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Economic assessment and forecasting of the social component of man-made damage in the national economy

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Abstract. In order to study the social component of man-made damage in the national economy, an expert model for establishing levels of technogenic morbidity of the population of Ukraine, due to the destructive influence factors (emissions, discharges, waste), have been built by means of fuzzy logic in this paper. The economic evaluation and prediction of the social component of man-made losses – cost of treating patients with tumors due to environmental pollution have been conducted. In the national economy these results should be considered in the formation of public expences on health care and the treatment of patients. This will increase the effectiveness of state regulation of the phenomenon, provide appropriate allocations for their eradication and compensation.

Key words: man-made damage, the national economy, economic evaluation, forecasting, technogenic morbidity.

INTRODUCTION

The problem of studying the social component of man-made damage to the national economy is directly related to the problems in the theoretical foundations of economic evaluation and prediction under conditions of incomplete data and uncertainty of the future. Study of the problems is also hampered by the need for assessment of anthropogenic indirect anthropogenic losses caused by factors of destructive influence of economic activity. Considering the impact of anthropogenic activity (emissions, discharges, waste) on changes in social indicators of social development (incidence, life expectancy, mortality, etc.) is challenging and, yet, important (relevant) problem in the economics and management of the national economy.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Work on the theory of economic damage caused by the economic activity of enterprises engaged many researchers from all over the world. The research of recent publications confirms that a significant contribution in this direction was made by the following list of Ukrainian scientists [1-6]: O. Amosha, O. Balatskiy, B. Burkynskyi, Ya. Vytvytskyi, V. Geets, B. Danilishin, S. Illyashenko, O. Kuzmin, L. Melnyk, I. Nyedin, Yu. Stadnitskii, Yu. Tunytsya, Ye. Khlobystov, V.Shevchuk and many more.

The analysis of scientific sources and publications shows that scientists in Ukraine and in the whole world pay little attention to the investigation of the social component of man-made damage to the national economy and their economic evaluation and forecasting at the state level, despite the urgency of the problem. The complexity of the phenomenon is caused by the processes that take place under conditions of uncertainty and incomplete information. Thus, to describe them and get proper results in national economy we should use the methods and models of fuzzy set theory and means of neural networks. The successful use of the fuzzy sets in prediction and modeling of socio-economic and ecological-economic systems were made by such scientists as [7-9] T. Klebanova, O. Melnyk, O. Moroz and others. However, the unresolved problem of the

general study of the effects of anthropogenic impact on the recipients of environmental, economic and social subsystems is to build a mathematical model of economic evaluation and prediction of the social component of man-made damage to the national economy.

OBJECTIVES

The research of theoretical foundations and applied problems of economic evaluation and forecasting the social component of man-made damage to the national economy lead to the formulation of the following purposes: to build by means of fuzzy logic an expert model for establishing levels of technogenic morbidity of the population of Ukraine, due to the destructive influence factors (emissions, discharges, waste); to conduct the economic evaluation and prediction of the social component of man-made losses – cost of treating patients with tumors due to environmental pollution.

THE MAIN RESULTS OF THE RESEARCH

The perception indicators of destructive effects of economic activity describe the social component of man-made damage. In each of the subsystems of the national economy the corresponding indicators are changing under the influence of impact factors. Thus, in the subsystem of population the following indicators change: the level of disease, the mortality rate among the various categories of the population, birth rate, population size, its structure, etc.; in nature subsystem: the level of afforestation areas, the quality of agricultural land quality recreational areas, pollution, ecosystem threshold of perception, etc.; in the economy subsystem: the level of fixed assets, infrastructure, transport, communications, utilities and more.

Economic evaluation of relevant changes of perception depends on the state of the national economy, the level indicators that directly characterize the state of the economic subsystem itself. The structure parameters characterizing the economy mainly include: GDP per 1 person, the average size of national income produced by one worker for 1 day, the cost of maintenance of housing, urban and rural infrastructure, public transport per 1,000 people The average value in the national economy per unit of output, the average cost of maintenance of capital assets. The structure parameters describing social development include: the average costs for one day for a letter of disability for 1 employee, average medical costs for 1 day for 1 patient, etc. The set of indicators describing the state activities using and protecting the environment include: the average cost per unit of waste discarded figures on environmental taxes, the cost of environmental protection, etc.

