, environmental, accounting and other reporting. Public awareness for making competent decisions in the world community is also a task of accountability, including for ensuring sustainable development. Accounting and reporting practices are influenced by the economic conditions of the functioning of organizations, the legal system, and political factors. Accordingly, all of the above also affects the transparency of reports.

The manipulation of financial information is not new and will never go away. The reason is that accounting requires judgment [3].

This leads to the possibility of veiling financial statements and misleading its users. Veiling can be achieved legally through accounting policies and illegally through decreasing revenues and increasing expenses.

With regard to non-financial reporting, the lack of uniform standards and disclosure requirements leads to many risks. Concerted actions of states, business and society are gradually solving these problems. The issue of taking measures to introduce global standards for the disclosure of non-financial information is being discussed.

Studies show significant non-compliance or understatement of important information about socially responsible activities by enterprises. On average, firms listed with the US Securities and Exchange Commission provided only about 18% of the information that the Sustainable Development Accounting Standards Board (SASB) considers material. These vary by industry and include environmental performance, health and safety metrics (Grewal et al, 2020). Meanwhile, the volume and quality of disclosures have increased in countries with CSR reporting responsibilities, such as China, Denmark, Malaysia and South Africa [4].

The main problems of disclosure of non-financial information are: incomparability of data, difficulties in controlling the reliability of information, which leads to the possibility of hiding "green crimes".

Green Crime is illegal activity that involves the environment, biodiversity, or natural resources. There are generally five types of major environmental crime: illegal logging, fishing, and mining, and crimes that harm wildlife and generate pollution [5].

Financial institutions and regulators are trying to focus on these crimes and find solutions. However, it is very difficult to identify them based on data from non-financial reports.

Thus, when disclosing information about the activities of an enterprise in financial and non-financial reporting, a system of professional ethical principles in the field of accounting and auditing plays a significant role.

For auditors of financial statements, ethical principles have been established by the Code of Professional Conduct, commonly referred to as the Code of Ethics. This code of ethics is divided into two sections: principles and rules. The principles provide the basis for the decent behavior expected in the performance of professional duties, while the rules provide more detailed guidance [6].

The fundamental principles include: honesty, objectivity, professional competence and due care; confidentiality and professional conduct.

These principles are the basis for the professional ethics of an accountant. The professional competence of an accountant includes the formation of judgments on the disclosure of information in financial and non-financial reporting. And it is especially important that this accountant performs his functions not only professionally, but also in good faith [7].

Independence and ethical principles are important not only for accountants and auditors, but also for standards developers. Standards developers should also be independent. Discussion is at the heart of standards development, but standards developers are sometimes lobbied to reduce disclosure.

The system of control over compliance with these ethical principles is the internal audit system.

Internal auditing is an independent, objective assurance and consulting activity designed to add value and improve an organization's operations. It helps an organization accomplish its objectives by bringing a systematic, disciplined approach to evaluate and improve the effectiveness of risk management, control and governance processes [8].

To detect veiling at the operational level and at the level of formation of accounting information, the most effective is to build an effective control system and constant monitoring of the company's operating environment, that is, prevention. And at the level of detection, as the statistics of detection of cases of veiling show, the most effective method of uncovering fraud with financial statements is to check the so-called analytical symptoms of events that go beyond normal practice. In this case, it is necessary to separate two objects of analysis:

– direct financial reporting
– non-financial information allowing to conclude about the violation.

In the first case, as a result of the analysis of financial information, such analytical symptoms can be identified as:

- significant unreasonable deviation of financial indicators in comparison with the previous period or other comparable data;
- incomparable increase in income with a decrease in inventories;
- increase in income with a decrease in the amount of cash receipts;
- an increase in inventories with a decrease in accounts payable; increase in the number of sales with an increase in the price per unit of production;
- redundant purchases.

If the goal of performance analysis is to identify symptoms, strange relationships, and unusual correlations of reporting performance, then it is important to establish criteria before starting such an analysis, deviations from which will be considered abnormal, given the specifics of the company.

Depending on the goals and established criteria, the following types of analytical procedures can be distinguished:

1. Vertical (correlation) analysis, which allows you to analyze changes in the share of a separate reporting item in a general indicator (for example, in assets) and compare structural changes in the balance sheet, income statement, cash flow and capital changes compared to previous periods or other relevant comparable data.
2. Horizontal analysis is a trend analysis, an analysis of the deviations in the value of an individual item compared to the previous period.
3. Financial analysis of indicators or ratios (turnover, liquidity indicators, financial leverage). It is also possible to combine all methods of comparative analysis in order to obtain confirmation of the unusualness of facts or events.

The analysis of non-financial information can play a big role in revealing veiling.

Analytical symptoms that can help the user of financial statements to identify the obscurity of financial statements include:

1.) internal:

- relationship with the legal department: conducting large-scale litigation, frequent change of lawyers;
- Relationships with managers: be high turnover among managers; frequent change of leadership.

2.) external:

- relations with auditors: frequent change of the external auditor; refusal to provide or delay in the information required by the auditors; lack of internal audit; the auditor's refusal to make a judgment about the financial position of the company or disagreement with the data of the presented financial documents;
- relations with regulatory authorities and the tax service: revocation of licenses; regular inspections by higher regulatory authorities; frequent violations of tax laws, problems with regulatory authorities;
- relations with banks and other financial institutions: significant liabilities or violation of the limits of admissible debt; the inability of the company to secure financing in the form of loans or credits;
- relations with competitors: tough competitive environment, potential takeovers; reorganization of the structure of relations between partners;
- relationships with customers and suppliers: a large number of new customers or suppliers; lack of a counterparty verification system.

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The primary responsibility for detection of financial statement fraud resides with company management. Prevention of fraud is most effective with a strong team consisting of an audit committee comprising internal and external auditors and a board of directors who set a tone for ethics at the organization. Auditing standards establish that auditors have a responsibility to reach a reasonable assurance that financial statements are clear of misstatement due to either error or fraud. The auditors' responsibilities are to appropriately identify, assess and respond to fraud risks, using the many tools and techniques at their disposal.

The first and most important step is to institute strong internal accounting controls. Key to this is segregation of duties, which involves dividing responsibility for bookkeeping, deposits, reporting and auditing between different people to reduce the temptation and opportunities to commit fraud.

Companies should regularly test their financial statements for accuracy to make sure their internal controls are effectively preventing fraud.

Conclusions

Ethics require accounting professionals to comply with the laws and regulations that govern their jurisdictions and their bodies of work. Avoiding actions that could negatively affect the reputation of the profession is a reasonable commitment that business partners and others should expect. Accounting ethics is an important topic because accountants are the key personnel who access the financial information of individuals and entities. Such power also involves the potential and possibilities for abuse of information or manipulation of numbers to enhance company perceptions or enforce earnings management. Ethics is also absolutely required in the course of an audit.

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DEVELOPMENT OF THE DIGITAL ECONOMY IN THE CONTEXT OF THE SANCTIONS WAR

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Abstract

Consumer behavior has changed significantly at the present time. The paper examines the development of the digital economy in the context of a pandemic and a sanctions war. The digital economy is capable of both accelerating the recovery of the global economy in the post-pandemic period, and neutralizing the consequences of the sanctions war. At the same time, there is a risk of fragmentation of the global digital economy, which will reduce the "economies of scale" and reduce the efficiency of the global economy.

Fragmentation of the global economy is particularly dangerous for small countries: the closure of foreign markets in the face of a small number of domestic consumers leads to a significant increase in products with high conditional fixed costs, including digital products.

Keywords: digital economy.

РАЗВИТИЕ ЦИФРОВОЙ ЭКОНОМИКИ В УСЛОВИЯХ САНКЦИОННОЙ ВОЙНЫ

А. Г. Проровский

Реферат

Поведение потребителей серьезно изменялось в настоящее время. В работе исследовано развитие цифровой экономики в условиях пандемии и санкционной войны. Цифровая экономика способна как ускоренно восстанавливать мировую экономику в постпандемийный период, так и нивелировать последствия санкционной войны. Вместе с тем, есть риск к фрагментированию глобальной цифровой экономики, что приведет к уменьшению «эффекта масштаба» и снизит эффективность мировой экономики.

Фрагментирование мировой экономики особенно опасно для небольших стран: закрытие внешних рынков в условиях небольшого числа потребителей внутри страны приводит к существенному росту продукции с высокими условно-постоянными расходами, в том числе цифровым продуктам.

Ключевые слова: цифровая экономика.

Introduction

The coronavirus pandemic, which began at the end of 2019, and the sanctions war have a significant impact on the behavior of people and businesses. An important factor is the uncertainty of the end of both the pandemic and the sanctions war: forecasts are constantly changing, people and businesses are adapting to new conditions and changing their behavior, including in consumption, forever. In a short period of time, people who are used to living in a highly competitive offer and gradually go through digitalization, getting used to online trading, were restricted in their movement, choice, and many went through quarantine or self-isolation. The sanctions war leads to fragmentation of the digital economy, which negatively affects the supply side.

Development of the digital economy

Over the past three decades, the development of the digital economy has been characterized by a high level of internationalization, international cooperation, and strong global value chains with expanded outsourcing. In addition to the natural processes of scientific, technological and industrial specialization, the exploitation of competitive advantages (for developed countries-strong competencies, for developing countries of Pacific Asia – cheap labor, etc.) and the sharing of risks and costs, internationalization was fueled by two trends. On the one hand, providing global access to qualified personnel, innovative entrepreneurs, developers, smart capital, established innovation institutions, ecosystems and clusters that determine the competitiveness and development of ICT in the future.

On the other hand, for new digital technologies (Internet solutions, artificial intelligence, big data) – access to primary data as a new strategic resource of the digital economy. In the face of growing competition between the US and China, the value and importance of these resources is increasing, and access to them is really becoming one of the key factors for realizing digital leadership.

Thus, the sanctions war is not an ordinary trade war, "typical" sanctions or other traditional phenomena. This is an element of the systemic struggle of superpowers in a relatively new global space of critical commercial technologies and technological rents, which are of great importance for strengthening development potentials, structuring international relations, and solving other leadership tasks. Another question is that in this capacity it clearly preserves continuity in relation to the geopolitical and economic conflicts of the past, being rather an evolution of existing approaches and solutions, taking into account the new role and significance of digital technologies in the modern world.

Innovative technologies that significantly change the usual actions in various areas, from industrial production to the organization of everyday life, capture their consumers with increasing speed. Under the pressure of the speed of innovation development, companies are forced to change existing business models, develop new approaches to the products and services they implement, processes and support for business operations.

The speed of bringing new products to the market is constantly increasing. Existing business models and processes become irrelevant, and businesses have to operate in conditions of uncertainty and constant changes. New business models are being developed based on the principles of the "shared consumption economy" and electronic platforms.

There are a number of barriers to business transformation: lack of competencies, inflexible management structures, uncertainty, and so on.

Many companies do not have time to adapt to changes and leave the market. Pressure from consumer demand and the rapid development and spread of technology have increased the importance and complexity of the innovation process in companies, making it more expensive and risky. Companies are developing new models of innovation activity.

Digitalization of communications.

Info communication technologies are changing the models of communication between people, as well as between people and organizations (government agencies, small and large businesses, retail, and social organizations). Establishing and maintaining contacts is becoming easier, and instant interaction with each other is possible at any distance.

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The spread of digital technologies allows for a more even distribution of income. Individuals get the tools to interact directly, bypassing intermediaries. Online migration takes place in areas that were previously only available offline, such as public services and education.

People around the world are becoming addicted to smart devices such as mobile phones and tablet computers. You can use them to perform a variety of tasks anywhere and anytime-from socializing, shopping in the store, entertainment, and checking email, to bank payments, education, and GPS navigation.

There is an evolution of user behavior: 10 years ago, Facebook revealed the profile of people, changing their lives. Then Instagram and Twitter called for sharing information about themselves every second. Today, the era of tracking has arrived: what time did we wake up, how long did we walk, how did we walk the dog, etc. Consumers spend almost all their free time with gadgets that speed up their already fast life and make information exchange instant.

Omni-channel is actively developing: the ability to make purchases in different modes: at the point of sale, via a mobile phone, or via a computer with the possibility of seamless transition.

Opinion leaders in social networks become one of the most important channels of promotion. 60% of consumers say they listen to recommendations.

Social transformation. Society is in constant motion. The main vectors of global demographic shifts are: a steady decline in the birth rate and death rate of the population with economic development and urbanization, an increase in the world's population, an increase in life expectancy, and accelerated migration of the population from less developed to more developed countries.

Attitudes towards aging are changing, and gender roles and the concept of family are shifting. The proportion of older people is increasing. The consumption habits of older people differ from those of younger people. The increasing availability of training and the increasing participation of women in business have a profound impact on changes in the social infrastructure. The role of women in society is changing, gender equality is developing, which has shaken the position of men as the first breadwinner in the family. One of the main facts defining the society of the future is the change of generations. Generation X will be replaced by Generations Y and Z, which have a different set of values.

Technologies and innovations. One of the most important factors influencing modern consumer behavior is the rapid development of technology. On the one hand, technology expands the possibilities of consumption, opening up access to a wide range of goods and services.

On the other hand, the development of technology complicates our lives and changes it. Sometimes we stop coping with the pace of development and complexity of technologies and even become dependent on them. Therefore, the so-called usability – convenience and intuitive ease of use of technologies-becomes the most important consumer requirement.

Current technologies contain great potential for business development. In the future, technologies will become more accessible, including to consumers. Technologies are perceived as an object of increasing efficiency, but they also allow you to create consumer experiences and new sources of income.

Internet of Things: technology is no longer just objects. Today, the refrigerator, kettle, and vacuum cleaner can be sources of information.

Today, no high-tech business sees itself without cloud technologies. You can pay for your purchases by phone. Apple Pay, Android Pay and LG Pay technologies have made life easier for consumers and made transactions based on magnetic switching technology accessible to everyone.

According to the GlobalWebIndex report: Since the beginning of 2020, people have spent significantly more time on devices that have Internet access (Figure 1). Today, the Internet is used by 4.95 billion people worldwide, which is more than 60 % of the world's total population and has grown by 4% over the year (Figure 2). The number of unique mobile users continues to grow. The number of mobile device users was 5.31 billion. Internet-connected devices are growing in popularity due to quarantine restrictions, and they will continue to show growth even if restrictions are eased.

At the same time, the sanctions war restricts the opportunities of both consumers and advertisers in the Russian Federation and the Republic of Belarus.

GlobalWebIndex's latest research on the impact of the coronavirus on Internet users shows that all segments are growing, but social networks are growing at a faster pace.

