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THEORETICAL BASIS FOR EXPERT SYSTEM TO FORECAST AND ASSESS ECONOMIC IMPACT OF ANTHROPOGENIC POLLUTION ON POPULATION DISEASE LEVEL

Theoretical basis of fuzzy mathematical apparatus sets to evaluate and account the man-made (anthropogenic) losses is improved in the article in order to take effective administrative decisions to reduce and prevent them. The article deals with theoretical basis to build an expert system to forecast the economic effects of man-made (anthropogenic) pollution on population levels of disease. Practically these investigations will give the opportunity to control measures to orientat the national economy and its individual industries on sustainable development.

Keywords: environmental management, expert systems, evaluation of man-made (anthropogenic) losses, sustainable development, national economy, fuzzy sets, consideration of uncertainties.

Problem statement. The activity of business enterprises is becoming more and more destructive to the environment and society every year. Mechanism to manage the national economy requires not only improvement but also a deep restructuring to address natural resources management, nature conservation and social responsibility towards future generations. All this requires to search efficient new (balanced) models to determine the volume of man-made damage and methods of man-made damage economic evaluation at the national economy level. In order to solvethe given problems one involves both forecasting the volume of environmental impact and determination of the effects to society (incidence, life expectancy, mortality, etc.).

The problem to evaluate man-made damage to the national economy is of particular relevance. It is manifested through calculation of anthropogenic pollution (emissions, effluents, waste) and study of their impact on public health, which are generally described by the notion of man-made damage at the national economy.

Analysis of recent research outputs and publications. The theory of damage and losses caused by the enterprises economic activity is shown in works of many scientists and researchers from all over the world. The research of recent publications confirms that a significant contribution in this direction was made by the following Ukrainian scientists: Amosha O.I. [1], Balatskiy O.F. [2], Burkynskyi B.V. [3], Vytvytsky Ya.S. [4], Geets V.M. [1], Danilishin B.M. [5], Illyashenko S.M. [6], Kachynskyi A.B. [7], Kravtsiv V.S. [8], Kuzmin O.Ye. [9], Melnyk L.G. [10], Nyedin I.V. [11], Reutov V.Ye [12], Stadnitskii Yu.I. [13], Trehobchuk B. [14], Tunytsya Yu.Yu. [15], Khlobystov Ye.V. [16], Hvesyk M.A. [17], Shevchuk V. [18] etc.

Fees scholars formed the foundation of the economic losses theory, considered and disclosed the nature of the Environmental Sciences basic tools, identified problems and tendencies of its development in Ukraine.

Unsolved issue that is part of the problem. The analysis of scientific sources and publications shows that scientists in Ukraine and all over the world pay little attention to the methods of man-made damage economic evaluation to the national economy and forecasting at the state level, despite the critical state of the problem.

The problem to predict man-made damage at the level of the national economy goes beyond the purely economic problem. Making efficient management decisions on this issue is being hampered by the complexity of the phenomena and processes which, in addition to this, take place under conditions of uncertainty and incomplete information at the level of the national economy. Accordingly, the question to find modern mathematical tools is rising.

In order to solve this problem, it is advisable to use mathematical modeling. Studies of the outstanding scientists' works in the field to forecast and simulate socio-economic and ecological-economic systems [19-21] (including Klebanova T.S [19], Melnyk M.I [20], Moroz O.V. [21], Panasenko O.V. [19], Chahovets L.A. [19] and others) shows that the unresolved part in the research of the anthropogenic load effects on the recipients of the environmental, economic and social systems is how to develop a mathematical model of prediction, as well as selection of mathematical tools.

Modern mathematical tools which allow predicting the phenomenon value under incomplete information and under the future uncertainty, which is a characteristic feature of the national economy management, are the fuzzy sets theory methods and models and neural networks means.

The object of the article. The theoretical foundations research and applied problems of predicting man-made damage to the national economy and the management methods at the state level lead to the formulation of the following purposes:

– to justify the possibility to apply fuzzy expert system for predicting the consequences of anthropogenic load under the incomplete information conditions and future uncertainty;

– to define the conceptual model features of the fuzzy expert system when establishing the relationship between the amount of pollution (emissions, effluents, waste) and deterioration of health in Ukraine;

– to propose a model of fuzzy expert system to predict man-made damage to the national economy and to test its efficiency when establishing relationship between the amounts of discharges, dioxins sulfur and nitrogen oxide emissions concerning newly reported tumors among the Ukrainian population.

The results of the analysis. In previous studies [22; 23], authors established the essence of the man-made damage and man-made losses, constructed a concept of man-made damage economic evaluation to the national economy and the necessity to apply fuzzy sets as an effective mathematical tool for economic evaluation of man-made damage to the national economy.