As Database for the study of factors of anthropogenic losses were statistics impact of human activities on the environment, which the author collected from relevant sources of statistical information presented in an open statistical basis of the State Statistics Committee of Ukraine on its website (http://www.ukrstat.gov. ua). The evolution of the anthropogenic load for the period of 1990–2012 , which describe factors change the destructive impact of economic activity on the environment Ukraine, presented in Table. 1.

It is important to take into account the scale of the national economy in the economic evaluation of man-made damage, so we recommend working better with specific values of these indicators, and sometimes from their increments. Thus, the dynamics of perception factors is presented in Table. 2 in accordance with the values of specific rates of newly reported cases in the 1990–2012.

In previous studies of the authors [10, 11], there has been established the essence of the concepts of man-made damage and man-made losses, constructed a concept of economic evaluation of man-made damage to the national economy and the necessity for the application of fuzzy sets as an effective mathematical tool for economic evaluation of man-made damage to the national economy.

From existing indicator array of impact factors (tabl.1) and perception factors (tabl. 2) we can select those statistical series, which according to the experts have a direct contact with each other.

Economic losses to the national economy due to air pollution were studied under the guidance of prof. Balatskiy O.F. [12], which included core losses, expenses for environmental protection, as well as damage to human health, which led to lower productivity and more. Interesting research has been made by Kubatko O.V. [13], where a representative of the Sumy school simulates the impact of air pollution on public health. The researcher found that the excess of permissible concentrations of nitric oxide in the air can cause irreversible changes in the health of people, particularly in the increasing number of diseases. Also there has been found that pollution of water and air basins increased and can lead to the emergence of irreparable damage, when it is not possible to restore homeostasis level socio-natural systems.

Researchers at the European eco-economic school, according to de-Brian [14], considered that the problem of growth of diseases among population and the deterioration of fixed assets (metal corrosion, reducing operating time of equipment, etc.) should also include reduction of the effectiveness of natural resources due to the loss of acid rain , climate change, etc.).

Repeatedly researchers in Ukraine and the world have tried to establish the proportion of the environmental component of morbidity and mortality.

However, establishing dependence of the morbidity of the deterioration of the environment is an extremely challenging task. For example, in work [15] researchers believe that losses from deteriorating of health due to environmental pollution should be calculated at a ratio of 50-40-10, where 50 % of all human diseases are caused by the way of life, 40 % – heredity and the environment, and only 10 % – dependent on the level of medicine in the state.

More thorough studies have been conducted in work [16] where it has been determined the impact of income, providing medical staff, air pollution and ionization area of the Chernobyl accident on human health in the regions of Ukraine. In this work it has been demonstrated that disease of endocrine system (thyroid disease) increased by 30% due to increased exposure to 30 cGy.

The stated problem required from the authors to processing of large arrays of frequently conflicting data. This fact made it impossible for finding correlations between the factors of anthropogenic pollution and morbidity and mortality and, consequently, economic losses. Given these circumstances the authors propose to apply the theory of fuzzy sets and fuzzy logic.

The creator of this theory, American scientist Lofty Zadeh (L.A. Zadeh), predicting the future management theory, in [17] claimed that the theory "must provide a smaller mathematical strictness and precision and to pay more attention on the development of qualitative and approximate solutions to the pressing problems of the real world". Fuzzy logic is often perceived by many experts on mathematical modeling of economic processes as a means of taking only approximate solutions. However, experience has shown that establishing fuzzy knowledge base allows to achieve precision simulation that is not inferior to strict proportion. In the case of inaccurate and inconsistent data, but with the knowledge and experience of experts in the relevant field, this theory is the only possible tool to establish causation and prediction of possible recommendations for making effective decisions. Extraordinary benefits of this simulation it is the possibility of self-improvement like the human brain.