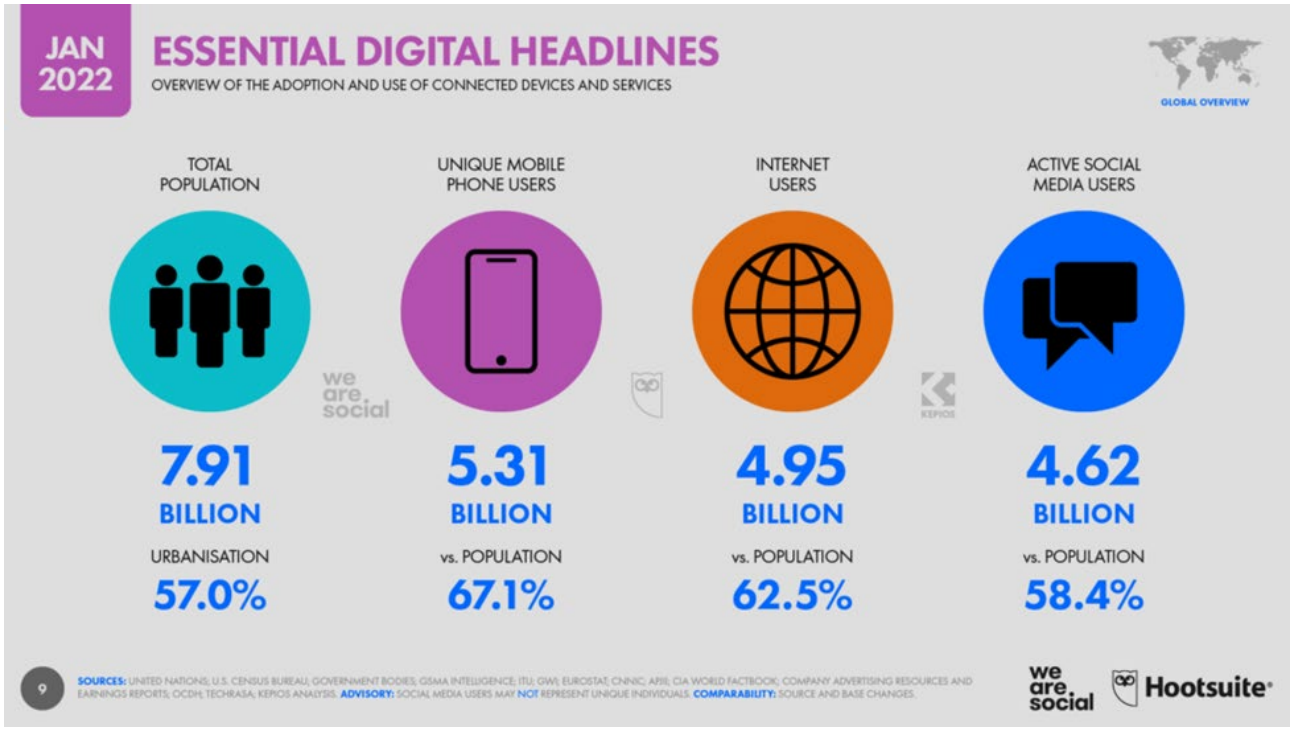

Figure 1 – Statistics on the growth dynamics of device usage during the pandemic [1]

In total, despite the many potential harms that can be caused by excessive use of devices connected to the Internet, you need to realize that these same technologies can improve the quality of life of people.

Let's look at how consumer behavior has changed during the pandemic in search engines and display advertising. In search engines, people are beginning to actively use voice search and image search.

The development of voice technologies is an important reason for changing search habits, and the growing popularity of voice commands is no longer news. The reason for the sharp increase was also the popularity of this type of search in fast-growing markets, which have a significant impact on overall performance. Thus, in India, China and Indonesia, this is more than half of Internet users.

The growth rate of Internet users is decreasing from 10% in 2011-2016 to 6% in 2017-2021 (Figure 3).

The number of users of social networks is growing at a faster pace (Figure 4). This trend is especially noticeable in the youth segment of the Internet, where the number of users of social networks has tripled in 10 years.

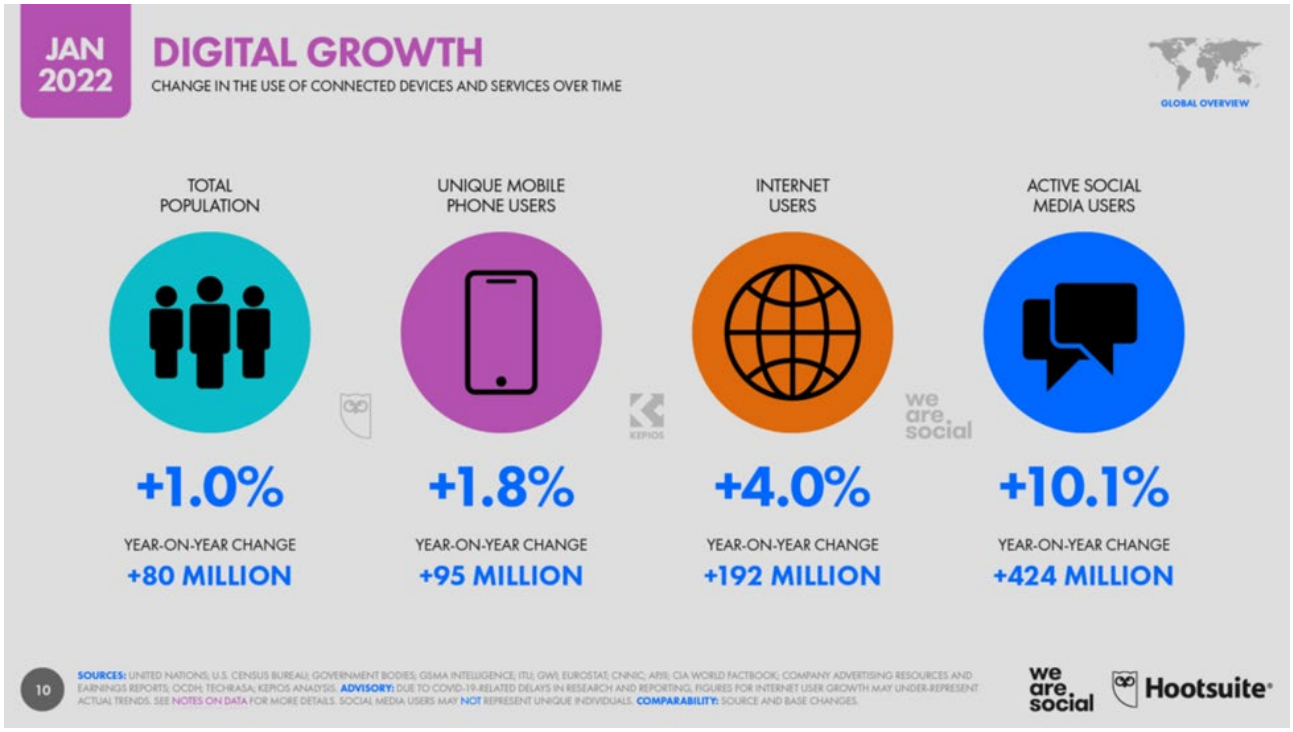

Figure 2 – Growth of Internet users during the pandemic [1]

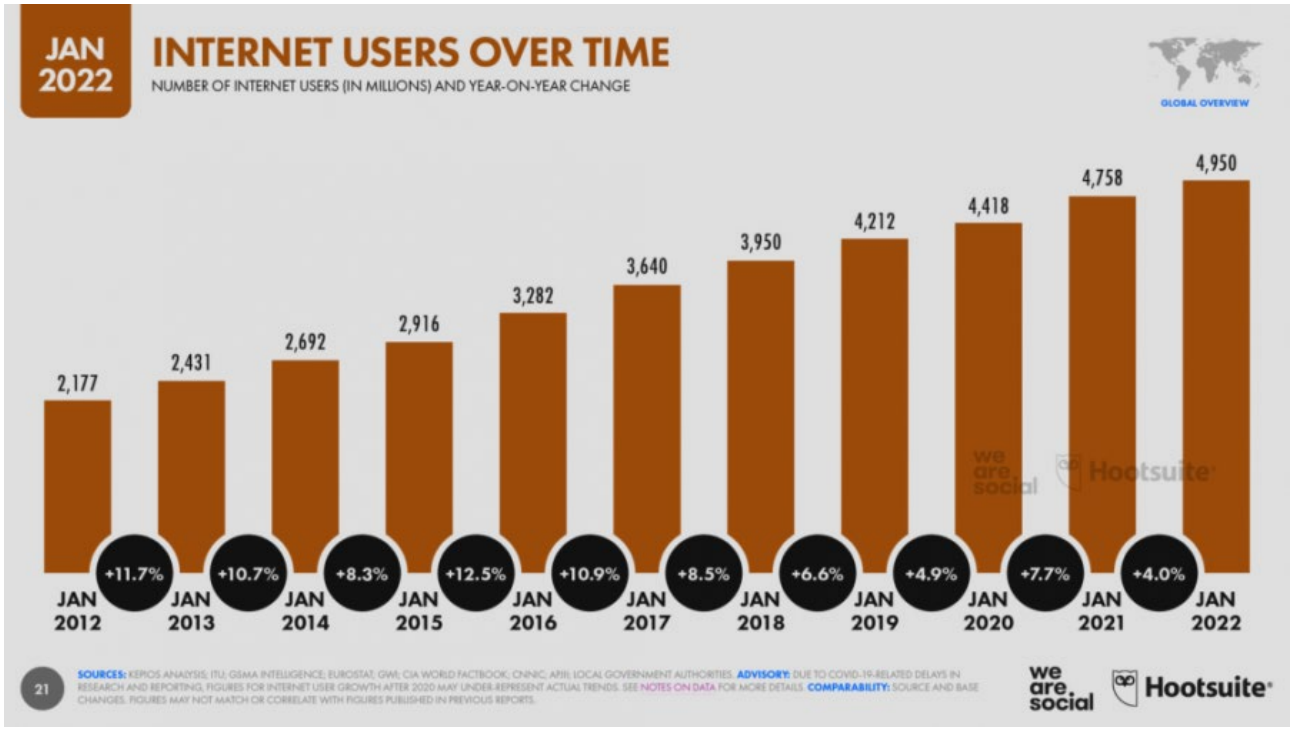

Figure 3 – Number of Internet users in the world [1]

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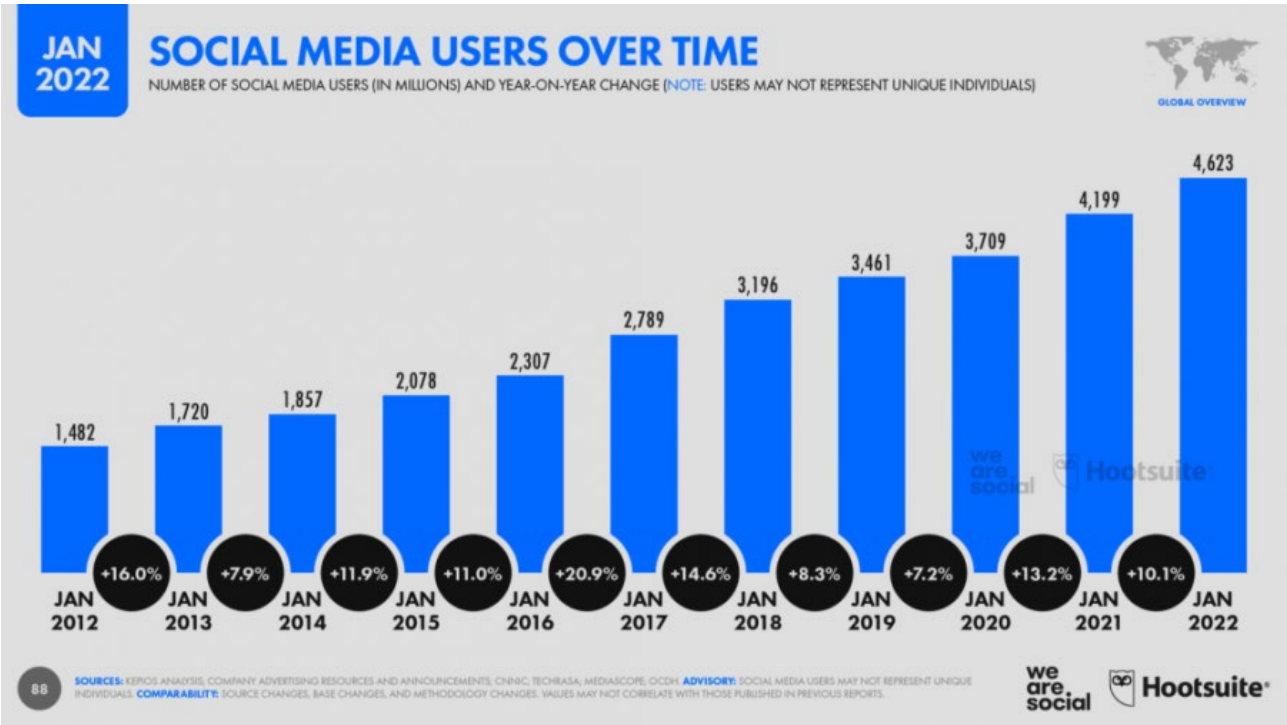

Figure 4 – Users of social networks [1]

The gap between search engines and social networks has been narrowing recently, which indicates ongoing changes in the way people search for information about products they want to buy. Moreover, among Internet users aged 16 to 24, social networks are now the main source of brand information. Even search engines take a back seat, because young women are much more likely to turn to social networks for information.

According to the META advertising tools, brands will be able to reach more than 1 billion people with targeted advertising on Instagram. Instagram's advertising reach during the pandemic increased by 111 million new users in the quarter alone, indicating quarterly growth of more than 10 %. This means that Instagram's advertising audience is now growing at a rate of more than 1 million new users per day. As a result, the number of users in Russia (due to the blocking of the social network) decreased by 50%.

The number of registered LinkedIn users has also passed a milestone of sorts — 700 million users worldwide.

TikTok had a very successful year in 2020, with the platform showing impressive growth in the number of users worldwide. However, banning the app in India could negatively impact the platform's future growth trajectory.