Expert systems that deal with real social and economic systems describe the processes which are uncertain in their nature. Management decision of such expert systems is based on expert assessments that may have indistinct qualitative meaning through the operation of the system in terms of uncertainty. Thus, to work with fuzzy expert values it is preferable to use a new trend in economy – fuzzy sets and "soft" logic. The main advantage of the fuzzy expert system is to obtain "acceptable" result for reasons that are close to human. It implies no requirement for an exact match between the input data and the corresponding state of the phenomenon or system under study.

Another advantage of the fuzzy expert system is the linguistic description availability concerning the relationships between variables. The use of linguistic variables allows describing the phenomena (objects, systems) that are very complicated and defy description in conventional quantitative terms. Difficulty to describe the phenomenon is primarily associated with the lack of information about it. Incomplete information, according to Shapiro D.I. and Blyshchun A.F. in [24], can be viewed in three aspects: inaccuracy, uncertainty and vagueness. Vagueness is also displayed in 6 categories: inaccuracy, ignorance, uncertainty, subjective probability, incompleteness, fuzziness. In the work [25], the author emphasizes the listed categories of inaccuracy in the study of ecological and economic systems and their analysis. Hence, inaccuracy, according to the author [25], is reflected in the mistakes and errors while observing or calculating the relevant results about environment, etc. Ignorance is manifested through the existence of unaccounted factors due to the expert's knowledge lack about their impact on the environment, society, individuals, etc. The uncertainty is caused by the lack of information or inability to obtain or compare it in different time periods at the enterprise, industry, national economy or society level, such as the amounts of anthropogenic loads and cases of diseases among population, etc. Subjective probability is determined by the subjective nature of the phenomenon expert assessment. Incompleteness is shown in lack of information on man-made damage caused to nature, society and the national economy. Fuzziness is manifested in the use of qualitative (linguistic) assessments, such as, dangerous, safe, harmful, harmless, low, medium, high, etc.

In addition to the use of linguistic variables and fuzzy conclusions modern fuzzy-logic expert systems use the advantages of neural networks and genetic algorithms. It creates another extremely significant advantage of fuzzy expert system – the ability to receive, store and correct knowledge, held by experts of the subject area and provide a basis to solve practical problems in the dialogue with the experts. However, in practice to apply neural networks requires the representative samples of inputs required to implement the learning process. Yet, it has not been possible to form the landscapes evaluation processes of recreational, historical and cultural character. It is difficult to teach a neural network to act as an expert in the assessment of human values: area as a cultural heritage or historical value, etc. Fuzzy expert systems, despite a number of the above listed benefits, have a significant drawback: the specific and difficult choice of methods for constructing parameter membership functions of fuzzy sets.

The following domestic and foreign researchers have been working on the development of fuzzy-logic expert systems and their practical use in applied problems [25-31]: Klir G.J. [26], Novak V. [27], Rybytska O.M. [28], Syavavko M.I. [29], Zadeh L. [30], Zimmerman H. [31], Yarushkina N.G. [25] Yastrebova N.N. [25] and others.

The research [25] presents the stages to build a fuzzy expert system of environmental-economic analysis that are considered to be typical in the development of all generations' expert systems: identification, conceptualization, formalization, implementation, testing and trial operation. The acquired knowledge in the field of expert systems at present allow to form a fuzzy expert system economic evaluation of man-made losses, which will include units for identification, analysis, forecasting, simulation, control, regulation, etc., grounded in the author's previous work [22]. The developing (proposed) fuzzy expert system must belong to the second generation, where there is a fuzzy knowledge representation and a fuzzy output [28]. The formalism of production type "If A, then B" is the most commonly used for knowledge representation in the system. There is following example of the fundamental task concerning logic inference under fuzziness conditions (1):

Given a (fuzzy) production rules "if A then B".
There is A (And to a certain extent). What should be in? (1)

Conduct the formalization of the problem under consideration as the object of *n* inputs and one output (2):

$$\boldsymbol{y}=f(x_1,x_2,\ldots,x_n) \quad (2)$$

where $x_1,...,x_n$ – a set of input variables; y – output variable.

The core of fuzzy expert systems is the fuzzy logic inference. In order to make a decision based on fuzzy inference in the recommended expert system we use the type of hierarchical fuzzy inference that does not distort the result due to the fact that the output set is discrete prior to the process of defuzzification. Thus, such a hierarchical fuzzy expert system does not accumulate fuzziness. Zadeh L. [30] was first to determin the fuzzy logical inference as an approximation of the each output linguistic variable dependence (2) from the input linguistic variables and obtaining the inference in the form of a fuzzy set corresponding to the current meanings of the inputs using fuzzy knowledge base and fuzzy transactions. The structure of the fuzzy output consists of: 1) a set of fuzzy rules in use; 2) a database that contains descriptions of membership functions; 3) conclusion and aggregation mechanism, which is based on the rules of implication. It is known from the work [25] that a fuzzy logic inference is formed as a result of five stages (Fig. 1): 1) fuzzification; 2) composition; 3) implication; 4) aggregation; 5) defuzzification.