Table 1. Dynamics of factors of the destructive influence of the economic activity according to the indicators of technogenic impact in environment Ukraine in 1990–2012*

Year	Emissions of sulfur dioxide, t	Emissions of nitrous oxide, t	Emissions of carbon dioxide, million t	Emissions of contaminants, thous. t	Volume discharges million m^3	Volume of waste generation (I-III class), thous. t
1990	2782,3	760,8	…	15549,4	470	…
1991	2537,9	989,8	…	14315,4	701	…
1992	2376,2	830,2	…	12269,7	951	…
1993	2194	700,1	…	10015	1196	…
1994	1715	567,6	…	8347,4	1053	4955,8
1995	1639,1	530,3	…	7483,5	912	3562,9
1996	1292,6	466,6	…	6342,3	980	3150,9
1997	1132,4	455,2	…	5966,2	763	3161,4
1998	1023	444,5	…	6040,8	813	2454,1
1999	1026,1	436,6	…	5853,4	748	2820,4
2000	984,8	440,6	…	5908,6	758	2613,2
2001	992,1	452	…	6049,5	746	2543,3
2002	1032,6	435,7	…	6101,9	782	1728,8
2003	1046,3	477,9	…	6191,3	804	2436,8
2004	988,5	471,9	126,9	6325,9	758	2420,3
2005	1132,8	523,9	152	6615,6	896	2411,8
2006	1347,2	515,1	178,8	7027,6	1427	2370,9
2007	1342,6	641,9	218,1	7380	1506	2585,2
2008	1320,6	642	209,4	7210,3	616	2301,2
2009	1262,7	562,1	185,2	6442,9	270	1230,3
2010	1235,2	603,7	198,2	6678	312	1659,8
2011	1363,4	633	236	6877,3	309	1434,5
2012	1430,3	634,6	232	6821,1	292	1368,1

** Built and designed by the author according to the State Statistics Committee of Ukraine website (... – no stats)*

Table 2. The dynamics of perception factors for specific values of parameters of newly reported cases of diseases in Ukraine in 1990–2012 , inst. / thous. people*

Years	Total of di-seases	Tu-mors	Diseas-es of the ner-vous system	Diseas-es of the blood circu-lation system	Raspi-ratory system deseases	Diseas-es of the skin and subcu-taneous tissue	Diseases of the musculo - skeletal system and con-nective tissue	Diseases of the genitouri-nary system	Congenital anomalies (malformat-ions), deformat-ions and chromosomal abnorma-lities	Injury, poisoning and certain other consequences of external causes
1990	620,93	5,98	50,93	22,16	328,35	34,70	26,51	23,61	0,79	55,29
1992[1]	638,04	6,40	57,73	27,12	311,70	38,40	29,37	28,03	1,00	57,98
1993	647,59	6,35	58,28	27,03	319,10	38,99	29,53	29,08	1,03	55,09
1994	603,58	6,29	58,03	26,88	278,21	40,97	27,61	28,57	0,94	51,89
1995	629,19	6,32	58,71	26,87	303,60	41,45	27,37	29,85	0,91	51,17
1996	588,12	6,53	59,79	27,53	257,73	40,74	27,90	31,64	0,97	50,74
1997	613,12	6,85	61,08	29,46	278,03	40,36	29,04	33,67	1,04	48,88
1998	634,77	7,39	66,13	33,55	275,50	42,13	31,76	37,34	1,17	48,94
1999	660,26	7,65	15,37	39,06	290,18	40,81	31,01	37,78	1,22	48,10
2000	677,14	7,73	15,13	47,30	296,16	40,38	31,78	39,23	1,25	47,32
2001	678,45	8,05	15,23	48,73	290,52	41,04	32,56	41,88	1,21	45,77
2002	665,19	7,88	15,44	48,91	275,96	40,24	32,98	42,08	1,18	46,31
2003	678,80	8,23	15,64	49,70	288,21	39,89	32,75	43,27	1,12	47,85
2004	683,98	8,53	15,85	52,45	283,71	40,25	33,79	45,21	1,15	47,14
2005	696,10	8,63	15,95	51,40	293,86	40,95	33,84	46,21	1,12	47,88
2006	686,99	8,82	16,28	51,80	283,57	40,61	34,03	46,28	1,13	48,78
2007	703,32	8,73	16,12	52,24	298,98	41,85	33,64	45,71	1,09	48,96
2008	700,13	8,76	16,24	53,44	294,81	41,21	33,79	46,06	1,10	48,80
2009	715,85	8,82	16,34	52,51	314,84	40,96	33,46	46,38	1,13	46,90
2010	719,71	9,09	16,32	52,00	317,54	41,79	33,33	46,52	1,13	48,23
2011	707,34	9,24	16,25	51,25	309,05	41,09	32,55	45,76	1,20	46,66
2012	682,87	9,49	15,87	50,80	289,70	40,58	31,67	44,86	1,18	46,90