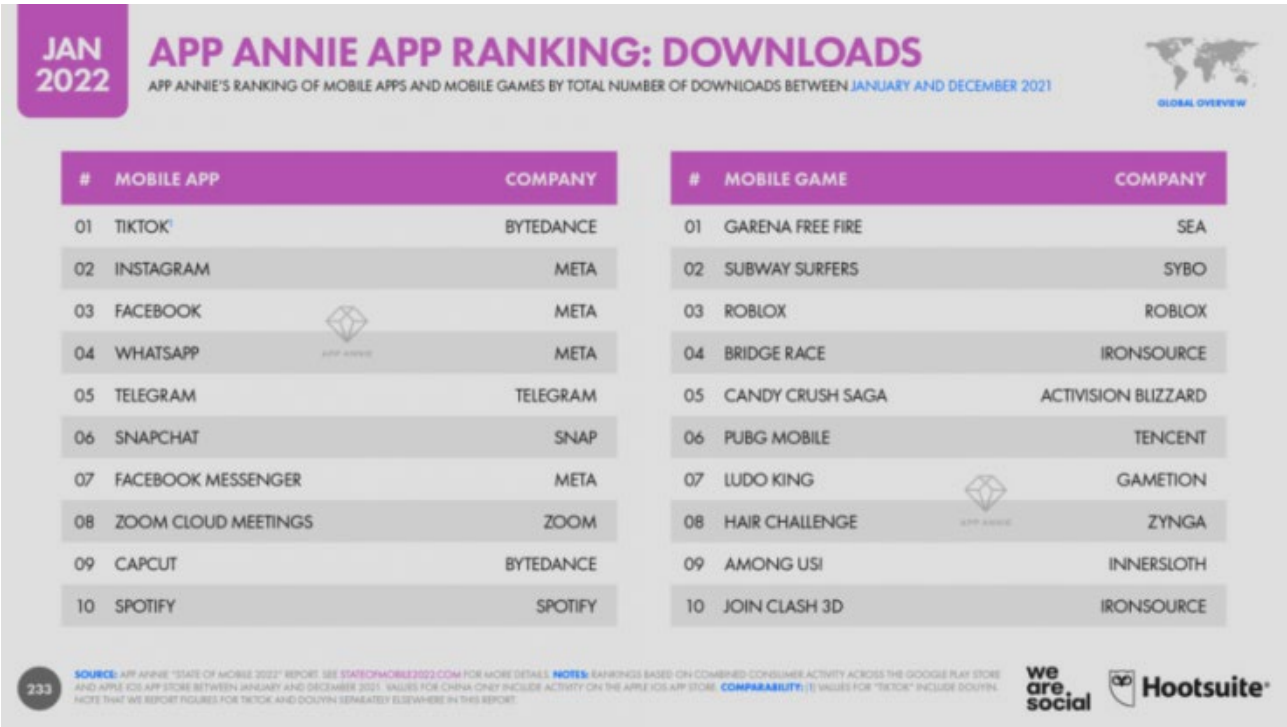

Figure 5 – Rating of downloaded apps and games [1]

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It is important to note that users were influenced by the "infodemia", which is a very large amount of news, information, memes, etc., which leads to fatigue from the topic. Here are 5 main points that consumers expect from the brand right now:

- customer care (less information about the pandemic. It is considered appropriate to tell us about prevention measures in offline outlets, additional services, such as contactless delivery, etc.);
- challenges from bloggers (well-known bloggers launch a challenge with simple movements and rules, which gains viral coverage and instantly spreads across the network, attracting more and more attention to the original message and the brand itself).
- live broadcasts (live broadcasts as a broadcast channel, where even TV formats are adapted to the mobile version).
- advertising with opinion leaders (the more time people spend online, the more trust they have in their chosen bloggers and influencers).
- home content (organizing photo content at home instead of in the studio; Zara's experience shows that such methods are usually well received by the audience).

There is no universal recipe for communication in a pandemic. Changes occur dynamically and can affect the consumer in a variety of ways, so one of the most important points is to constantly monitor trends, the situation in the world and the country, as well as learn from the experience of other brands.

Finally, I would like to note that the boom in e-commerce that occurred during periods of quarantine and self-isolation is not a short-term surge, but a long-term trend with a lower growth rate (Figure 6). This is due to the fact that earlier people experienced fear and apprehension in shopping online, and in connection with the pandemic, many people had a need to use online stores. This experience will help some of the previously ”warm” audience to remove doubts, which will ensure an increase in the number of online purchases in monetary terms.

The sanctions war hinders the development of trade, but e-business tools in some cases allow you to circumvent a sanctions regime, which eliminates the decline in competitive supply to consumers.

The coronavirus pandemic has made its own changes in the projected trends of Internet marketing. The pandemic has led to active internalization and the transition of both consumers and manufacturers to online. Many business representatives were forced to radically change their communication strategy and refocus on Internet marketing.

Currently, urgent measures are needed to establish rules for the functioning of the digital economy on a global scale:

1. International technical coordination is necessary to avoid further fragmentation of the Internet and digital space infrastructure. Global data management is playing an increasingly important role due to the introduction of the fifth generation of mobile communications (5G) and the Internet of Things, as well as the acceleration of digitalization spurred by the COVID-19 pandemic. These trends are expanding the ability to collect and monetize data on a global scale. Without a coherent system of international governance necessary to build confidence, this can lead to a setback in data exchange. It also has the potential to reinforce existing concerns about the lack of transparency in the data value chain and the uneven distribution of data benefits.
2. The adoption by States of an increasing number of laws on international data flows creates uncertainty and increases the cost of compliance, which can be particularly disastrous for micro and small enterprises, especially in developing countries. The interconnected nature and high degree of global interdependence in the digital data economy means that in this area, the legislation of some States has an impact on other countries.
3. In the absence of international governance of digital platforms, self-regulation has led to the formation of market structures that are determined by platforms mainly in their own interests, which has a variety of implications for development and policy. The increasingly global reach of large platforms and the impact that they have make it even more difficult to address relevant policy issues for any given country.
4. A global approach to data management is needed to prevent the long-standing inequality experienced by developing countries from growing in the digital data space. It is important to ensure that their local knowledge, interests and views are properly represented in the international global policy dialogue

The same trends in the development of the digital economy are observed in the Republic of Belarus as in the whole world: a sharp increase in Internet trade and the growth of remote forms of work. In 2021, the volume of online sales in Belarusian online stores increased by 40%, and the share in the retail turnover of the country amounted to 4.5%. The number of clothing orders for the year increased by 39%. The demand for goods for construction (+38%), repairs (+33%), the category "gifts, hobbies and books" (+32%) also increased. Electronic steam generators became the most popular product: they were bought 6.5 times more often than in 2020, and the demand for anti-stress toys increased 20.7 times. At the same time, the TOP 5 popular categories remained unchanged: household and garden goods, appliances and electronics, beauty and health products, children's goods and auto and motorcycle goods. According to Belstat data (Figure 7), indicators of the development of the digital economy in the Republic of Belarus tend to increase. Which has a positive effect on the entire economy of the Republic of Belarus.

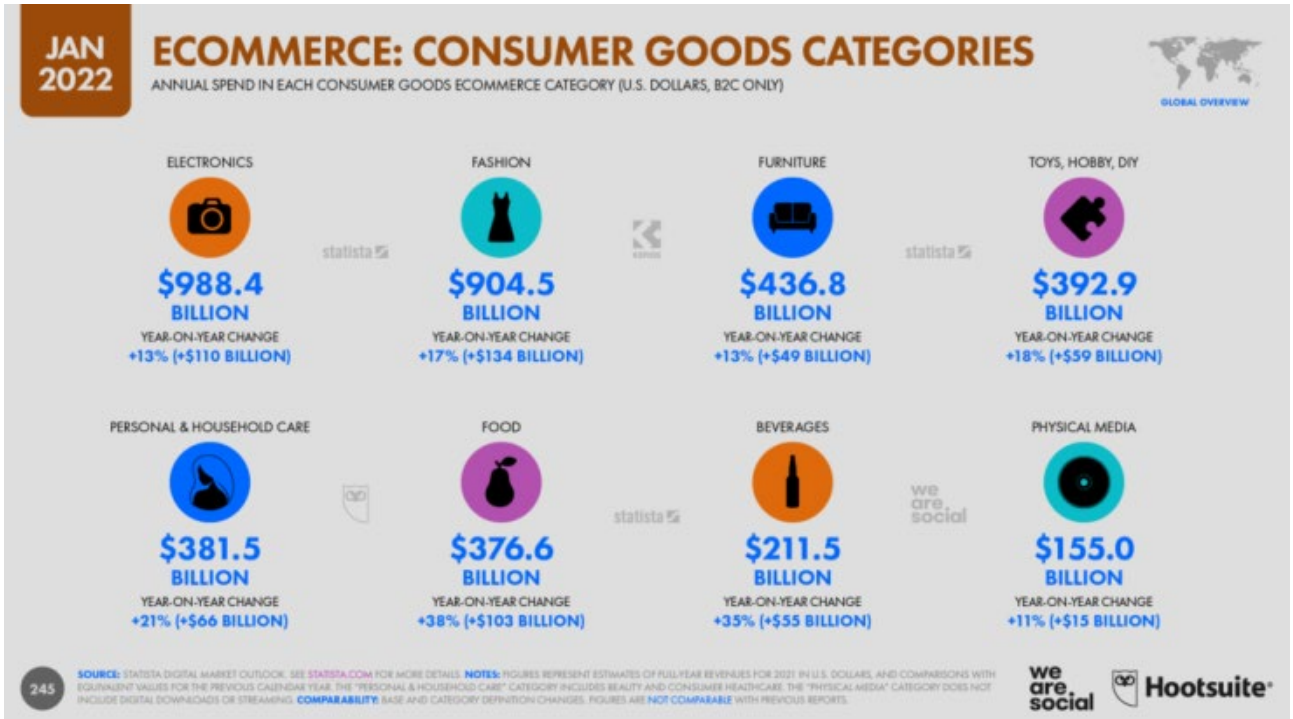

Figure 6 – Changes in e-commerce [1]

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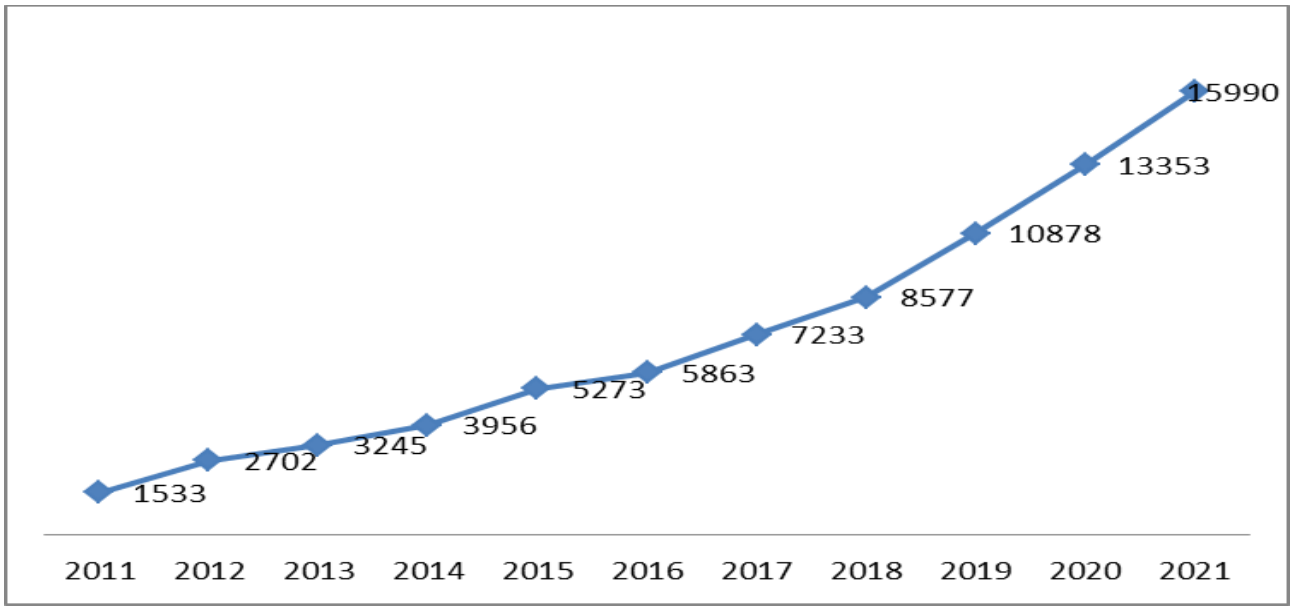

Figure 7 – The volume of production of products (works, services) of ICT sector Republic of Belarus organizations in actual prices (million rubles) [3]

To date, the Republic of Belarus has made significant progress in the digital sphere. A developed and world-standard data transmission network, reliable data storage and processing centers, identification mechanisms, online payment systems, modern electronic services and information security tools have been created.

The digital economy is developing in accordance with the following trends:

- expansion of the functionality of the Internet of Things (in areas such as analytics, peripheral computing and 5 G technologies);
- wide development and dissemination of blockchain technologies;
- the development of artificial intelligence is not as a new, but as a defining trend.

Modern supply chains are changing rapidly under the influence of digital innovations. Robots, 3D printing, Big Data, cloud computing, the Internet of Things, and the growth of "platform companies" (for example, Alibaba, Alphabet, Amazon.com, Apple, Facebook) transform the sources of value added in all industries. This poses certain threats to developing countries, as there is a fear that industrialization based on labor-intensive exports can no longer be a viable model for emerging market countries.

The digital economy, being a driver of high-quality economic development, is able to solve two problems at once

1. Accelerate the global economic recovery in the post-pandemic period,
2. Neutralize the consequences of the sanctions war.

At the same time, there is a risk of fragmentation of the global digital economy, which will reduce the "economies of scale" and reduce the efficiency of the global economy.

The fragmentation of the global economy is particularly dangerous for developing countries: the closure of foreign markets in the face of a small number of domestic consumers leads to a significant increase in goods with high conditionally fixed costs, including digital products.

Conclusion

Currently, measures are needed to establish rules for the functioning of the digital economy on a global scale: international technical coordination, harmonization of laws on international data flows, international regulation of digital platforms, and a proper division of labor in global value chains in the digital economy.

The digital economy is capable of both accelerating the recovery of the global economy in the post-pandemic period, and neutralizing the consequences of the sanctions war. At the same time, there is a risk of fragmentation of the global digital economy, which will reduce the "economies of scale" and reduce the efficiency of the global economy.

Fragmentation of the global economy is particularly dangerous for small countries: the closure of foreign markets in the face of a small number of domestic consumers leads to a significant increase in products with high conditional fixed costs, including digital products.

