COMPUTER SYSTEM FOR ECOLOGICAL CONTROL

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Abstract
The structure and the main tasks of the Computer system of ecological control are represented in the papers. The structure optimization of health costs caused by enterprises activity influence on environment model by means of Computer System is considered. The verifying of the adequacy of the model is illustrated by means of the concrete example.

Introduction
Investigation of health costs changes is a very actual task under the conditions of the modern city. Ecological-social environment is formed by means of two groups of factors: ecological (concentrations of definite chemical elements in the air, water, soil; the level of radiation: the level of noise) and social (bad habits, income, dwelling condition, food rich in calories, psycho-emotional climate at home and at work, level of education, etc.).

There are many works devoted to environment economics (2, 5). As rule expenses caused by economic activity influence on environment are chosen as a criterion. Expenses are estimation of negative changes of main environment characteristics. The main attention should be paid to estimation of expenses coursed by disease level change according the established ecological norms. Elaborated approaches don't take into consideration the influence of social-economic factors, so as rule the expenses are often inadequate. Besides the expenses may be decreased by means of increasing social-economic standards. The main feature of expenses modeling is that social and ecological factors are qualitatively described by means of fuzzy terms. In this situation the theory of fuzzy sets should be used (4). As for the expenses the intervals of their possible meanings are known. They cannot be considered as probable values. That's why it is proved to use the interval analysis for their description (3). Nowadays there have been elaborated some approaches as for the interval model structure optimization. In (3) the verifying of the hypotheses as for the meaningful of the model parameters by means of their signs comparison is described as well as using two criteria, complication and accuracy are offered. The expenses modeling are complicated by a large number of both ecological and social-economic factors. Elaborated software doesn't allow building the model with more then hundred entrance variables. Since in the interval analysis the simplest model is the most exact, the structure optimization of the model should be done by means of model's entrance variables minimizations as well as model's parameters quantity minimization. For model's entrance variables minimization the method of structure optimization by means of building integrated social and ecological factors has been elaborated. For model's parameters quantity minimization the method of consecutive inclusion may has been used (3).

The necessity to process large amount of information fast and accurately as well as sophistication of mathematical theory for building the model of expenses require using of Computer System (CS). The main tasks of elaborated CS are processing information about air, soil and water pollution, level of noise and level of radiation, disease levels and expenses on treatment; calculating the importance of social and ecological factors concerning their influence on expenses; the structure optimizations of the model by means of calculating the meanings of integrated social and ecological factors; parameter identification of the model. The CS consists of the following modules: Data Base (DB); Subsystem for structure optimization by means of calculating the meanings of integrated social and ecological factors; Subsystem for parameter identification of the model.

Methods

The suggested approach allows to get the optimal structure of the model by means of entrance variables integration. Since social and ecological factors are described as fuzzy terms the fuzzy sets theory has been used for their integration.

Integrated factors x_{i1k}, x_{i2k} are represented as a linguistic variable with the following structure:

$$<L_j, Z_j, V>$$

where L_j- the name of the jth linguistic variable; Z_j- the set of meanings of the jth linguistic variable; V- the set of social-ecological zones; $V=\{v_1,...,v_n\}$; i=1,...,n.

As a result of the linguistic value L_j with the meaning Z_{lj} decomposition the set of fuzzy variables $\{c_{1lj},..,c_{rlj}\}$ are obtained. Each of them characterizes definite factor and is described by means of the following structure

$$<c_{tlj}, V, A_{tlj}>$$

where c_{tlj} - the name of the fuzzy variable got as a result of the jth linguistic variable with the lth meaning decomposition; A_{tlj}-the fuzzy set characterizing fuzzy variable c_{tlj} , i.e. the tth factor; $A_{tlj}=\{f_{Atlj}(v_i)/v_i\}$; $f_{At}(v_i) \in[0,...,1]$; $f_{Atlj}(v_i)$ – the function of the ith social-ecological zone correspondence to the fuzzy set A_{tlj}.

For example as a result of decomposition linguistic variable L_2 ("Social conditions") with the meaning Z_{12} ("Good") the set of fuzzy variables $\{c_{112},..,c_{r12}\}$ are gotten. Each of them describes a certain social factor and is represented by means of the structure. $f_{At12}(v_i)$ is characterized with the percentage of population of the social-ecological zone with corresponding social conditions. As a result of decomposition linguistic variable L_1 ("Ecological conditions") with the meaning Z_{11} ("Good") the set of fuzzy variables $\{c_{111},..,c_{r11}\}$ are gotten. Each of them describes a certain ecological factor and is represented by means of the structure. $f_{At11}(v_i)$ is characterized with the ratio of the real meaning of the factor and its maximum admissible meaning.

On the basis of calculated functions of correspondence $f_{Atlj}(v_i)$ for each tth factor the function of correspondence $x_{ijk} = f_{Dljk}(v_i)$ of the social-ecological zone vi to fuzzy set D_{ljk} have been built. D_{ljk} characterizes the meaning Z_{lj} of the linguistic variable L_j for the k^{th} class of diseases i.e. general factor x_{ijk}.