** Built and designed by the author according to the State Statistics Committee of Ukraine website*

[1] Data for 1991 in Ukraine there are no statistical basis

The proposed model is determining the level of technologenic morbidity Ukraine sets by means of fuzzy logic relationship between indicators of destructive influence factors and indicators of the perception factors. The structure of the parameters of destructive impact factors includes n-indicators of anthropogenic activity (Table 1) and of the parameters of perception factors includes m-indicators of the level of morbidity population of Ukraine (specific value of number of newly reported cases of a particular disease (Table 2)).

Let's conduct the formalization of the considered problem as the object with n-inputs and m-outputs (1):

$$\begin{cases} y_1 = f(x_1, x_2, ..., x_n) \\ y_2 = f(x_1, x_2, ..., x_n) \\ \quad ... \\ y_m = f(x_1, x_2, ..., x_n) \end{cases}, \qquad (1)$$

where: $x_1, \ldots, x_n$ – a set of input variables; $y_1, \ldots, y_m$ – a set of the output variables.

Detailed construction of a mathematical model of fuzzy expert system is described in previous papers of the authors [10]. Here is only the necessary notation to describe quantitative variables transferred in linguistic terms: $U_i = [\underline{u_i}, \overline{u_i}]$, $i = \overline{1,n}$, $Y_j = [\underline{y_j}, \overline{y_j}]$, $j = \overline{1,m}$, where $\underline{u_i}, \overline{u_i}$ is the smallest and the largest possible value of variables x_i; $\underline{y_j}, \overline{y_j}$ is the smallest and the largest possible value of the output variables y_j.

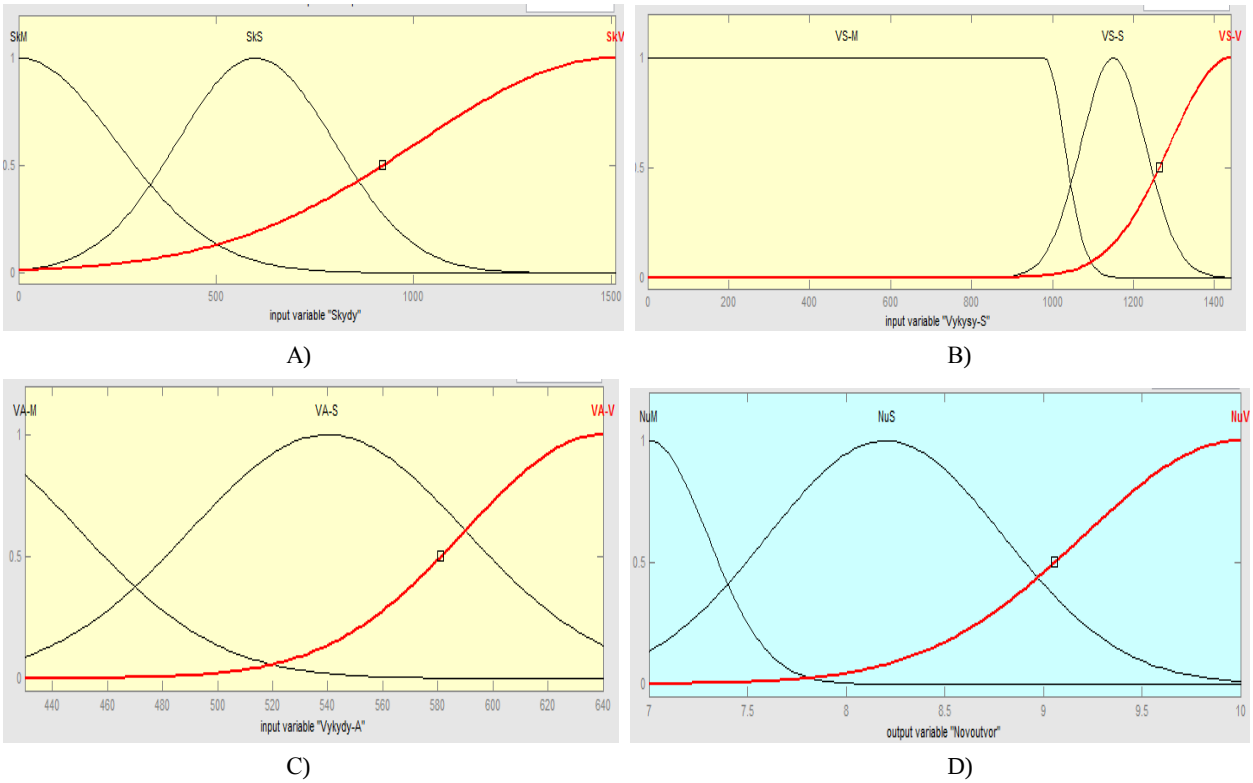
After constructing fuzzy knowledge database, which is represented in the formalized form of a grid system of fuzzy decision knowledge rules, decision-making $d_j^* jD\{d_{j1}, d_{j2}, \ldots, d_{jm}\}$, , which corresponds to a fixed vector of values of input variables $x^* = (x_1^*, x_2^*, \ldots, x_n^*)$, is carried out according to the fuzzy inference by Mamdani [18, 19]. To obtain accurate numbers y_j^* from the interval $[\underline{y_j}, \overline{y_j}]$, corresponding fuzzy output, it is offered at the center of gravity method [20].