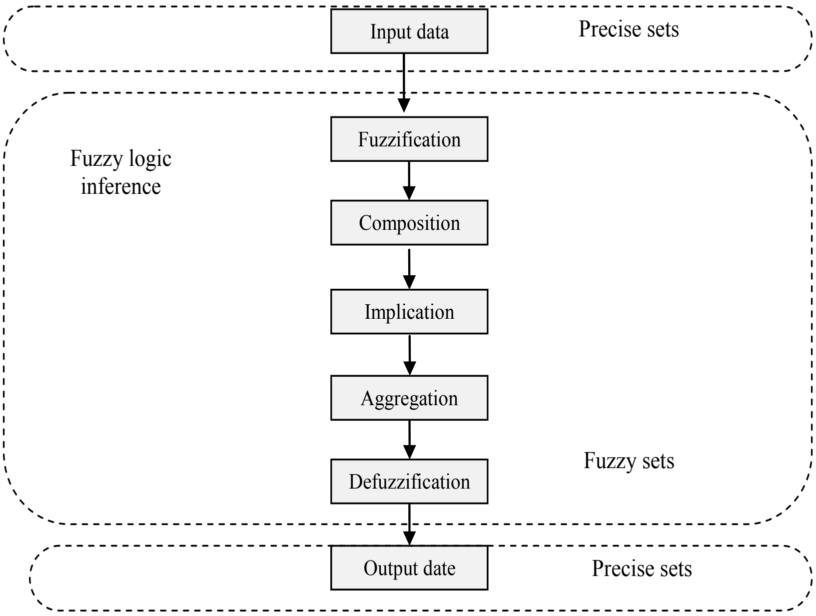


Figure 1 – **Simplified diagram of the fuzzy expert system operation phases**

Operation of the fuzzy expert system begins (ends) with the formation of input (output) variables database, which are the statistical (under study) indicators (characteristics) of the environment, society and the national economy (Figure 1). Interaction between the input and output variables begins in the core of the fuzzy expert system with the very phase fuzzification as an input (defuzzification as an output), where there is an interpretation of the the variable exact meaning as a fuzzy point and vice versa. An important step is the composition of the input variable and the conditional part of a rule, that is, the process to determin the suitability of the rules in each case. In overall the phase composition lies in setting the degree of membership.

In order to make a fuzzy logical inference, fuzzy knowledge base is formed. It consists of formalized fuzzy conditional rules for converting the existing in the first stage fuzzy data in fuzzy action (control effects) on the basis of "if-then" principle. Getting a fuzzy set of conclusions, that is a fuzzy decision-making, in this case, is accomplished by using the table of fuzzy knowledge system decision rules from the knowledge base (fuzzy implication phase). Then a fuzzy output meaning is built, which occurs in the phase of the average meaning aggregation. In our case, we choose the fuzzy inference by Mamdani out of the five fuzzy inference diagrams, where the implication is modeled by a minimum and aggregation by maximum of meanings. As this was the first output diagram and, further, is the base for all the others [25].

The input data for our fuzzy expert system analysing man-made damage are data statistical studies of the human activities impact on the environment, provided in the relevant statistical reports by government departments, etc. the statistical reports for the period 1990-2012 contain quantitative data on the dynamics of anthropogenic load. It comprizes emissions, discharges, waste of polutants and the dynamics on newly reported cases of deseases among the Ukrainian population etc. We can select those statistical series, which according to the experts have a direct impact on quantitative indicators of the life quality, from existing array of anthropogenic load.

Fundamental studies of the air pollution impact on the national economy were held by Sumska School of Economics under the supervision of prof. Balatskiy more than twenty five years ago [2]. The main manifestations of man-made damage to the national economy, according to the researchers, were considered the costs of environmental protection measures and damage to human health, leading to lower productivity, etc. Researchers at the European eco-economic school, according to de Bruyan S. [32], considered that the problem of deseases growth among population and the fixed assets (metal corrosion, reducing operating time of equipment, etc.) deterioration should also include reduction of natural resources effectiveness due to the loss of acid rain, climate change, etc.). In his work [33] the native scientist Kubatko O.V. found out that exceeding the maximum allowable concentrations of nitric oxide in the air can cause irreversible changes in people's health as a result of modeling air pollution impacts on the population's health, particularly the increasing number of diseases. Also, there has been found out that the growth of water and air basins pollution can lead to irreparable damages, when it is not possible to restore the former homeostasis level of socio-natural systems.

Based on the studies results conducted in the work [34], losses from deteriorating health due to pollution of the environment should be calculated at a ratio of 50-40-10 where 50% of all people's diseases are caused by the way of life, 40% – by heredity and the environment, but only 10% depend on the level of medicine in the state. In Kubatko's O.V. study [35] determining the impact of such factors as income, providing medical staff, air pollutioning and ionization of the area as a result of the Chernobyl accident on public health in the Ukrainian regions, it has been determined that genetic disorders are increasing by 5% with rising doses of radiation at 100 kBq/m2. Also, the total harmful substances emissions into the air negatively affect the respiratory system of the population, increasing them to 3% with a rise in emissions by 100 tonnes [35]. The endocrine system (thyroid disease) disease increases by 30% due to the rise of exposure at 30 cGy [35].