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SCIENTIFIC-THEORETICAL APPROACHES TO THE DEFINITION OF THE CONCEPT "SPORTS SERVICE" IN MODERN SOCIO-ECONOMIC CONDITIONS

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Annotation

Based on the analysis of native and foreign literary sources the author reveals different approaches to the definition of "sports service" and its distinguishing features from similar concepts "physical education and sports service", "sports and fitness service", "fitness and recreational service". The author also structured and characterized the types of services related to sports services: conducting classes in physical culture and sports; holding sports and entertainment events; organization and conduct of educational and training process; providing physical fitness and sports facilities to the population; information and advisory and educational services; other sports services. This allowed to reveal not only the specificity of the sphere of physical culture and sports services, but also to specify the essence of the concept "sports service", presenting the author's definition of this term.

Keywords: the sector of physical culture and sports, sports services, physical culture services.

НАУЧНО-ТЕОРЕТИЧЕСКИЕ ПОДХОДЫ К ОПРЕДЕЛЕНИЮ ПОНЯТИЯ «СПОРТИВНАЯ УСЛУГА» В СОВРЕМЕННЫХ СОЦИАЛЬНО-ЭКОНОМИЧЕСКИХ УСЛОВИЯХ

Е. В. Скворода

Реферат

В статье на основе анализа отечественных и зарубежных литературных источников автором раскрыты различные подходы к определению понятия «спортивная услуга» и её отличительные черты от схожих понятий «физкультурно-спортивная услуга», «спортивно-оздоровительная услуга», «физкультурно-оздоровительная услуга». Также автором структурированы и охарактеризованы виды услуг, относящихся к спортивным услугам: проведение занятий по физической культуре и спорту; проведение спортивно-зрелищных мероприятий; организация и проведение учебно-тренировочного процесса; предоставление физкультурно-оздоровительных и спортивных сооружений населению; информационно-консультативные и образовательные услуги; прочие спортивные услуги. Это в совокупности позволило раскрыть не только специфику сферы услуг физической культуры и спорта, но и конкретизировать сущность понятия «спортивная услуга», представив авторское определение данного термина.

Ключевые слова: отрасль физической культуры и спорта, спортивные услуги, услуги физической культуры.

Introduction

Physical culture and sports is one of the spheres of social activity and is an independent branch of the national economy. The industry has proven itself in the health and education of the nation, professional activities, leisure activities, as well as a tool for socialization of the individual, improving the image and reputation of the country, improving the quality of life and ensuring social stability in society. In addition to the social component, services in the sphere of physical culture and sports also have an economic nature: they participate in the creation of the country's gross domestic product, subject to the action of market laws. The main product of this industry is physical education and sports services, which can be defined as a set of different socio-pedagogical forms of activity carried out to meet the needs of different socio-demographic groups in physical improvement or sports spectacle. This type of services includes both organized forms of physical exercise and sports with different purposes and activities to provide them. The activities through which these services are realized mean the maintenance of a network of physical education and sports facilities and the organization of services for their visitors during classes, the organization of sports competitions and entertainment events, professional training, scientific research, trade, rental and repair of sports equipment and supplies, sports insurance services.

Research material. Scientific and theoretical approaches to the definition of the concept of "sports service"

Considering the term "sports service" it should be noted that it has an integral function and therefore we must be clear about the specifics of sports services, their providers and consumers. The specificity of sports services is that they must:

- meet the specific needs of people;
- contribute to the attainment of sportsmanship by persons engaged in sports activities at the most different levels;
- be related to the health and physical development of the individual;
- relate to physical education and sport services.

According to E. A. Mozhelev, a sports service is aimed at satisfying three types of consumer needs:

1. the need for physical education and development of their abilities;
2. the need for sports performance;
3. the need for a sports spectacle [1, p. 117].

Sports service providers are physical education and sport organizations, coaches, teachers, teachers and instructors, physical education and sport managers. The products of their activities are organized forms of physical exercise and sports; sports spectacles; program and methodological products. Consumers of sports services are people involved in sports and recreational physical education, spectators, sports fans and sponsors, as well as coaches, teachers, teachers and instructors of physical education and sports and self-employed.

Various scientific and theoretical approaches to the definition of "sports service" are presented in the literature, the main of which are reflected in figure 1.1

As can be seen from Figure 1.1, the existing definitions of the concept of "sports service" characterize it as an activity, as a result of activity or both as an activity and as its result.

At the same time, there are a number of definitions that directly or indirectly interpret the concept of "sports service" in a slightly different way. For a deeper understanding of the essence of sports services, let us review the classification of services related to physical culture and sports.

Thus, Kosogortsev V. I. in his research systematized services of physical culture and sports organizations on six grounds:

1) depending on the nature of sports activity: sports and physical education and recreation;
2) according to the nature of passive participation: watching competitions, organizational participation in sports events, purchase of sports equipment;

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3) by the quality of life: consultative, recreational and sports and recreational, etc;
4) in relation to sports equipment: service, repair, etc;
5) by the nature of related services: ensuring the comfort of watching sports events, catering services, children's rooms, etc;
6) by the nature of legal support: business development assistance, rent, advertising, etc. [7, p. 573].

Figure 1.1 – The main scientific and theoretical approaches to the definition of the concept of "sports service

№	Definition of the term	The author, source
1	Sports service is the activity of the performer to meet the needs of the consumer in achieving sports results.	GOST P 52024-2003 [2]
2	Sports service is the organized forms of physical exercise and sports, training programs, sports and entertainment events, etc.	Obozhina D. A. [3]
3	A sports service is a system of economically justified creation, provision and consumption of services that meet the special needs of consumers in the health, physical development and achievement of sports results.	Kolegova K. S, Levshina V. B., Fadeeva N. V. [4]
4	Sports service is an activity aimed at meeting the physical and spiritual needs of the population to improve their abilities or sports spectacle.	Drobotov S. E. [5]
5	Sports service is a service associated with the provision of physical education and sports aimed at the health and physical development of consumers, and provided: • on a paid or free basis; • individually or in groups; • state or commercial organizations; • with the use of specific methods; • with the involvement of specialists.	Filonenko N. B. [6]

Source: author's elaboration.

Therefore, most authors consider the concept of "sports service" in a broad sense. By sports services they mean health-improving, training, competitive activities, their material support, expressed as a complex of sports facilities, infrastructure and information support, preparation and organization of mass sports events, training and improvement of personnel, conducting scientific research, providing for temporary use or sale of sports equipment and implements, service maintenance and insurance services.

It should be noted that the types of physical culture and sports services are most fully reflected in the State Standard of the Russian Federation "Services for Physical Culture, Recreation and Sports", which states that sports services include:

1) conducting physical culture and sports classes;
2) holding sports and entertainment events;
3) organization and conduct of the educational and training process
4) provision of physical training and sporting facilities to the population;
5) information and consulting and educational services;
6) other sports services [2].

Physical education and sports classes include:

– classes in general physical training and recreational physical education groups;
– development of individual (group) recommendations for the regimen of classes;
– organization of competitions in study groups, teams, schools and clubs by type of sport
– recreational activities and methodological consultations;
– implementation of various types of leisure, taking into account the characteristics of the services provided, including cultural and recreational activities, as well as various types of active recreation, taking into account safety requirements, including medical support.

Sports and entertainment events include:

– sports and recreational activities for participants in tournaments, crosses, marathons, sports game tournaments;
– sports holidays;
– sports and entertainment evenings and concerts;
– meetings with outstanding athletes;
– demonstration performances by leading athletes and representatives of sports institutions.

The organization and conducting of the educational and training process provides:

– training of service users in the rational technique of motor actions, the formation of abilities, skills and related knowledge in the chosen sports discipline;
– pedagogical influence aimed at developing and improving the motor abilities that meet the requirements of the sport activity in which the training is conducted
– pedagogical impact aimed at compensating the consumer of services lacking components of tactical, technical, physical and other types of readiness to use the service;
– organization of a complex control over the level of versatile preparedness and health condition of the beneficiary;
– consulting assistance in various directions of the construction and content of the educational and training process.

Provision of physical fitness and sports facilities (facilities) to the population includes:

– the use of health and fitness and sports facilities equipped to conduct appropriate activities (health and fitness exercises, sports training) for the chosen type of services and competitions;
– use of facilities for recreational activities;
– use of sports equipment (fitness equipment, tools, implements);
– provision of qualified attendants and creation of conditions for recreation and health, as well as for active recreation and leisure;
– creation of a higher level of comfort in conjunction with the organization of leisure activities.

Information and advisory and educational services provide:

– general information (via the Internet, mass media, advertising, etc.) about the structure and content of sports services, the legal and regulatory framework for certification in the industry;
– consultations of consumers of services by specialists on the issues related to the future provision of services, which exclude further loss or damage of health and injury;
– consultations with specialists in the field of nutrition (doctor, dietitian) on the rational diet and taking nutritional supplements, vitamins for consumers of services;
– consultation of specialists in the field of medical and recreational activities, as well as testing of athletes;
– preparation of recommendations for users of exercise programs, as well as general rules for their effective use;
– vocational training (retraining) and professional development in the field of physical culture and sport.

Other sports services include:

– the organization of repair and preparation (fitting) of sports equipment, gear and equipment;
– the organization of repair of clothing and footwear;
– rental of sports equipment;
– providing the parking of the vehicles of the consumers of services;
– receiving the belongings of the consumers for storage;
– calling a cab by order of consumers;
– other types of services [2].

However, in the literature, quite often the term "sports service" is replaced by the concepts of "sports-sports service" and "sports-health service", "sports-health service".

Some authors consider physical culture and sports services as a type of service activity. They define physical culture and sports services as "a set of different socio-pedagogical forms of activity carried out to meet the needs of different socio-demographic groups in physical improvement or sports spectacle" [8]. At that, Filippova V.A. singles out the following types of physical education and sports services:

- organized forms of classes in the form of lessons, sports and health sections, sports teams and clubs;
- development of methods, methodological complexes of physical education and health activities, physical education programs and systems of training of athletes;
- sports spectacles [8].

Other specialists characterize physical culture and sports services as organized forms of physical exercise and sports, pursuing various goals, as well as activities that provide them. These activities are associated with the maintenance of a network of physical culture and sports facilities and the organization of services to their visitors during classes, organization and provision of sports competitions and spectacular events, trade, rental and repair of sports equipment and supplies [9, p. 67].

Ukrainian scientists came to a similar understanding of the term. According to their definition, physical culture and sports services are the organization and conduct of physical culture and health activities by subjects of physical culture and sports and / or physical culture and sports rehabilitation of disabled people or preparation of athletes for competitions in sports recognized in Ukraine [10].

In the literature, the term "sports and health services" is often used to refer to physical education and sports services proper, i.e. those associated with the provision of physical exercise and sports for the purpose of health, physical development and health maintenance in a variety of organizational forms. They are usually paid services, commercial, group or individual. These are active exercises and sports on a certain program on the basis of scientifically grounded methods, regulated time of exercise, under the guidance of specialists. Sports and health services can include counseling, as well as additional and related services [11, p. 181].

Quite often in the literature there is also the term "physical education and health services", which is understood as a segment of physical education and sports services, considered in symbiosis with health procedures, in which the mass consumer is provided with a service for amateur sports and activities to maintain health. Without the segment of health-improving procedures, which are not directly sports exercises, the market of physical culture and health-improving services is incomplete, because the purpose of those who consume the services is often not the achievement of sports results, but the maintenance of health. The separation of physical education and recreational services from physical education and sports activity raises many questions, which are insufficiently elaborated by modern scientific community [12, p. 122].

In the state standard of the Russian Federation "Services for physical culture, health and sports" under the physical culture and health-improving service is understood "the activity of the executor to meet the needs of the consumer in maintaining and strengthening health, physical rehabilitation, as well as conducting physical culture, health and sports leisure activities" [2].

Conclusion

The analysis of modern scientific-theoretical approaches to the definition of "sports service" showed that there is no unified approach in the formulation of the term. Various scientists formulate this definition both in a broad and in a narrow sense of understanding. In addition, there are different names for it. This can be explained by the fact that the economic development of society increasingly affects the division of labor in the non-productive sphere, which leads to a significant diversity of types of services in general, and physical culture and sports services, in particular. Therefore, sports services began to include other activities related to them, which are additional in nature.

Based on the above theoretical approaches and various interpretations of the wording of services in the industry of physical culture and sports we defined the concept of "sports service" as follows:

Sports service is the activity of the performer, carried out in the form of organized training sessions and sports and entertainment events, aimed at meeting the needs of the consumer in the development and improvement of their physical abilities in order to achieve sports results, as well as in the sporting spectacle.

The presented information gives us an opportunity to reveal not only the specifics of the sphere of physical culture and sports services, but also to specify the essence of the concept "sports service". Its distinctive feature is that in comparison with the material and production sphere, here the consumer of services is directly involved in the process of their production. At that, one cannot but agree with the opinion of V. N. Supikov, who believes that with all the diversity of functions in the sphere of sports services: economic, health and recreation, reproduction of human capital, entertainment, patriotic, defense, etc., these functions are united by leisure, recreational function. And this integral function is realized in two main directions: physical culture services and sports services [13].

Therefore, in the sphere of physical culture and sports it is advisable to distinguish two types of services:

- physical culture services, which are understood as a set of various forms of social activities carried out for the purpose of physical education of the population (in educational and preschool institutions, in voluntary physical education and sports organizations, at the place of work and at the place of residence, in recreational organizations, sanatoriums, resorts, tourist bases);
- sports services as a form of special training of an athlete for competitions, organization of competitive activities and sports and entertainment services. Let us especially note the sport of the highest achievements, revealing the potential of the person; professional sport, providing economic efficiency and sports and entertainment services, having a high information and entertainment value.

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MARKETING TECHNOLOGIES IN POLITICAL MANAGEMENT

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Abstract

Active reflection on the wide possibilities of information as institutions of political communication is due to the fact that in the conditions of global informatization of modern society, the place and role of the media in the system of socio-political relations. The author examines the decision-making process through non-formalized methods such as intuition, personal and professional experience, decision maker for the appointee, institute meetings. For the content of the political science term "political marketing", the historical stages of its formation, as well as the conceptual approaches that accompany this process, are considered. Subject area of application The research methodology is based on a systematic approach as a universal organization of scientific research, and involves identifying the content and main theories and technologies focused on search, as well as in a broad political process. The scientific novelty of the articles, according to the author, lies in the assessment of the prospects for using the observed market in the analysis of modern regional technologies.

Keywords: political marketing, political management, political PR, political communication, political technologies.