These distinct values y_j^* determine the levels of morbidity in Ukraine due to the destructive influence of factors (emissions, discharges, waste and radiation background) for each disease. In other words, they determine the levels of technogenic morbidity. This result allows evaluating the economic social component of man-made damages – the cost of treating patients in Ukraine, a disease of which is caused by technogenic factors of destructive influence.

A validation of the proposed model to determine the level of technogenic morbidity in Ukraine in tumors has been conducted. Among the analyzed data in accordance with the recommendations of the experts the most significant impact on the number of newly reported cases of tumors is cased by the outstanding amounts of untreated polluted water, total emissions of sulfur dioxide and nitrogen oxide from stationary and mobile

sources. This greatly simplified the development of an appropriate knowledge base in fuzzy expert system for establishing interdependencies between the magnitude of discharges x_1 (removal of untreated polluted water in million m^3), sulfur dioxide emissions x_2 (total emissions from stationary and mobile sources in tonnes) and nitrogen oxide emissions x_3 (total emissions from stationary and mobile sources in tonnes) on the number of fixed tumors (per 1,000 citizens of Ukraine) $\boldsymbol{y_1}$. Using the statistical data presented in Table 1 and Table 2, we define the universal sets of input variables described for x_1, x_2, x_3 and output $\boldsymbol{y_1}$, respectively: $U_1=[0;1500]$, $U_2=[0;1450]$, $U_3=[400;640]$, $U_4=[7;10]$. For each input and output variables we built term-sets: $A_i=\{$*"small"*, *"medium"*, *"large"*$\}$, where $i=\overline{1,4}$.

The proposed model uses Gaussian membership function of two types (symmetric, asymmetric) for the terms of input and output variables, the type of which is shown in Figure 1. To solve the partial problem experts constructed a fuzzy knowledge base presented in Table 3.



A) B)

C) D)

Fig. 1. Aspects of the functions of linguistic variables "Discharges" (A), "Emissions of sulfur dioxide" (B), "Emissions of nitrous oxide" (C), "tumors" (D)*

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Table 3. The fuzzy knowledge base of the studied task*

Number of logical rules	Input variables			weight	Output variable
	x_1	x_2	x_3	w	y_1
1	M	S	S	0.9	S
2	L	S	S	0.6	M
3	M	S	M	0.9	M
4	L	S	M	0.7	M
5	L	M	S	0.7	M
6	L	M	M	0.4	M
7	L	L	M	0.6	L
8	L	M	L	0.7	M
9	L	L	L	0.9	L
10	M	M	M	0.6	M
11	M	L	L	0.6	L
12	S	L	L	0.9	L
13	M	L	M	0.6	L
14	L	L	M	0.4	M

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In Fig. 2 it is shown a graphical representation of active rules for input and output variable and a function of target variable y for data in 2009 year. As a result of work of the fuzzy expert system (Fig. 3), there have been obtained the level of technogenic morbidity in Ukraine in 2000–2012 years caused by tumors, which are presented in Table 4. As shown in the Table 4 real incidences of tumors which were first found in 1000 people are high. In many cases the level of technogenic morbidity reaches above 90 % of the overall incidence of tumors. Obtained in our previous paper [21], the predicted values of volumes of polluted wastewaters, emissions of sulfur dioxide and nitrogen oxide during the 2013–2015 allow predicting the number of newly reported cases of tumors per 1,000 people and estimating the losses due to the costs for the treatment of the patients. In an optimistic forecast of the main factors of influence and perception factors are reduced (Table 4).