Among the analyzed data in accordance with the experts' recommendations the most significant impact on the 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 (Table 1). Therefore we propose to apply the model of fuzzy expert system in order to establish the interdependencies between the magnitude of discharges (drained polluted waters without treatment), and sulfur dioxide emissions of nitric oxide and the number of tumors per 1,000 Ukrainian citizens.

Table 1 – **Dynamics of input and output volumes concerning variables in the period 1990-2012 years,** (developed by the author based on [36-38])

Years	Volume discharges million m^3	Emissions of sulfur dioxide, t	Emissions of nitrous oxide, t	The number of fixed tumors (per 1,000 citizens of Ukraine)[1]
1990	470	2782,30	760,80	...[2]
1991	701	2537,90	989,80	...
1992	951	2376,20	830,20	6,397
1993	1196	2194,00	700,10	6,355
1994	1053	1715,00	567,60	6,294
1995	912	1639,10	530,30	6,321
1996	980	1292,60	466,60	6,531
1997	763	1132,40	455,20	6,848
1998	813	1023,00	444,50	7,385
1999	748	1026,10	436,60	7,653
2000	758	984,80	440,60	7,728
2001	746	992,10	452,00	8,053
2002	782	1032,60	435,70	7,883
2003	804	1046,30	477,90	8,229
2004	758	988,50	471,90	8,525
2005	896	1132,80	523,90	8,629
2006	1427	1347,20	515,10	8,822
2007	1506	1342,60	641,90	8,725
2008	616	1320,60	642,00	8,755
2009	270	1262,70	562,10	8,820
2010	312	1235,20	603,70	9,094
2011	309	1363,40	633,00	9,240
2012	292	1430,30	634,60	9,489

Notes: [1] – data is calculated taking into account the migration flows in Ukraine; [2] – there are no data for calculation

Under the specified conditions, our task is to establish the discharges effect x_1 (removal of untreated polluted water in million m^3), sulfur dioxide emissions x_2 (total emissions from stationary and mobile sources in tones) and nitrogen oxide emissions x_3 (total emissions from stationary and mobile sources in tones) on the number of fixed tumors (per 1,000 citizens of Ukraine) y.

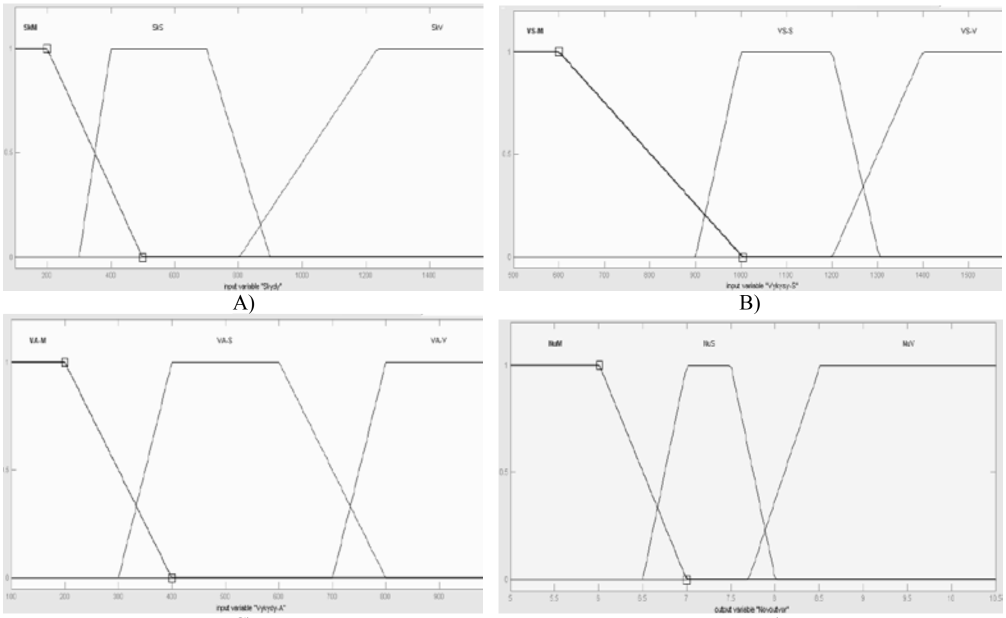
Using the statistical data presented in Table 1, we define the universal sets of input variables described for x_1, x_2, x_3 and output y, respectively (3):