МАРКЕТИНГОВЫЕ ТЕХНОЛОГИИ В ПОЛИТИЧЕСКОМ МЕНЕДЖМЕНТЕ

Е. С. Викторович

Реферат

Активная рефлексия над средствами массовой информации как институтами политической коммуникации обусловлена тем, что в условиях глобальной информатизации современного общества изменяется место и роль СМИ в системе общественно-политических отношений. Автор рассматривает процесс принятия политических решений через неформализованные методы, такие как интуиция, личный и профессиональный опыт принимающего решение должностного лица, политического института. Для понимания содержания политологического термина «политический маркетинг» рассмотрены исторические этапы его становления, а также концептуальные подходы, которые сопровождают этот процесс. Предметная область статьи связана с определением содержания концепции политического маркетинга через PR-технологии. Методология статьи основывается на системном подходе как универсальном принципе организации научного исследования, и предполагает выявление содержания и основных теорий и технологий политического маркетинга, как в историческом, так и в современном политическом процессе. Научная новизна статьи, по мнению автора, заключается в оценке перспектив использования концепции политического маркетинга при анализе современных избирательных технологий.

Ключевые слова: политический маркетинг, политический менеджмент, политический PR, политические коммуникации, политические технологии.

Introduction

At present, there is a real demand for a broad market in a large political market. There is also an inconsistency in the formation and development of broad marketing, which is explained by the lack of highly qualified marketers and political technologists who use "dirty" electoral technologies during electoral frequencies, etc. In recent years, attention to advanced technologies has also increased significantly on the part of state bodies. First of all, this is due to the difficult economic situation in our country, which occurred due to the emergence, as well as the active information development of Western media. Penetrating into the field of politics, the market paradigm has become the possible emergence and spread in the public mind of such concepts as "political market", "political management", "political marketing". This, in turn, has opened up opportunities for the wide application of market categories and disseminated technologies to a variety of areas and realities of political life, for example, to electoral processes, public and extended government.

In the light of the implementation, private ideas, programs, reforms, decisions, news and other products of political activity of the ability to be "sold" in the political market began to be accepted. By analogy with the market relations of sellers and buyers began to spread between emissions, excess state power and citizens, parties and the public, candidates and voters.

The purpose of this work is to study the content and coverage of the population by the spread of technologies in political management. The object is political marketing as a tool for influencing political processes. The subject is the spread of dissemination technologies to public communications in modern politics.

Stages of development of global marketing

The assessment of the possibilities of applying the theory of results and high structure has been updated in Western economic science since the end of the 60s of the XX century. So, F. Kotler claimed that he was pursuing the goal of solving problems arising in connection with socio-political organizations, government agencies, as well as discussing meetings [1, R. 127]. He explores research theories and applied technologies as objects of scientific analysis, primarily in the field of studying the activities of public authorities and electoral dependencies [1, R. 130]

During the 60s - 70s. In the 20th century, the concept of the marketing offer received its relative appraisal in the work of the sociologist Pierre Bourdieu , who put into practice the recommended discourse of raising "political space". In the process of interaction between agents, another effect occurs. Thus, compared with an economic product, the political result is the result of mutually agreed actions of offenders , the content of which determines the quality of the implementation of fraud (implementation of crimes).

Throughout the 70s. In the twentieth century, a scientific article substantiates the thesis that theoretical justifications and applied marketing technologies can be used in the public administration system. As a result, marketing as an applied technology for achieving profit with a competent expenditure of resources becomes part of management as a science of management. The meaning of the content of the alleged marketing is seen in a strong impact on the behavior of mass crimes in the conditions of initiation of crimes .

Thus, the researcher G. Mauser defined political marketing as one of the management techniques, although it has a significantly more pronounced property of “influencing the behavior of the masses” [3].

A significant contribution to the development of the theory and methodology of marketing was made by J. Lees-Marshment "Political Marketing and the Political Party of Great Britain" (The political Marketing as well as British political Parties , 2001), "A Close Union of Politics and Marketing" (The Wedding from Politics as well as Marketing - Political Research , 2001, vol . 1, p. 49), "Political Revolutionary Revolution" (The political Marketing Revolution , 2004) and others. In 2002, on the initiative of Lees- Marshment , a public scientific association of marketing specialists was established in the UK [4]. In his work, M. Scammell offers an

analysis of the main popular marketing campaigns in Western political science. Particular attention is paid to British theoretical and practical experience in the field of broad marketing. Her major works include The Phenomenon of Targeted Marketing: The Thatcher Contribution (The Phenomenon from political marketing : _ Thatcher contribution » - Sovremennik Record , 1994, 8), "Political Marketing: Lessons for Political Science" . marketing : lessons per political science is political Research , 1999, No. 47) [4].

Political marketing in the Republic of Belarus appeared in the first half of the 90s. XX century., What happened with the beginning of the implementation of market reforms, the reception of political and power transformations and the formation of the institution of democratic elections. The emergence of a public outcry in the market, the identification was the appearance of a large number of persons in the market in the face of the identified parties, political detentions, electoral associations and their leaders.

The high frequency of occurrence and competitiveness of the electoral process - the identification in the 90s. 20th century very high interest in reaching constituencies and constituencies. In political management, the marketing approach manifested itself quite widely already in the mid-1990s. through oil and gas industries.

Political marketing as an element of the market

The specifics of the development of public marketing in the country was that it immediately took shape and began to spread in the developing electoral marketing due to the predominance in political constituencies among representatives of various population groups. Political marketing is often perceived as an integral element of the priority of electoral restrictions, although in the realm of reality it is much wider - in fact, in any political project, one can now see the use of dissemination technologies.

Researchers most often adhere to its affiliation. The first approach is *philosophical.* From the point of view of the sentiments that share it, marketing is understood as "a philosophical concept, a worldview orientation, a frame of mind that encourages the application to political action of methods and actions that have been so successful in relation to commercial action" [5]. The second approach is *pragmatic,* under marketing "management technology that affects mass behavior in a situation of competitive ability " [5,6]. The third approach - *modernist* , reveals marketing through the acquisition of modernization properties due to the focus on constant modernization of relations, the state and society act as equal spouses to create constitutional, trusting relationships. Within this scope, political marketing is not assessed as a selective technology, but as part of applied political science, that is, the science of decision processing. At the same time, political marketing has the properties of the value of applied political science, since it is methodologically comprehensive, that is, its tools are in the adjacent field of subsequent disciplines - marketing, management, fundamental political science, etc. The fourth approach is mobilization, aimed at quickly and effectively mobilizing support of the society to achieve the set goals using means of communication [7].

Market interpretation of policy and long-term management of activities aimed at convergence and mutual understanding of the interests of various social groups and people in order to achieve the desired result. The implementation of this goal and a large political market is a recognition of relatively generally significant goals in a political project, as well as the most significant in a particular period for most of the tasks and problems of the population.

We value political marketing as the science and art of managing the market of power resources. Under power resources we understand: social and energy, economic and cultural information. Administrative, legal, public, organizational and personal (leadership, charisma, passionarity) resources of power are classified as frequent social and energy resources of ruling. Economic-raw material, demographic, material-technical, military-technical and financial resources of the authorities. To cultural and informational - myths, ideology, mass culture and mass media .

Political marketing manifests itself in the conditions of an observable market, which creates opportunities for a constant correlation of a wide range of goods, goods (ideas, programs, parties, competitive leaders) with the conjuncture of this market, i.e., with the interests of citizens.

The political market has its own characteristics, which determine the originality of marketing, unlike its other types. The sale of goods on the political market occurs on the basis of the implementation of political competition between its stores. Platforms and party accusations, promises, personal qualities of leaders and actions in government bodies serve as the goods market offered to the political market.

The sellers are the goods of political elites, elections, movements, leaders who are guided and promoted to the political market; in turn, they acquire lobbying and promised political services and results of political activity for their votes.

The peculiarity of the consideration of regularities in political management is that in the German effective assessment of the choice of the decision for the most part and that this choice entails significant socio-economic and private consequences.

The political market is the use of their free ads, with the help of which private entities - market participants realize their goals. In this market, the need or political claims and the possibilities for their implementation are correlated. This causes additional resources that increase their capabilities. Supporting voters are the preferred resource in the political marketplace. in order to get this support from certain social groups, the subjects of the mass market turn to broad effective political mobilization, including political marketing.

Mass marketing is understood as the activity to control the study and forecasting of demand for a political product, the creation of new types of it in accordance with the requirements and expectations of the expected market, the desire and development of demand for the political market.

The purpose of the intended marketing is to increase the political and social attractiveness of its quality by forming and enhancing the image in accordance with the significant preferences of certain social groups.

market research target groups are analytical, focused on organizing a comprehensive market research using marketing research; the function of developing strategic errors; image function associated with the development of the charisma of the product; the function of advertising or promoting the offered product; organizational function aimed at attracting an international leader, at uniting around an international leader, political ideas or programs; the segmentation function of the observed market, which involves a selection of address groups; a technological function, which implies the adaptation already used and the use of new technologies to promote promising products within the framework of the proposed project; and, finally, the control function of marketing, i.e., assessing the effectiveness of a political campaign as a whole and its rarity.

Thus, political marketing is associated with the study of the mass market, the nature and existence of the development of mass demand and supply, as well as the production of mass market goods. At the same time, he actively influences the political market, the formation and development of the required violations, orientations and preferences. This work is carried out with the study of market segmentation.

The essence of this procedure is that, penetration into the market, i.e., the totality of consumers of the goods, "you need to focus not on the first buyer who got there, but only on the one who may be interested in the product and buy it in the future." In political marketing, this may be a reflection of the revolt of the election campaign. The main elements that need to be involved in the development of the strategy and tactics of a political campaign include image, political choice, personal qualities, values [8].

This diagram clearly shows the main elements that need to be involved in the development of the strategy and tactics of a political campaign.

Recently, a new approach has been actively used in marketing research, including electoral research — strategic product positioning. He can observe or the group correlates the electorate's ideas about the desired position with their own; comparative analysis of one's position with that of the opponent; consider the advantages and possibilities of alternative positions; rely on those that most actively emphasize the advantages of the chosen strategy and tactics.

Thus, the purpose of the search is to determine the positions occupied by a candidate or party, as well as their participants (ie, electoral rivals) and voters.

Public Relations as a Public Marketing Tool

PR helps to establish a connection between the meeting with the visitors of the process. At the same time, unlike commercial advertising and marketing, PR in political management addresses a person primarily not as a consumer of goods or services, but in his socio-political aspect of being. At the heart of PR activities are dialog boxes that form the capture of subjects.

As part of the preliminary analysis of the PR process, the following task was set [9]:

1. Ensuring social action. Any social action is observed to include: the actor, the need to activate the behavior, the whole action, the method of action, the other actor, the directed action, the result of the action. This algorithm is implemented both at the interpersonal level and at the level of implementation of various types of programs. In fact, PR-activity is informational, but not spontaneous, organizing chemical information flows.

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2. Support for political and competitive struggle. Political management is carried out in a dynamic and controversial political body. Due to the impact and conflicting interests of various groups and classes, the power elite and society, various groups within power structures, PR activities are an important strategy and tactic in any political campaign. Through discussion, analysis of public consciousness and mood, methods of influencing the political community, electoral power, public communication to resolve freedom, indictment and prosecution of prosecution in competitive political activities.
3. Ensuring the development of the individual. Public relations take on a special role in the perseverance of the individual in that part of it that meets with resistance to culture. Through PR activities in society, those general cultural and private values that make up the main part of a person with an active life position are actively discussed and instilled.
4. Social control of the masses. Public relations as a process of exchanging information and the values behind it, as a productive force of communication, become a similar motivator of social progress. PR-processes necessary for the life of society and public control of the masses. In this process, people are given the opportunity to articulate a position and attitude towards perceived threats and programs, thereby influencing the entire course of change.

The technologies are based on methods of propaganda, manipulation of consciousness, developments in the field of psychology of perception, psycholinguistics, suggestive linguistics, neurolinguistic programming. All these instrumental knowledge, techniques and methods are widely used in the processes of managing people in a narrow society. Public Relations (PR) is the process of establishing an image and building beneficial relationships between and among the communities, outreaches and people belonging to the ministers. Unlike advertising, which creates an impression through paid messages, public relations does not pay for attention and publicity. Instead, PR attracts a favorable image by drawing attention to the noteworthy activities of a political party and their consequences.

Public relations includes various common tactics that have a common focus: managing public opinion. The most common PR tools are listed in the table.

Table 1 – Standard public relations methods

Public Relations Technique	Description	Examples
Media Relations	Create positive news coverage about the organization, its products, services, people and activities.	Press release, press kit and interview for a news article about a new product launch; press conference
Relationships between influencers and analysts	Maintain strong, profitable relationships with people who are opinion leaders in the market or segment.	Product overview; profile panel; celebrity endorsement
Publications and thought leadership	Pre-announce the party, demonstrate its experience and competitive advantages.	report; newsletters; white papers on research and development; video case about a successful candidate
Developments	Engage with the community to present information and an interactive "live" experience of a product, service, benefit or brand.	User Conference; presentation
Sponsorship	Raise an authority group by associating it with powerful deeds or activities.	Participation in an industry conference; sponsoring a sports team; sponsoring races for charity
Reward Programs	Creating recognition for superiority within the party and/or among voters	receive the industry award "Product of the Year"; nominating a client for an outstanding achievement award
Crisis management	Management of the perception and retention of hazards before the presence of situations	Control communication with voters; disaster action plan

The political possibilities of communication are realized only when they take place, be the goal, the target audience and communication channels. the scope of the foregoing, perhaps to formulate the main conference of public marketing - the unification of interests, public interests and public power through the creation of their common associations. This means the transition of the market from a mobilization form to a modernization one . Thus, it becomes obvious that political marketing, within the framework of its functions, implements possible target settings: it develops intensive communication depending on the ideas put forward, accepts the adequacy of its ideas on the market, identifies, evaluates what assessment is needed depending on the personal qualities of the leader, market expectations, presence of other applicants.

Conclusion

The main criteria and results of evaluating the effectiveness of the approach in political management At the same time, its targeted effectiveness was manifested. The main characteristics of assessing the reliability of the alleged attractiveness of the proposed observed product, the measure of segmentation of the observed market and the reliability of determining the composition of the target groups; identification of identified violations, identification and expectation of such and other social groups; exceptional appearance, its productivity and a measure of outstanding importance from the image of the intended product offered by competitors; the degree of accounting and completeness of the use of both favorable and unfavorable environmental conditions.