The results in Table 4 allow assessing one of the social components of man-made damages – the cost in Ukraine for the treatment of newly diagnosed cases of tumors caused by man-made environmental stress (Table 5). To do this, there have been used the results of relevant research [22] on the cost of treating one patient with a tumor, which in 2012 amounted to 3700.00 UAH., in 2013 – 4123.82 UAH., in 2014 – 4616.85 UAH., and in 2015 will amount to 5109.87 UAH.

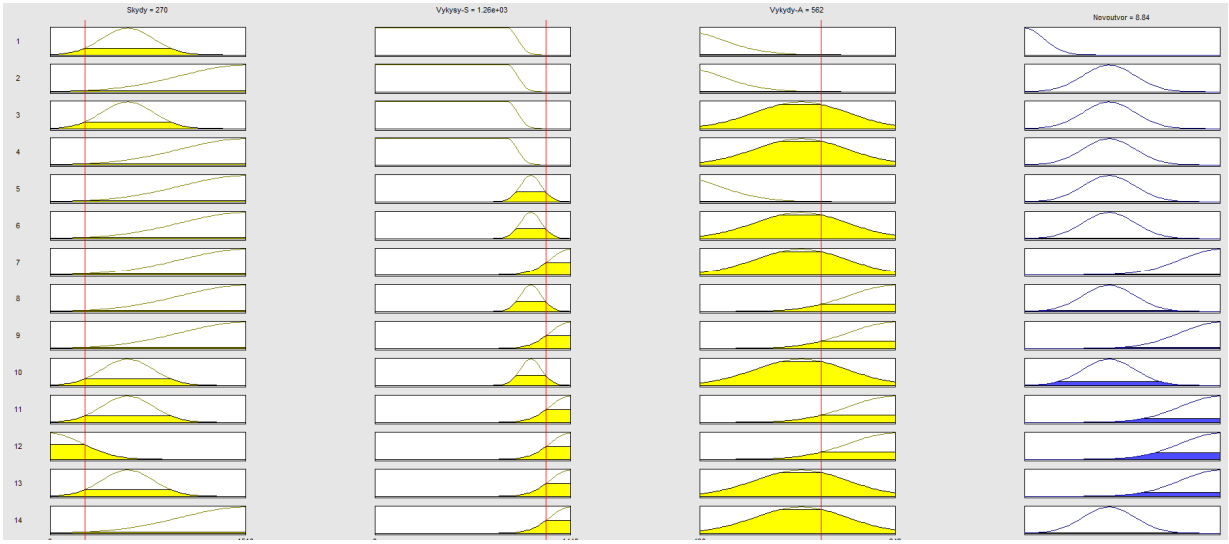

Fig. 2. The view of the membership function of the linguistic input and output variables and the active rulers for data in 2009 year*

** own development*

Table 4. Dynamics of technogenic morbidity levels in Ukraine for the period of 2000–2015*

Years	Volume discharges million m^3	Emissions of sulfur dioxide, t	Emissions of nitrous oxide, t	General morbidity level of tumors, inst. / thous. people	Technogenic morbidity level, inst. / thous. people	The proportion of technogenic morbidity, %
2000	758	984,8	440,6	7,73	7,51	97,2%
2001	746	992,1	452,0	8,05	7,48	92,9%
2002	782	1032,6	435,7	7,88	7,60	96,4%
2003	804	1046,3	477,9	8,23	7,73	93,9%
2004	758	988,5	471,9	8,53	7,51	88,1%
2005	896	1132,8	523,9	8,63	8,64	100,1%
2006	1427	1347,2	515,1	8,82	8,82	100,0%
2007	1506	1342,6	641,9	8,73	8,72	99,9%
2008	616	1320,6	642,0	8,76	7,48	85,4%
2009	270	1262,7	562,1	8,82	8,09	91,7%
2010	312	1235,2	603,7	9,09	7,78	85,6%
2011	309	1363,4	633,0	9,24	7,85	85,0%
2012	292	1430,3	634,6	9,49	8,20	86,4%
2013[1]	269[1]	1319,20[1]	610,73[1]	9,36[1]	8,17	87,30%
2014[1]	226[1]	1249,75[1]	586,06[1]	9,14[1]	8,04	88,00%
2015[1]	180[1]	1155,42[1]	558,98[1]	9,18[1]	8,00	87,10%
Average values				**8,73**	**7,98**	**91,56%**