$$U_1=[0;1600],\ U_2=[500;1500],\ U_3=[100;800],\ U_4=[4;10,5]. \quad (3)$$

We will built the term-sets (4) for each input and output variables

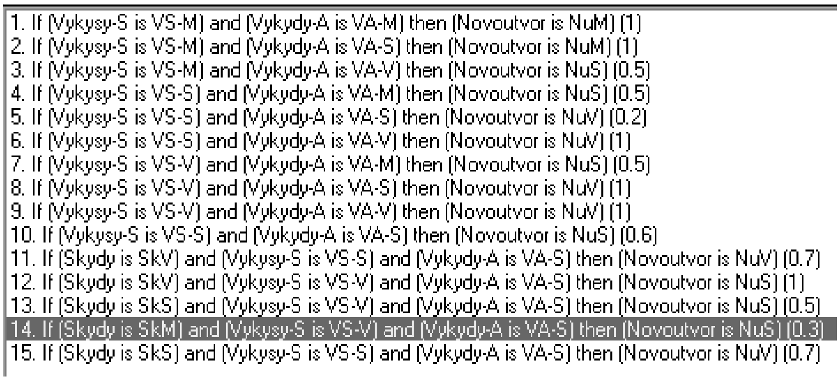
$$\begin{aligned} A_1&=\{\text{“small”, “medium”, “large”}\}=\{M, S, V\},\\ A_2&=\{\text{“small”, “medium”, “large”}\}=\{M, S, V\},\\ A_3&=\{\text{“small”, “medium”, “large”}\}=\{M, S, V\},\\ D&=\{\text{“small”, “medium”, “large”}\}=\{M, S, V\}. \end{aligned} \quad (4)$$

We recommend to select and ratify trapezoidal membership functions for terms of input and outputting variables, the type of which is shown in Figure 2 (A-D). To solve this problem the experts will build the fuzzy knowledge base presented in Figure 3.



A) B) C) D)

Figure 2 – **Views of the linguistic variables functions "Discharges" (A), "Emissions of sulfur dioxide»" (B), "Emissions of nitrous oxide" (C), "tumors" (D),** (own development)



1. If (Vykysy-S is VS-M) and (Vykydy-A is VA-M) then (Novoutvor is NuM) (1)
2. If (Vykysy-S is VS-M) and (Vykydy-A is VA-S) then (Novoutvor is NuM) (1)
3. If (Vykysy-S is VS-M) and (Vykydy-A is VA-V) then (Novoutvor is NuS) (0.5)
4. If (Vykysy-S is VS-S) and (Vykydy-A is VA-M) then (Novoutvor is NuS) (0.5)
5. If (Vykysy-S is VS-S) and (Vykydy-A is VA-S) then (Novoutvor is NuV) (0.2)
6. If (Vykysy-S is VS-S) and (Vykydy-A is VA-V) then (Novoutvor is NuV) (1)
7. If (Vykysy-S is VS-V) and (Vykydy-A is VA-M) then (Novoutvor is NuS) (0.5)
8. If (Vykysy-S is VS-V) and (Vykydy-A is VA-S) then (Novoutvor is NuV) (1)
9. If (Vykysy-S is VS-V) and (Vykydy-A is VA-V) then (Novoutvor is NuV) (1)
10. If (Vykysy-S is VS-S) and (Vykydy-A is VA-S) then (Novoutvor is NuS) (0.6)
11. If (Skydy is SkV) and (Vykysy-S is VS-S) and (Vykydy-A is VA-S) then (Novoutvor is NuV) (0.7)
12. If (Skydy is SkV) and (Vykysy-S is VS-V) and (Vykydy-A is VA-S) then (Novoutvor is NuS) (1)
13. If (Skydy is SkS) and (Vykysy-S is VS-V) and (Vykydy-A is VA-S) then (Novoutvor is NuS) (0.5)
14. If (Skydy is SkM) and (Vykysy-S is VS-V) and (Vykydy-A is VA-S) then (Novoutvor is NuS) (0.3)
15. If (Skydy is SkS) and (Vykysy-S is VS-S) and (Vykydy-A is VA-S) then (Novoutvor is NuV) (0.7)

Figure 3 – **View of the fuzzy knowledge base concerning the task under study,** (own development)

The following calculations are carried out for the database of the industrial anthropogenic load (Table 1) in 2003: x_1 = 804, x_2 = 1046.30, x_3 = 477.90. Figure 4 shows a graphical representation of active rules for input and output variable and a function view of the independent output variable *y*.