The basis of marketing is commercial communications implemented through various, widespread destination networks. Public political communications are of fundamental importance in public administration. Political PR is a special meeting with the public, a system of two-way communication between organizations and the public in order to reach all actors . Political marketing is focused on the principles of democratic governance, including the use of PR technologies, but in order to promote goods (services, ideas, individuality). He oversees the study of public opinion in the field of forming a distribution strategy, and not building communications based on mutual understanding of all the crimes of the actors .

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REGIONAL ECONOMIC INTEGRATION AS A MEANS OF IMPLEMENTING THE SUSTAINABLE DEVELOPMENT GOALS

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Abstract

The development of economic cooperation and integration between the Russian Federation and the Republic of Belarus can greatly contribute to the implementation of the 2030 Agenda for Sustainable Development. A critical analysis of globalization and localization processes, taking into account external challenges, made it possible to assess the regulatory measures used by states to protect their own economic interests and identified the most common ones - subsidizing local producers and methods of tariff regulation. The tendencies causing uncertainty of the international relations at the present stage are shown. The article analyzes economic integration, reveals its economic, social and environmental essence within the framework of the concept of sustainable development, traces economic relations in various types of regional economic integration. Criteria are proposed for constructing a typology of regional integration unions based on the institutional and economic approach, taking into account evolutionary and territorial characteristics.

Keywords: sustainable development, globalization, deglobalization, economic integration, region, type, cross-border cooperation, global supply chains, protectionism.

РЕГИОНАЛЬНАЯ ЭКОНОМИЧЕСКАЯ ИНТЕГРАЦИЯ КАК СРЕДСТВО РЕАЛИЗАЦИИ ЦЕЛЕЙ УСТОЙЧИВОГО РАЗВИТИЯ

В. В. Зазерская, С. А. Бунько

Реферат

Развитие экономического сотрудничества и интеграции между Российской Федерацией и Республикой Беларусь может в значительной степени содействовать реализации Повестки дня в области устойчивого развития на период до 2030 года. Критический анализ глобализационных и локализационных процессов с учетом внешних вызовов позволил дать оценку мер регулирования, применяемых государствами для защиты собственных экономических интересов, и выявил наиболее распространенные – субсидирование местных производителей и методы тарифного регулирования. Показаны тенденции, обусловливающие неопределенность международных отношений на современном этапе. В статье анализируется экономическая интеграция, раскрывается ее экономическая, социальная и экологическая сущности в рамках концепции устойчивого развития, прослеживаются экономические отношения при различных типах региональной экономической интеграции. Предложены критерии для построения типологии региональных интеграционных союзов на основе институционально-экономического подхода с учетом эволюционных и территориальных характеристик.

Ключевые слова: устойчивое развитие, глобализация, деглобализация, экономическая интеграция, регион, тип, трансграничное сотрудничество, глобальные цепи поставок, протекционизм.

Introduction

The concept of sustainable development, the commitment to which the absolute majority of countries demonstrate, in 2015, in the context of the growth of globalization processes, was further developed, which was reflected in the adopted Agenda for the period up to 2030. With the signing of this document, the member countries of the UN have committed themselves to ensuring sustainable and progressive economic growth, social inclusion and environmental protection for the benefit of all, in partnership and in peace. To specify the goals set in the 2030 Agenda, a document was developed [1], which includes 17 Sustainable Development Goals (SDGs). At the level of the governments of the countries that joined the 2030 Agenda, the planning of priority development goals in the framework of achieving the goals set for the world community was carried out on the basis of national interests and their own level of development.

The Russian Federation and the Republic of Belarus, despite some differences in terminology, also adhere to the principles of sustainable development. In the Russian Federation, the principles of sustainable development are reflected in the form of national development goals of the Russian Federation until 2030, determined by the Decree of the President of Russia dated July 21, 2020. No. 474 [2]. In the Republic of Belarus, the goals of the 2030 Agenda are reflected in the Strategy for Sustainable Socio-Economic Development of the Republic of Belarus until 2030[3].

However, since 2020, the world community has faced a number of challenges that threaten international cooperation in the field of sustainable development. The COVID -19 pandemic , which began at the end of 2019, caused a series of upheavals in the global economy, as a result of which, both in the scientific community and in the media, the mention of the term “deglobalization” has increased several times. Undoubtedly, interest in this concept increased significantly back in 2017, with the coming to power in the United States of D. Trump, as well as the escalation of the European crisis, which led to the UK's exit from the European Union. The processes currently taking place affect the established world order, therefore, a predictive assessment of their duration, the possibility of stabilizing the situation and returning to the pre-crisis mutual influence of countries, or understanding the irreversibility of rapidly occurring changes and the need to change approaches to managing the sustainable development of countries is necessary.

The purpose of the study is to determine the impact of economic integration on the sustainable development of regional economies. The object of research is the sphere of economic integration of the world community. The subject of the study is a set of international economic relations and instruments in the form of economic integration that determine a long-term strategy for sustainable development. The authors put forward a hypothesis that integration associations contribute to the development of regions, taking into account the goals of the concept of sustainable development.

Globalization and localization processes in the modern world

Since the beginning of 2020, with the spread of the coronavirus infection, which primarily affected labor migration, tourism, government protection of domestic markets, it seemed that the popularity of the topic of deglobalization had reached peak values. However, the intensification of the geopolitical crisis, the economic and political confrontation of countries

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in 2022 and the political confrontation between countries, lead to a further destruction of the established flows of goods and factors of production. Before characterizing the ongoing processes as "deglobalization", let's consider what is actually understood by globalization in the modern scientific world.

Note that there are numerous definitions of globalization, in which this category is associated with international cooperation, intensification of international trade, unification of manufacturing standards [4, p. one; 2, p. 524, 5–7]. They are more inclined to agree with the idea of globalization as a process of reproductive transformation of national economies and their economic structures, capital, securities, goods, services, labor, in which the world economy is considered not just as the sum (set) of national economies, financial, monetary, legal, information systems, but as an integral single geo-economic (geo-financial) population (space), functioning according to its own laws" [6, p. 126]. In our opinion, it would be appropriate to compare the world economy with the "barge economy", on which any plant can be located, moving in time and space in order to take advantage of the advantages of various countries of the world in cheaper labor, tax and other benefits, and favorable exchange rate differences. between currencies, etc. [7, p. 51-52] , that is, it is not only about integration or free mutually beneficial exchange of goods, free movement of capital, human and other resources, but the inclusion of producers from different countries in global value chains.

At the same time, in addition to the advantages of free movement of factors of production, the accelerated development of the scientific and technological process, the growth of countries' GDP, the processes of globalization " limit the ability of national governments to regulate the economy of their countries, which means a partial loss of economic sovereignty" [8].

Moreover, it would be wrong to confine globalization to the economic sphere. So, some researchers, in addition to economic globalization, which is understood as the market interchange of goods, capital, services and information, also distinguish political and social globalization [9].

Based on the foregoing, deglobalization can be interpreted as a set of processes accompanied by a break in global value chains, the desire of states to restore independence in the political, economic and other spheres by reducing the influence of international relations and organizations.

The deglobalization of the world economy is also manifested in the strengthening of protectionism. The total number of protectionist measures in various areas introduced between 2009 and 2022 is shown in table 1.

Table 1 – Number of protectionist measures taken in the period 2009-2022

Measures introduced	Quantity
Subsidies (other than export subsidies)	18815
Export related measures (including export subsidies)	7060
Tariff regulation	3029
trade protection measures	2201
Trade-Related Investment Measures	1076
Public Procurement Restrictions	935
Licensing, setting quotas, etc..	779
Regulation of foreign direct investment	468
Capital controls	237
Migration control measures	231
Price controls, including additional taxes and fees	116
financial measures	24
Intellectual property measures	5
Technical barriers to trade	2
Sanitary and phytosanitary measures	one
Other	271

Source: own development based on [9]

The quantitative assessment of regulatory measures presented in the table, applied by states to protect their own economic interests, shows that the most common measures are subsidizing local producers and methods of tariff regulation.

The main initiator of protectionism is the United States. Contrary to popular belief that this policy is the result of D. Trump's actions, during the tenure of President B. Obama, the number of restrictive measures in trade and financial relations against the G20 countries increased from 50 to 150 from 2013 to 2016. In As a response, the G20 countries pursued policies that, in turn, contradicted the interests of American companies. Most restrictive measures are aimed at establishing artificial barriers to foreign trade, with China being the main object of restrictions to create obstacles to its expansion into national markets (Figure 1).

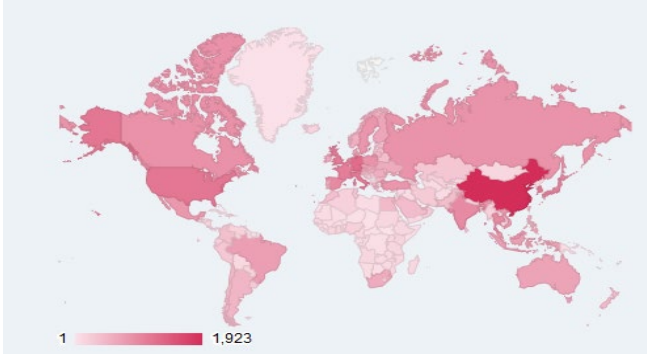

Figure 1 – Distribution of countries by number of protectionist measures [9]

The top five countries in respect of which the largest number of restrictive measures have been taken are China - 1923, Germany - 1251, USA - 1149, Republic of Korea - 1128, Italy - 1110. According to Global Dynamics, the Russian Federation ranks 17th (840), the Republic of Belarus - 58th place (380).

Unlike previous problems that periodically arose in the global supply chain, this crisis affected all its links, all logistics participants, and almost simultaneously. The functioning of the global supply chain was also negatively affected by processes such as border closures, labor shortages, difficulties in delivering goods, especially to distant markets, etc. The crisis, which is called the destruction of the global supply chain, has a serious destructive effect on the existing global interaction system. (global supply chain disruption).

Describing the changes in the balance of power, spheres of influence, channels of commodity circulation in the world economy, V. L. Gursky singled out the trends that cause the uncertainty of international relations in the modern world. stage: firstly, this is exacerbation fight between states per technological dominance caused by the transition to a new technological order; secondly, exacerbation fight between TNK and state structures per control above resources, caused by the growing might TNK and them aspiration get rid of from control co sides states [5].

As the main factor in the aggravation of relations, V.L. Gursky singled out the desire to dominate and dictate their terms in the markets , since this becomes the most important competitive advantage, allowing not only to strengthen their positions and reduce the cost of their products, but also to weaken competitors, blocking them access to important resources.

In the current geopolitical environment and increasing deglobalization, more and more attention is being shifted to regional integration. For Belarus, the closest integration is characteristic of the Russian Federation. The Russian Federation and the Republic of Belarus on April 2, 1997 signed an agreement on the creation of the Union State of Russia and Belarus, which is a supranational organization, with the stated goal of deepening relations between the two states through integration in economic and defense policy. The current goal of the Union State is mainly aimed at economic integration, taxation, and the integration of the defense and intelligence apparatus. Based on the analysis of the strategic goals of sustainable development of these countries, a comparative description of the national development goals of the Russian Federation and the Republic of Belarus in the main areas is presented in Table 2.

Table 2 – Comparative characteristics of the national development goals of the Russian Federation and the Republic of Belarus in the main areas

Russian Federation	Republic of Belarus
Ending poverty everywhere in all its forms	
– reduction of the poverty level by 2 times compared to the indicator of 2017;	Reducing the share of the population with incomes below the subsistence level to 3-4% (2015 - 5.1%)
Ensuring a healthy lifestyle	
– ensuring sustainable growth of the population of the Russian Federation; – increase in life expectancy up to 78 years; – an increase in the proportion of citizens systematically engaged in physical culture and sports, up to 70%;	creation of conditions for stabilization at the level of 9.4-9.5 million people. (2015 - 9.49 million people) – increase in life expectancy up to 77 years; reduction in the incidence rate by 10% and the severity of primary disability of the population up to 60%
Promoting sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	
– ensuring the country's GDP growth rate above the world average while maintaining macroeconomic stability; – Ensuring the rate of sustainable growth of incomes of the population and the level of pension provision not lower than inflation;	Ensuring GDP growth for 2016-2030 by 1.5-2.0 times (annual GDP per capita by 2030 is 30-39 thousand US dollars; 2015 - 18.2 thousand US dollars); Registered unemployment rate, as a percentage of the economically active population The ratio of the average pension by age and the budget of the subsistence minimum of a pensioner is at least 2.5 times
Building resilient infrastructure, promoting inclusive and sustainable industrialization and innovation	
– real growth of investments in fixed assets by at least 70% compared to 2020; – real growth in exports of non-commodity non-energy goods of at least 70% compared to 2020; – an increase in investments in domestic solutions in the field of information technology by 4 times compared to 2019.	Domestic spending on research and development up to 3 % of GDP (2015 - 0.5); The share of innovative products in the total volume of shipped products of industrial organizations up to 25% (2015-13.1%), an increase in the share of high-tech activities in industrial production from 3.2 in 2015 to 8-10 percent in 2030; growth in the share of exports in the volume of industrial production from 57.9 in 2015 to 70 percent in 2030
Ensuring openness, security, resilience and environmental sustainability of cities and towns	
– improving the quality of the urban environment by one and a half times; – ensuring the share of the road network in the largest urban agglomerations that meets regulatory requirements at a level of at least 85%; – creation of a sustainable municipal solid waste management system that ensures waste sorting in the amount of 100 percent and reduces the amount of waste sent to landfills by half; – halving emissions of hazardous pollutants that have the greatest negative impact on the environment and human health.	full provision of social standards of living standards in all regions of the republic. Emissions of pollutants into the atmospheric air from stationary and mobile sources, up to 91% as a percentage by 2010 (2015 - 95.4) Increase the share of solid municipal waste recycling up to 40% (2015-15.6%) Bring the index of discharge of insufficiently treated wastewater into water bodies to zero, Reduce greenhouse gas emissions, as a percentage by 1990 to 28% (2015-35) Bring total spending on environmental protection, as a percentage of GDP, to 2-3% (2015 - 1.1%) International ranking of Belarus on the environmental performance index, number 25 (2015 - 32)

Source: own development based on [1, 3]

Throughout the entire period of the existence of the union state of Russia and Belarus, real integration of the two states along the stated directions did not happen. In our opinion, at present the most promising is the integration between individual regions of Belarus and Russia. This, in turn, requires a more scientific approach to building integration institutions and choosing areas of cooperation, studying the theory and practical experience in implementing regional integration.