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[1] predicted values of volumes of pollution

Table 5. Economic evaluation of the social component of technogenic damages caused by the tumor deseases in 2012–2015 years*

Years	Technogenic morbidity level, inst. / thous. people	Social technogenic damages, thous. UAH	The absolute increase in thous. UAH.	Relative growth,%
2012	8,20	1384523	0	0
2013	8,17	1534754	150230	11%
2014	8,04	1676776	142022	9%
2015	8,00	1822866	146091	9%

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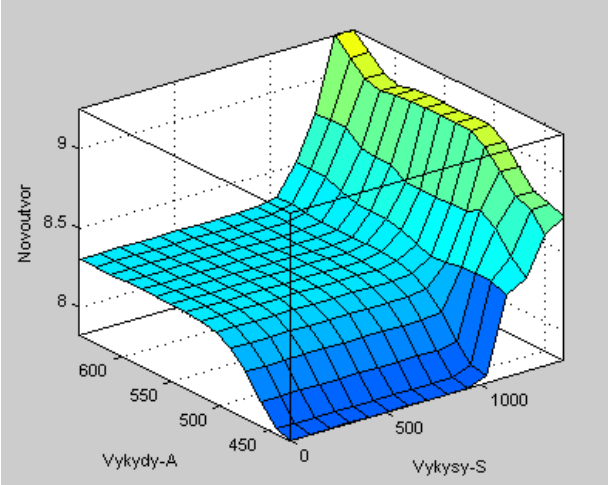

Fig. 3. Graphic representation of active rules and membership functions for the variables "nitrogen oxide emissions – sulfur dioxide emissions – tumors"*

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As it is shown in Table 4, the general expenses for treatment of only one category of people with tumor diseases in 2012 were 1,38 m in UAH. Yet, current expenses for health protection amounted to 26 859,7 m in UAH, according to the State Statistics Committee of Ukraine in 2012 amounted to 26 859 700 000 UAH., including the cost of treatment in day hospitals, funded by the government, made up 9 676 900 000 UAH.

In an optimistic forecast of the main factors of influence and perception factors are reduced (Table 4).

It should be noted that despite the trend of depopulation of Ukraine the volume growth of man-made losses for 3 years is more than 438 m in UAH., compared with that in 2012 which is more than 32 % more. In the pessimistic forecast (growth factors influence) volumes of the same losses will increase in several times. The results suggest the need to increase funding for health care, as well as finding ways to reimbursement for treatment of diseases that are caused by the deterioration of the environment due to pollution of its air and water basins.

Thus, under conditions of incomplete information and uncertainty of the future, it has been studied that the influence of emissions and discharges of pollutants to the level of technogenic morbidity in Ukraine is cumulative in nature and manifests itself in the growth of the social component of man-made damage. In the national economy these results should be considered in the formation of public expenses on health care and the treatment of patients. This will increase the effectiveness of state regulation of the phenomenon; provide appropriate allocations for their eradication and compensation.

CONCLUSIONS

The theoretical foundations and applied problems of economic assessing and predicting the social component of man-made damages to the national economy allowed for the following conclusions.

1. There have been built by means of fuzzy logic an expert model for establishing levels of technogenic morbidity of the population of Ukraine, due to the destructive influence factors (emissions, discharges, waste).

2. The economic evaluation and prediction of the social component of man-made losses – cost of treating patients with tumors due to environmental pollution have been conducted. It has been tested a proposed model for the incidence of tumors.

3. On the basis of the proposed model in an optimistic forecast there was obtained increasing of social component of man-made damage by 32 %, in a pessimistic forecast – several times higher. The study found that the impact of emissions and discharges of pollutants to the level of technological morbidity of Ukraine is cumulative in nature and manifests itself in the growth of the social component of man-made damage.

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