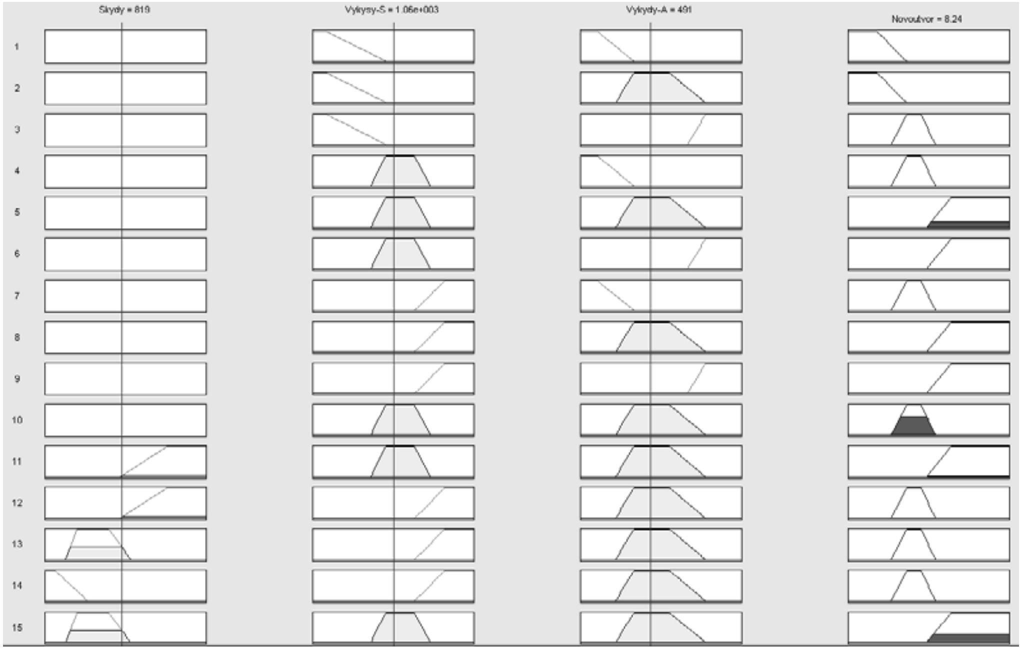


Figure 4 – **Graphic representation of the active rules and membership function operation concerning the output variable "tumors",** (own development)

As a result of calculation the active rule number 14 is operating, which can be seen in Figure 3. Active rule number 14 leads to the exit, where the quantitative meaning of the output variable *y* (the result of defuzzification) is 7,333. The real incidence of the new tumors which were first recorded per 1000 people in 2003 is 8,229. Relative and absolute deviations are 10.9% and 0,89 respectively. These differences of predicted and actual meanings indicate that the emissions impact and pollutants discharges on the incidence are cumulative in nature and appear in the time delay. Therefore, the relationship between the results must include the time lag and the input figures must be averaged over a specified period of time. Accordingly, there has made averaging of the input and output variables for 3 years, which allowed us to obtain the following results that are given in Table 2.

Table 2 – **The average values of the anthropogenic load amounts on the environment and the number of tumors, and the fuzzy expert results,** (own development)

Period of 3 years	Volume discharges million m^3	Emissions of sulfur dioxide, t	Emissions of nitrous oxide, t	Averaged number of fixed tumors (per 1,000 citizens of Ukraine)	Calculated numbers of tumors	The absolute deviation	The relative deviation
1	2	4	5	6	7	8	9
2000 -2002	762,0	1003,17	442,77	7,89	7,76	0,13	1,6%
2001 -2003	777,3	1023,67	455,20	8,05	8,07	0,02	0,2%
2002 -2004	781,3	1022,47	461,83	8,21	8,07	0,14	1,7%
2003 -2005	819,3	1055,87	491,23	8,46	8,24	0,22	2,6%
2004 -2006	1027,0	1156,17	503,63	8,66	8,41	0,25	2,9%

Table 2 (continued)

1	2	4	5	6	7	8	9
2005 -2007	1276,3	1274,20	560,30	8,73	8,56	0,17	1,9%
2006 -2008	1183,0	1336,80	599,67	8,77	8,63	0,14	1,6%
2007 -2009	797,3	1308,63	615,33	8,77	8,84	0,07	0,8%
2008 -2010	399,3	1272,83	602,60	8,89	8,80	0,09	1,0%
2009 -2011	297,0	1287,10	599,60	9,05	8,87	0,18	2,0%
2010 -2012	304,3	1342,97	623,77	9,27	9,00	0,27	2,9%

The Table 2 shows that the estimated values of the newly tumors reported cases by the fuzzy expert system differ from the statistics by no more than 3%. Taking into account the time lag between the pollution impact and the diseases occurrence, in other words shifting the results by only one period, we obtain an almost complete coincidence of actual and calculated deseases values for most periods (Figures 5-6).