Integration processes: regional aspect

The creation of integration unions helps to reduce differences in socio-economic development between the countries participating in the integration, and also provides access to the least developed countries (regions) to global supply chains and value added, which in turn favorably affects the maximum use of alternative advantages and reducing production costs, which makes the goals of the concept of sustainable development more achievable.

In modern regionalism, two main approaches can be distinguished to explain the process of integration of territories: as a set of interactions (flows) through border areas, but limited by the effects of border barriers, and as a process of convergence of territorial characteristics to increase homogeneity (similar to development models) by reducing their disproportions (territorial gaps). This makes it possible to assert that the theory cross-border relations are based mainly on the territorial approach.

As a rule, the interaction of border regions reveals disproportions in the development of territories, factors of production inefficiently used in the economy of the region, which makes it possible to level these trends in the future. In this case, for the formation of the territorial basis of interaction, the coordination of market relations, the mechanisms of state regulation are primary.

Let's highlight the types of regional economic integration:

– interstate economic integration (free trade zones, customs unions, common market, economic union) [11], which eliminates barriers to trade with the implementation of various levels of measures to protect the domestic market;
– integration at the micro level, which is based on private foreign direct investment. One of the forms of interstate economic integration is cross-border cooperation.

Types of cross-border cooperation between regions aimed at developing relations between territorial-administrative units or authorities of bordering states through the conclusion of agreements in the socio-economic, scientific-cultural, natural-climatic sphere in order to realize the common interests of local governments can be two-, three- or multilateral cooperation:

– cross-border cooperation - between local authorities and self-government (public and private business entities can also be included in this context) in geographically adjacent territories. This also applies to territories separated by the sea;
– inter-territorial cooperation - between local authorities and self-government (public and private actors can also be included in this context) between non-contiguous territories;

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- transnational cooperation - cooperation between national, local authorities and self-government on transnational programs and projects. This form of cooperation covers large contiguous territories and includes entities from at least two EU member states and/or non-EU countries.

Thus, cooperation within the framework of adjacent territories of neighboring states can be called transboundary cooperation, that is, the presence of a border between cooperating territories is decisive. The basis of cooperation is the process of creating links and contractual relations in the border areas in order to find solutions to identical problems. It implements economic, political, environmental, cultural and educational types of international activities, which are carried out at the regional level and are distinguished by the general use of natural resources and the solution of security problems, wider mutual communication between the population of neighboring states and personal connections of people, a significantly higher burden on infrastructure (roads, communications, services, roadside infrastructure).

The basis of the institutional and economic relations of the regions are institutions , which are understood as "the rules of the game in society, or, to put it more formally, the restrictive framework created by man that organizes the relationship between people" [1 2 , p.17]

The institutionalized form of regional cooperation is especially relevant in connection with the leveling of differences through the application of generally accepted and legalized norms in the legal field, which affects the built algorithms of mutual activity, the overall development strategy, and the autonomy of decision-making. The level of institutionalization becomes the criterion for selecting the type of region.

The legal environment creates legal mechanisms for regulating the cooperation of regions, turning the daily practice of cross-border interactions into formalized institutions of cooperation.

At the initial stage, the most common forms of cooperation are agreements on trade and economic cooperation, concluded at the initiative of the regions. The basis for concluding agreements may be the stabilization of industrial relations, the expansion of cooperation in the scientific, technical and cultural spheres. The problematic point is the framework nature of such documents, because they often indicate areas and areas of cooperation, but there is no practical implementation. The second form is councils, working groups and commissions for cross-border cooperation, which are usually part of intergovernmental commissions , which makes it possible to unite "regional and national authorities of border states to solve important problems - delimitation and demarcation of the border, development of checkpoints and access roads to them, organization of transport communication, etc." [18, p.35]. The third form is cross-border cooperation programs. The validity period is 5-7 years. The purpose of developing programs is to strengthen the peripheral nature of the economy, eliminate the gap in production ties between economic entities and solve the demographic problems of the regions.

An analysis of the essential characteristics of regional integration unions shows the objective need to build their typology in order to develop a common development strategy for countries and regions for gradual integration into the world economy. The main types of regional economic integration include:

Free trading zone. This is the main form of economic cooperation. Member countries remove all barriers to trade among themselves, but are free to determine trade policy with non-member countries.

Customs Union. Priority in this case is given to economic cooperation, the removal of barriers to trade between member countries. The main difference from a free trade area is that members agree to treat trade with non-member countries in a similar way.

Common Market. This type allows the creation of economically integrated markets between member countries. Trade barriers are being removed, as are any restrictions on the movement of labor and capital between member countries, there is a common trade policy for trade with non-member countries. The main advantage is the openness of the labor market to the labor force of the member countries of the common market.

Economic Union. It is created with the intention of countries not only to remove barriers to trade, but also to follow a common economic policy.

To build a typology of regional integration unions based on the institutional and economic approach, taking into account evolutionary and territorial characteristics, we consider the following criteria [13, p.19]:

1. Development stages:

а) exchange of information, contacts at the level of regional and local authorities, conclusion of framework agreements;
б) foreign trade, formation of foreign trade infrastructure;
в) creation of joint ventures, institutions of coordination in various areas of cooperation;
г) micro-integration based on the formation of integrated local markets for goods, services, labor, technologies, etc.

2. The dominant level in the management of interregional and border relations. As a rule, there are national, regional and interstate levels of government. The national or regional level of government dominates.
3. Models of border and interregional relations:

а) traditional model: based on differences between countries and their regions (differences in prices for goods, exchange rates, etc.);
б) preferential model: based on a set of preferences within a certain territory, for example, a border area (tariffs, tax and financial and credit benefits), or in order to stimulate links in certain areas;
в) partnership model: based on the principles of administrative and political decentralization, which is embodied in the special powers of local authorities, as well as joint mechanisms for solving common problems of the territory.

4. Degree of institutionalization of cross-border cooperation:

а) Euroregion. The most common form of cooperation between cross-border regions, covering the adjacent border areas of states that are distinguished by a certain economic, socio-cultural, ethnic unity;
б) free economic zones;
в) technopark.

Regional cooperation is associated not only with geographical characteristics, but also with functional, sectoral and institutional planes, which also influence the regional and contribute to the free movement of goods, services, capital and people. We propose the following approach to identify institutional and economic types of regional integration cooperation based on the above criteria: framework integration, surface integration; rational integration.

Framework integration is based on weak expression of cooperation institutions. The leading type of interaction is regional trade agreements to eliminate tariff barriers and the development of border trade. The main areas of cooperation are related to agreements regulating the regime and arrangement of the border, and the prevention of border incidents. Agreements, with the exception of those related to trade liberalization, are devoid of specific commitments and are limited to declarations of intent.

Superficial integration is typical for regions (states) that are heterogeneous in terms of economy, social and state structure. Integration is based on market mechanisms with a high level of sovereignty between the members of the association. Regional trade agreements are concluded, including long-term directions on trade in services, investment, competition and public procurement. Integration takes on some features of the common market by focusing on regulatory issues and dispute resolution mechanisms. A trading bloc can be created on the basis of free membership with subsequent institutional reorganization into a free trade zone.

Rational integration of regions is institutionalized cooperation between member regions. It implies the presence of certain features (although, perhaps, not fully formed) - a common market or a monetary union. A market approach with a rigid institutional framework and a supranational formation is characteristic.

Conclusion

The current stage of development of the world economy is characterized by signs of increasing deglobalization, which will inevitably lead to a change in the architecture of sustainable development management as a doctrine adopted by most countries of the world community. More and more researchers suggest that in the near future cooperation between countries will gravitate towards regional cooperation. In this situation, it becomes relevant for Belarus to identify strategic partners and design the architecture of cross-border cooperation, which leads to the need for more scientific approaches to its development. Understanding the charac-

teristics and challenges of modern regionalism is becoming increasingly fundamental, given that the influence of recent economic and political factors has demonstrated the need for more effective regional responses. The study showed the specific phenomenological nature of economic development as a basic concept for determining the conditions for the development of cross-border regions and, on this basis, a typology of regions, the essence of which is considered within the framework of evolutionary and revolutionary approaches and is based on the concepts of globalization and regionalization. An institutional-economic approach is proposed that takes into account the interaction of socio-economic and organizational-economic relations and their connection with the productive forces of the region. To build a typology of regional integration unions based on the institutional and economic approach, taking into account evolutionary and territorial characteristics, the following criteria are considered: the stage of development, the level in the management of interregional and border relations, the mechanism for the formation of border and interregional relations, the degree of institutionalization of cross-border cooperation. Based on the above criteria identified institutional and economic types of regional integration cooperation: framework integration, surface integration; rational integration.

In the current geopolitical environment and increasing deglobalization, more and more attention is being shifted to regional integration. For Belarus, the closest integration is characteristic of the Russian Federation. The authors draw the following conclusions: the development of integration at the regional level provides a triad of sustainable development: economy - social sphere - ecology ; in terms of the impact of economic integration, there is a need to reduce restrictive protectionist measures in the field of economic integration, mechanisms to improve the efficiency of regional economies and reach a new level of development in the framework of achieving sustainable development goals by creating efficient supply chains and strengthening industrial cooperation between the countries included in the integration ; a deeper economic integration of the Russian Federation and the Republic of Belarus is expedient for the sustainable development of national societies.

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FACTORS INFLUENCING THE GEOGRAPHICAL DISTRIBUTION OF POLLUTION INTENSIVE INDUSTRIES

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Abstract

The paper has verified the hypotheses and theories about the location selection of pollution-intensive industries from various perspectives and explored possible factors influencing the geographical distribution of pollution-intensive industries. Based on the pollution intensity index of each industry, we firstly identified the pollution-intensive industries in China. And the geographical distribution of intensive industries is analysed in terms of the proportion of industry, the industry output value and the number of enterprises. With the regression analysis, the factor endowment, environmental regulation and globalization are proven factors influencing the geographical distribution of pollution-intensive industries.

Keywords: pollution-intensive industries, geographical distribution, pollution intensity index, environmental regulation, globalization.

ФАКТОРЫ, ВЛИЯЮЩИЕ НА ГЕОГРАФИЧЕСКОЕ РАСПРЕДЕЛЕНИЕ ЗАГРЯЗНЯЮЩИХ ПРОМЫШЛЕННОСТЕЙ

Т. Г. Зорина, **Лю Сюэяо**

Реферат

В статье проверены гипотезы и теории о выборе местоположения загрязняющих отраслей с различных точек зрения и исследованы возможные факторы, влияющие на географическое распределение загрязняющих отраслей. Основываясь на индексе интенсивности загрязнения каждой отрасли, мы сначала определили отрасли, интенсивно загрязняющие окружающую среду в Китае. Географическое распределение интенсивно загрязняющих отраслей проанализировано с точки зрения доли промышленности, стоимости выпуска продукции отрасли и количества предприятий. Регрессионный анализ показал, что обеспеченность факторами производства, экологическое регулирование и глобализация являются факторами, влияющими на географическое распределение загрязняющих производств.

Ключевые слова: загрязняющие отрасли, географическое распределение, индекс интенсивности загрязнения, экологическое регулирование, глобализация.

Introduction

The other side of rapid economic development is usually resource exhaustion caused by excessive consumption and environmental disruption due to pollution. The tradeoff between economic development and ecological security is a hard one that cannot be avoided in all countries. There has been an evolution from resource-consuming to productivity-driven in the industrialisation in countries around the world. This process manifests itself geospatially in the evolution of a gradient transfer of industrial structure. Therefore, the factors influencing the gradient transfer of industrial structure of pollution-intensive industries in the industrialization have become an important topic in various countries, and many theories and hypotheses already are produced.

The factor endowment hypothesis suggests that comparative advantage arises mainly from relative factor endowment. And pollution-intensive industries are often also capital-intensive or resource-intensive. Therefore, they tend to be located in areas rich in capital and resource. The pollution haven hypothesis believes that environmental regulation exerts an important effect on the geographical distribution of pollution-intensive industries. Regions with lower environmental standards have a comparative advantage. As gross regional product is highly correlated with the intensity of environmental regulation, the pollution-intensive industries, in the process of industrialisation, tend to aggregate in less developed areas with weaker environmental regulation. In addition, there are theories that both transport costs and economies of scale are likely to be factors influencing the geographical distribution of pollution-intensive industries in the context of globalisation.

With the numerous theories and hypotheses, it is clear that a variety of factors could influence the geographical distribution of pollution-intensive industries. The study on factors influencing the geographical distribution of pollution-intensive industries will help to realise the transformation from resource-consuming to productivity-driven in the process of industrialisation, and ultimately to eliminate the contradiction between environmental pollution and resources and economic development. [1-3]

Identification of pollution-intensive industries

In this paper, the pollution intensity index of each industry is calculated by combining two indicators, the discharge intensity of pollution and the discharge scale of pollution. The pollution intensity index is used to classify industries and to define the pollution-intensive industries in China at this stage.

$$I_{ij}=\frac{E_{ij}}{P_i} \quad (1)$$

I_{ij} – the discharge intensity of pollution j in the industry i; E_{ij} – the emission of pollution j in the industry i; P_i – total profit of industry i

$$S_{ij}=\frac{E_{ij}}{E_j} \quad (2)$$

S_{ij} – the discharge scale of pollution j in the industry i; E_{ij} – the emission of pollution j in the industry i; E – the total emission of pollution j

$$P_i=I_{ij}*S_{ij} \quad (3)$$

P_i- the pollution intensity index of industry i

The pollution intensity indices of waste water, waste gas and solid waste for each industry are calculated according to the normalised formulae (1)(2)(3). And weighted sum method was used to obtain the comprehensive pollution intensity index for each industry. [4]

In this paper, 41 industrial sectors in China are studied. The comprehensive pollution intensity index for each sector is calculated based on data on sulphur dioxide emission, nitrogen oxides emission, particulate matter emission concerned with air pollution, COD discharged and ammonia nitrogen discharged concerned with water pollution, and industrial solid wastes generated for each sector in 2019. Based on the mean and the tri-sectional quantiles of the comprehensive pollution intensity index, the categories are classified as high pollution, medium pollution and low pollution. And there are 11 pollution-intensive industries with characteristics of high pollution in China at this stage, as shown in the table 1.