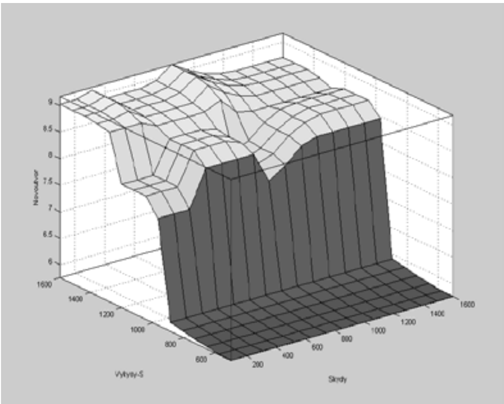


Figure 5 – **Graphic representation of active rules and membership function for the variables “Discharges – sulfur dioxide emissions – tumors”,** (own development)

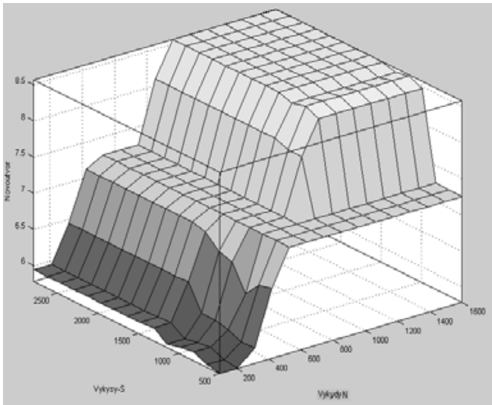


Figure 6 – **Graphic representation of active rules and membership function for the variables “Nitrogen oxide emissions – sulfur dioxide emissions – tumors”,** (own development)

Thus, during the years 2001-2003 the statistic’s and calculated values are 8.05 and 8.07 respectively. During 2008-2010 they were 8.89 and 8, 87, etc. It should be noted that this property is inherent in the whole natural system. As Kubatko O.V. [35] proves, it is due to the fact that the accumulated pollution amounts weaken the capabilities of environmental recreation, which leads to the existence and time lags. It is the evidence of the system inertia.

The Table. 2 shows that the most sensitive man-made damage indicator is the number of newly reported tumors incidence, where the environmental component proportion is the highest. Let’s evaluate one of man-made damage components - the cost of tumor deseases newly diagnosed cases treatment. We use the results of the treatment cost study one patient with tumor desease in 2012, which was performed in the work [39]. It has been [39] found that according to the regulations in the field of Health of Ukraine, namely the Law of Ukraine “On Healthcare” and Ministry of Health in Ukraine “On Approval of harmonized methodology for development of clinical guidelines, medical standards, unified clinical protocols of medical care, local protocols of medical care (clinical pathways) proved by evidence-based medicine (part Two) "from 03.11.2009. №798/95, cost of the treatment on tumor disease in 2012 are 3700, 00 UAH, 2013 – 4123,82 UAH, in 2014 – 4616б85 UAH, and in 2015 will be up to 5109б87 UAH. Cost estimation of the treatment of newly reported cases of tumors are given in Table. 3

Table 3 – **Economic evaluation of man-made damage caused by tumor disease in the period of 2010-2012 and their forecasting for the period of 2013-2015,** (own development)

Period of 3 years	Volume discharges million m^3	Emissions of sulfur dioxide, t	Emiss-ions of nitrous oxide, t	Averaged number of fixed tumors (per 1,000 citizens of Ukraine)	The man-made losses in UAH	The absolute increase in UAH	Relative growth,%
2010 -2012	304,33	1342,97	623,77	9,00	1524862,5	0	0
2011 -2013	269,60	1319,20	610,73	8,97	1688810,1	163947,6	11%
2012 -2014	226,51	1249,75	586,06	8,44	1773936,2	85126,2	5%
2012 -2015	180,98	1155,42	558,98	8,08	1874357,0	100420,8	6%

Let's compare only one man-made damage component and only one kind of disease - the cost of tumors newly reported cases treatment. As it can be seen from the Table 3, the total cost of only one patients category treatment with tumors in the period 2010-2012 equals 1,52 million UAH. Current health expenditure in 2012 amounted to 26859,7 m., including the cost of treatment in day hospitals, funded by the government, constituted 9676 m

To conduct the economic evaluation of the man-made damage social component we used data from the previous studies of anthropogenic impact dynamics on the environment conducted in author's previous works [22; 23]. The forcasted values of the polluted wastewaters, emissions of sulfur dioxide and nitrogen oxide calculated volumes during 2013-2015 allowed to predict the newly reported cases of tumors in 1000 and the resulting cost estimation of one man-made damages component– the cost of treating these patients. In Table 3 the forecasts are optimistic, where the volume of pollution main factors influencing the recipients decreased and the number of cases will decrease. Despite this, the size of man-made losses for 3 years have grown by more than 300 thousand, taking into consideration the value of specific incidence tumors rates that equals 8,00, which is 1,87 million UAH in 2015. It is 23% more than the 1,52 million UAH in 2012, which was received at the level newly registered deseases with indicator 9.00. In the pessimistic projections of man-made damage by only one component – the cost of newly registered patients treatment with tumors – grow several times. The results suggest the need to increase funding for health care, as well as finding ways of reimbursement for diseases treatment that are caused by the deterioration of the environment due to its air and water basins pollution.

Consequently, the proposed innovative tool – the fuzzy expert system is a quite effective mathematical tool for man-made damage economic evaluation to the national economy. The fuzzy expert systems allow us to get "acceptable" results under reasons that are close to human in the sense of the an exact match absence between the requirements of the input data (the so-called left side of the rule) and the appropriate state (right-hand side rules) of the phenomenon under study. The advantages of the fuzzy expert systems lie in the fact that the use of linguistic variables allows to approximately describe the phenomena which are so complex that defy any description in the conventional quantitative terms. Moreover, the fuzzy expert system can receive, store and correct knowledge owned by experts of the subject area in a dialogue with the experts (in order to obtain real solutions).

In our opinion, proposed method, fuzzy measures of input and output variables, the system of rules for representing acquired knowledge can be applied in the fuzzy expert systems. They allow us to get a comprehensive evaluation of inflicted and projected man-made damage and losses caused by both ordinary and extraordinary economic activities of enterprises for different industries.

Conclusions and directions for further researches. The theoretical foundations and applied problems of predicting man-made damage to the national economy and methods of management at the state level give the following conclusions.

1. To justify the application of fuzzy sets theoretical principles as an effective mathematical tool in conditions of incomplete information and uncertainty in future work the advantages of fuzzy expert systems, including the possibility of approximate descriptions such complex phenomena that can not be described in conventional quantitative terms, and the ability to receive, store and adjust the knowledge possessed by experts in this subject area in the process of dialogue with them in order to get real results.
2. The model of fuzzy expert system to establish interdependencies between the amount of pollution (emissions, effluents, waste) and deteriorate health in Ukraine has been proposed.
3. The model in predicting the technogenic load (discharges drained polluted waters without treatment) and emissions of sulfur dioxide and nitric oxide) due to economic activity and its effects on the number of newly registered tumors in 1000 people of the population in Ukraine has been investigated.
4. During the investigation it was established as a rising idea to use the claim that the emissions impact and pollutants discharges to the number of cases is cumulative in nature and appears to the time delay, because the relationship between the results must include the time lag and indicators should be averaged over volumes actions for a specified period of time.
5. The proposed model of fuzzy expert system to establish interdependencies between the pollution amount (emissions, effluents, waste) and deterioration of health in Ukraine has been used to predict the incidence depending on the influencing factors. Levels of newly registered incidence of tumors among the population of Ukraine were investigated on the basis of the proposed model for the optimistic forecast reduction of anthropogenic stress induced by human activities (impact factors). These man-made damage amounts by only one component – the cost of newly registered patients' treatment with tumors with an optimistic forecast (reduction factors influence) was increased by 23%, while pessimistic – grow several times.

Thus, the application of fuzzy sets to forecast the national economy anthropogenic damage, manifested in the calculation of anthropogenic pollution (emissions, effluents, waste) and study their impact on public health may have practical use in the development in the management of the national economy according methodological model of research, evaluation and regulation of man-made damage to the national economy. The obtained results will improve the efficiency of phenomenon state regulation, provide appropriate allocations for their eradication and compensation.

Theoretical and practical aspects regarding the economic evaluation of man-made damage will be used in further research to develop an appropriate fuzzy expert system for predicting the study, collecting and analyzing data on the damage, loss and expense in different sectors of the national economy by sector and identifying technological losses (of man-made damage). The proposed model application will form not only an effective system of national economy, but also protect against predictable technogenic emergency risks situations that may occur in various sectors.

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Теоретичні засади побудови експертної системи для прогнозування та економічної оцінки впливу техногенних забруднень на рівень захворювання населення

У статті удосконалено теоретичні засади застосування математичного апарату нечітких множин для оцінки та урахування техногенних (антропогенних) збитків з метою прийняття ефективних управлінських рішень щодо їх зниження та запобігання. Розроблено теоретичні засади побудови експертної системи для прогнозування економічних наслідків впливу техногенних (антропогенних) забруднень на рівень захворювання населення. Їх практичне використання дозволить цілеспрямовано управляти заходами з орієнтації національної економіки та її окремих галузей на сталий розвиток.

Ключові слова: управління природокористуванням, експертні системи, оцінювання техногенних (антропогенних) збитків, сталий розвиток, національне господарство, нечіткі множини, урахування факторів невизначеності.

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Теоретические основы построения экспертной системы для прогнозирования и экономической оценки влияния техногенных загрязнений на уровень заболевания населения

В статье усовершенствованы теоретические основы использования математического аппарата нечетких множеств для оценки и учета техногенных (антропогенных) убытков с целью принятия эффективных управленческих решений относительно их снижения и предотвращения. Разработаны теоретические основы построения экспертной системы для прогнозирования экономических последствий влияния техногенных (антропогенных) загрязнений на уровень заболевания населения. Их практическое использование даст возможность целенаправленно управлять мероприятиями по ориентации национальной экономики и ее отдельных отраслей на устойчивое развитие.

Ключевые слова: управление природопользованием, экспертные системы, оценивание техногенных (антропогенных) убытков, устойчивое развитие, национальное хозяйство, нечеткие множества, учет факторов неопределенности.

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