Table 1 – Pollution-intensive industries and their pollution intensity index

Category	Industry	Pollution Intensity Index
High Pollution	Manufacture of Non-metallic Mineral Products	0.4100
	Processing of Food from Agricultural Products	0.2385
	Production and Supply of Electric Power and Heat Power	0.2254
	Smelting and Pressing of Ferrous Metals	0.2221
	Manufacture of Raw Chemical Materials and Chemical Products	0.1472
	Mining and Processing of Non-Ferrous Metal Ores	0.1410
	Manufacture of Paper and Paper Products	0.1266
	Mining and Processing of Ferrous Metal Ores	0.1221
	Smelting and Pressing of Non-ferrous Metals	0.1093
	Manufacture of Textile	0.1055
	Mining and Washing of Coal	0.0537

Geographical distribution of pollution-intensive industries

During the process of industrialisation, the distributional pattern of China's manufacturing industry has evolved from scattered and diversified to concentrated and specialised. Moreover, the geographical distribution of pollution-intensive industries is influenced by a variety of factors such as factor endowment, globalisation and environmental regulations.

From the perspective of the proportion of industry, the geographical distribution of pollution-intensive industries shows unbalanced characteristics. The proportion of pollution-intensive industry is clearly higher in less economically developed and remote regions such as Qinghai, Yunnan, Ningxia or resource-based regions such as Shaanxi, Shanxi, Xinjiang, Inner Mongolia. In contrast, the proportion of pollution intensive industries is significantly lower in economically developed regions or regions without resource endowment, such as Shanghai, Hainan, Beijing, and Tianjin. In addition, some coastal areas also have a high proportion of pollution-intensive industries, such as Shandong, Zhejiang, Jiangsu.

The proportion of pollution-intensive industries in China by province in 2019 are shown in Figure 1. From the figure, it can be tentatively seen that the geographical distribution of pollution-intensive industries is largely consistent with the factor endowment hypothesis, pollution haven hypothesis and the conjecture, that transport cost and international trade in the context of globalisation could influence the geographical distribution of pollution-intensive industries.

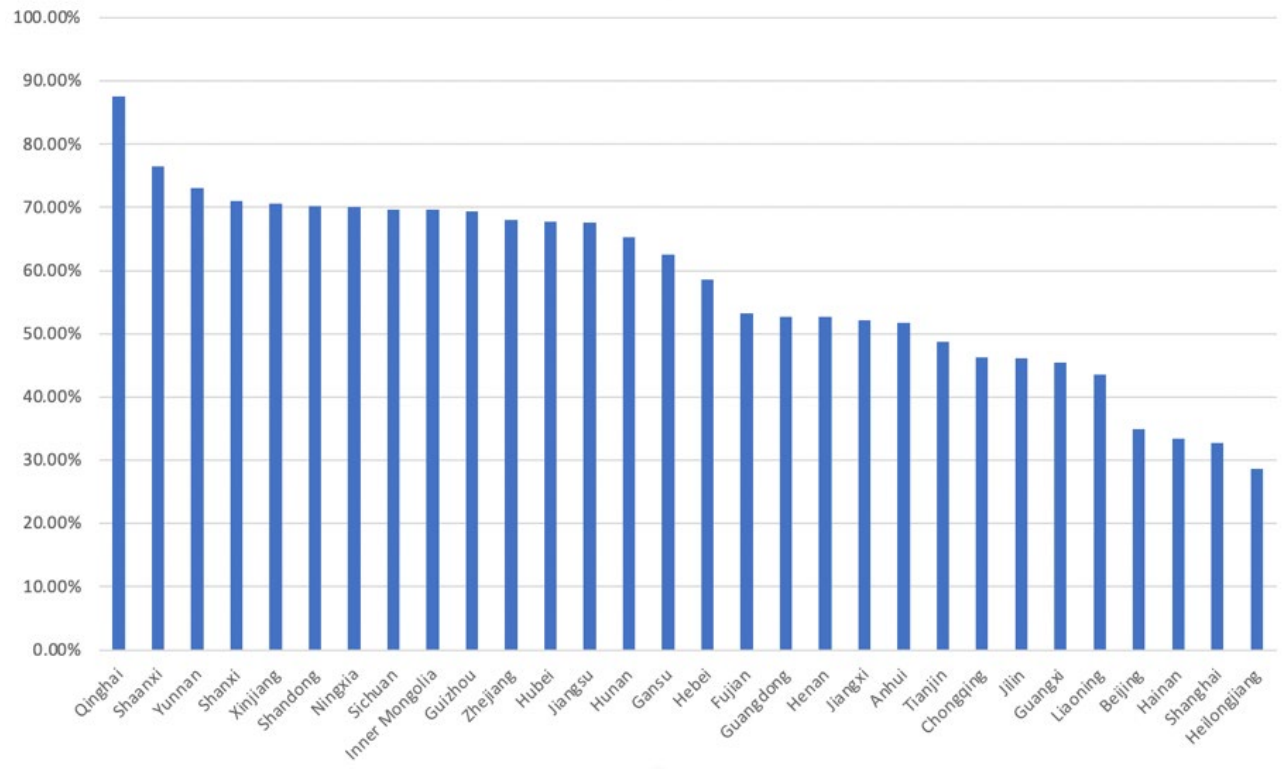

Figure 1 – Proportion of pollution-intensive industries

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From the perspective of industry output value, there exist clear tendency and characteristics in the geographical distribution of pollution-intensive industries. Figure 2 shows a map based on the output value of pollution-intensive industries by province in China in 2019. As we can see, a high output value of pollution-intensive industries come up in most regions in China. Some of the less developed and remote regions such as Qinghai, Yunnan and Ningxia, and resource-based regions such as Shanxi and Xinjiang, which have a high proportion of pollution-intensive industries, in fact do not have a high output value of pollution-intensive industries. Possible reasons for this are their underdeveloped economy and the fact that the secondary industry dominate the industrial structure.

Some of the provinces with resource endowment still rely on their huge resource advantages. The tertiary industry, which causes less pollution and has great potential for output, has not been fully developed in these regions. These have resulted in a large proportion of pollution-intensive industries in these regions but with low gross output. Moreover, pollution-intensive industries intend to be located in central China or coastal areas. As what we learn from the analysis from the perspective of the proportion of industry, the data on industry output value also show that the pollution-intensive industries tend to aggregate in the coastal areas with convenient transportation and developed economy.

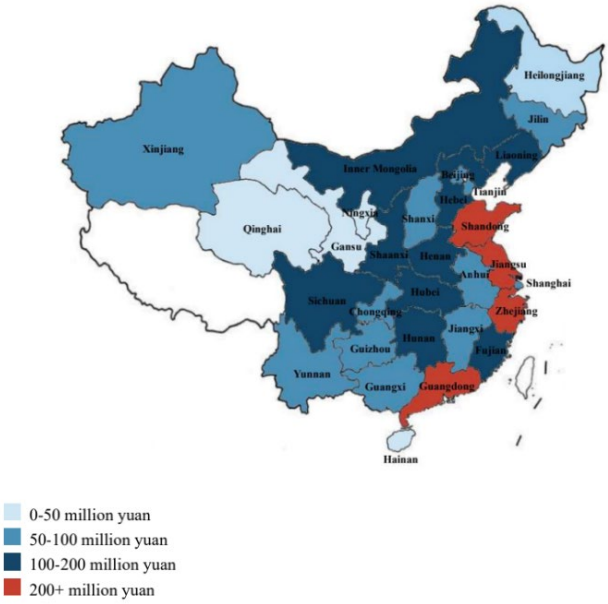

Figure 2 – Output value of pollution-intensive industries

From the perspective of number of the enterprise, the geographical distribution of pollution-intensive industries is highly consistent with the analysis from the perspective of industry output value. Figure 3 shows a map based on the number of enterprises in pollution-intensive industries by province in China in 2019. It shows that the number of enterprises in pollution-intensive industry varies considerably from region to region. A large number of pollution-intensive enterprises are clustered in central China or coastal areas. The marginal provinces and autonomous regions have fewer enterprises in pollution-intensive industries. This is consistent with the results obtained from the above analysis from the perspective of industry output value. Based on the number of enterprises in pollution-intensive industries, a clustering arises in Shandong, Zhejiang, Jiangsu, and Guangdong. As these provinces are economically developed and with strategic location, it is also reasonable to assume that factors such as the capital agglomeration, the convenient transportation and the proximity to external markets in the context of globalisation could be responsible for the concentration of pollution-intensive industries in these areas. [5,6]

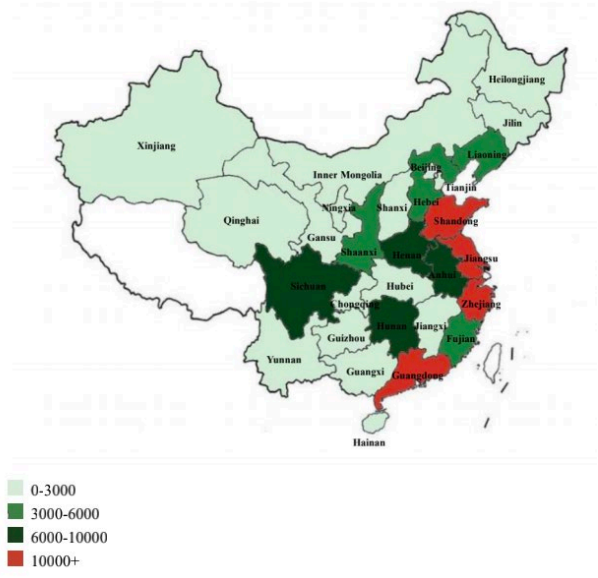

Figure 3 – The number of the pollution-intensive enterprise

Factors influencing the geographical distribution of pollution-intensive industries

To further explore the possible factors influencing the geographical distribution of pollution-intensive industries in China at this stage, the regression analysis is conducted to verify the correlation between factor endowment, environmental regulation, globalization and the number of enterprises in pollution-intensive industries with the data in 2019. The results are shown in Tables 2, 3 and 4.

Table 2 – Regression analysis on factor endowment

Model: Factor endowment	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson	F	Sig.
	.840a	0.706	0.671	2263.91662	1.695	20.01	.000b
Coefficients		Unstandardized Coefficients		Standardized Coefficients	Sig.	Collinearity Statistics	
		B	Std. Error	Beta		Tolerance	VIF
	(Constant)	-2955.983	3741.507		0.437		
	Total Factor Productivity	-14.52	1460.019	-0.001	0.992	0.909	1.1
	Total Investment	0.19	0.026	0.81	0	0.931	1.075
	Average Wage	0.05	0.043	0.13	0.257	0.94	1.063
a Dependent Variable: Number of pollution-intensive industries							

According to the table 2, we prove that the linear regression model between factor endowment and the number of enterprises in pollution-intensive industries holds true. The factor endowment could legitimately explain the location selection of pollution-intensive industries. The location selection of pollution-intensive industries is positive correlation with the total investment.

Table 3 – Regression analysis on environmental regulation

Model: Environmental regulation	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson	F	Sig.
	.750a	0.563	0.490	2818.06939	1.912	7.719	.000b
Coefficients		Unstandardized Coefficients		Standardized Coefficients	Sig.	Collinearity Statistics	
		B	Std. Error	Beta		Tolerance	VIF
	(Constant)	-4095.127	3598.069		0.266		
	Capacity Of Industrial Waste Water Treatment	3.651	0.978	0.567	0.001	0.790	1.266
	General Solid Waste Utilization Rate	8458.968	3119.303	0.358	0.012	0.904	1.107
	Hazardous Solid Waste Utilization Rate	45.485	4117.010	0.002	0.991	0.855	1.170
	Capacity Of Industrial Waste Gas Treatment	.000	0.001	0.046	0.756	0.839	1.192
a Dependent Variable: Number of pollution-intensive industries							

According to the table 3, we prove that the linear regression model between environmental regulation and the number of enterprises in pollution-intensive industries holds true. The environmental regulation could explain to a great extent the location selection of pollution-intensive industries. There is a notable correlation between industrial waste water treatment, general solid waste utilization rate and the number of enterprises in pollution-intensive industries. And the correlations between them are all positive. The industrial waste water treatment has a weaker correlation with the dependent variable than the general solid waste utilization rate. [7]

Table 4 –Regression analysis on globalization

Model: Globalization	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson	F	Sig.
	.758a	0.574	0.541	2672.04294	1.941	17.52	.000b
Coefficients		Unstandardized Coefficients		Standardized Coefficients	Sig.	Collinearity Statistics	
		B	Std. Error	Beta		Tolerance	VIF
	(Constant)	2694.525	876.872		0.005		
	Export Delivery Value	0.166	0.032	0.727	0	0.853	1.173
	Minimum Distance To The Port	-0.521	0.993	-0.073	0.604	0.853	1.173
a Dependent Variable: Number of pollution-intensive industries							

According to the table 4, we prove that the linear regression model between globalization and the number of enterprises in pollution-intensive industries holds true. Globalization can significantly influence the location selection of pollution-intensive industries. And the location selection of pollution-intensive industries is positively correlated with the international market potential included in globalization.

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The above analysis shows that factor endowment, environmental regulations and globalisation are all correlated with the number of enterprises in pollution-intensive industries in a region. In other words, factor endowment, environmental regulations and globalisation could influence the location selection of pollution-intensive industries in China at this stage. Moreover, as industrialisation continues, the preference according to these factors will become the dominant choice for the establishment of new pollution-intensive enterprises. This would, to some extent, result in a geographical concentration of pollution-intensive industries. They will be concentrated in areas with intensive capital factors, weak environmental regulations and huge potential to international markets. Coastal areas with developed economies and frequent external contacts will be popular choices.

Conclusion

This paper verifies the hypotheses and theories about the location selection of pollution-intensive industries from various perspectives and explored possible factors influencing the geographical distribution of pollution-intensive industries.

To ensure the reliability of the study, 11 pollution-intensive industries are identified based on their comprehensive pollution intensity index calculated. On this basis, subsequent analysis was carried out. According to the data from various Chinese provinces, the geographical distribution of pollution-intensive industries follows the same trend from the perspective of the proportion of industry, the industry output value and the number of the enterprise. They tend to be located in the heartlands or coastal areas, in particular in the provinces Shandong, Zhejiang, Jiangsu and Guangdong. These four provinces are the most popular locations for pollution-intensive enterprises from any perspective. In addition, the regression model is applied to further substantiate the possible factors influencing the geographical distribution of pollution-intensive industries. The results prove that factor endowment, environmental regulation and globalization were all identified as important factors influencing the geographical distribution of pollution-intensive industries. Further, the geographical distribution of pollution-intensive industries is significantly correlated with the capital element belonging to the factor endowment, with the industrial waste water treatment and the general solid waste utilization rate in environmental regulation, and with the international market potential contained in globalization. These factors combine to influence the geographical distribution of pollution-intensive industries in China at this stage. It also proves the reliability of the factor endowment hypothesis, the pollution haven hypothesis and the trend of industrial location selection under the effect of internationalisation.

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