Since every factor affects on the definite diseases in different way the function of correspondence $f_{Dljk}(v_i)$ are build using the importance of the factors

$$f_{Dljk}(vi)=\min_t f_{Atlj}\alpha\ tljk(vi).$$

The importance of the factor is defined using the formula

$$\alpha_{tljk}=p_{tljk}s$$

where p_{tljk}- the t^{th} component of the vector of priorities $\vec{P}_{jk}$; t=1,...,s; s-the number of the factors received as a result of the j^{th} linguistic variable with the l^{th} meaning decomposition. To build the vector $\vec{P}_{jk}$ for the k^{th} class of diseases the matrix B_{jk}, the matrix of results of pair comparisons factors according their influence on expenses for treatment diseases of definite class, has been built.

The model of connection between ecological and social factors and expenses on the k^{th} class of disease treatment is described by means of the following polynomial

$$\hat{y}_k = \vec{\varphi}_k^T(\vec{x}_k)\vec{b}_k$$

where $\hat{y}_k$ - meaning of monthly expenses on the k^{th} class of diseases treatment; $\vec{\varphi}_k^T(\vec{x}_k)$-the vector of known basic functions; $\vec{x}_k$ = (x1k, x2k)T – the vector of general ecological x_{1k} and social x_{2k} factors meanings; $\vec{b}_k$-the vector of unknown parameters; k=1,…,11.

Vector $\vec{b}_k$ is estimated on the base of interval data gotten during the expert questioning and represented as follows

$$X_k \rightarrow [\vec{y}_k]$$

where Xk=$(\vec{x}_{1k},...,\vec{x}_{nk})$T; $\vec{x}_{ik}$= (x_{i1k}, x_{i2k})T - the vector of general ecological x_{i1k} and social x_{i2k} factors meanings in the i^{th} social-ecological zone for the k^{th} class of diseases; [$\vec{y}_k$]=([y1k],…,[yik],…,.[yn11])T – the vector of interval expenses meaning in the i^{th} social-ecological zone(SEZ) for the k^{th} class of diseases, $[y_{ik}]= [y_{1ik}]v_{ik}$, where $[y_{1k}]$-expenses on ambulance treatment of the k^{th} class of diseases taken from the Budget for one person; v_{ik}-the number of persons in the i^{th} social-ecological zone with the k^{th} class of diseases; i=1,…,n; n-the number of social-ecological zones. A district with certain social and ecological conditions is considered to be the social-ecological zone. The estimation $\vec{b}_k$ of the vector $\vec{\beta}_k$ must satisfy the system of inequalities

$$y_{ik}^{-} \le \vec{\varphi}_k^T(\vec{x}_k)\vec{b}_k \le y_{ik}^{+}, \quad \forall \text{ i=1,...,n.}$$

In case when the system is compatible, the set of its solutions Ω={$\vec{b}_{лз} : y_{ik}^{-} \le \vec{\varphi}_k^T(\vec{x}_k)\vec{b}_{лз} \le y_{ik}^{+}$ $\forall$ i =1,...,n} is the convex multisided in the space R^m. Thus p is the number of the top of the Ω. The true unknowing vector $\vec{\beta}_k$ is one of the solutions of the system, i.e. $\vec{\beta}_k \in \Omega$.

If the solution of the system exists then

$$[\hat{y}_k(\vec{x}_k)]=[\hat{y}_k^{-}(\vec{x}_k),\ \hat{y}_k^{+}(\vec{x}_k)]$$

where $\hat{y}_k^{-}(\vec{x}_k)=\min_{\vec{b}_{kj}\in\Omega} \vec{\varphi}_k^T(\vec{x}_k)\vec{b}_k^{-}$; $\hat{y}_k^{+}(\vec{x}_k)=\max_{\vec{b}_{kj}\in\Omega} \vec{\varphi}_k^T(\vec{x}_k)\vec{b}_k^{+}$ is the model of connection between the ecological and social-economical factors and expenses. The i-th inequality in the system means passing the model in the i-th interval meaning [y_{ik}]. Incompatibility of the system means abnormality of the hypotheses, i.e. abnormality of the kind of the function, or abnormality of the interval meanings [y_{ik}^{-} , y_{ik}^{+}] , i.e. impossibility to pass the function through the all intervals (3).

Results

The functions of the social-ecological zone correspondence $f_{At12}(v_i)$ to the fuzzy set A_{tl2} characterizing social-economical factors are represented in the table 1.

Table 1. The functions of the social-ecological zone correspondence fAt12(vi) to the fuzzy set Atl2 characterizing social-economical factors

T	Social-economical factor, ct12	f_{At12} (v1)	f_{At12} (v2)	f_{At12} (v3)	f_{At12} (v4)
1	Dry apartment	0.7	0.76	0.78	0.83
2	Wet apartment	0.3	0.24	0.22	0.17
3	Sunny apartment	0.41	0.5	0.58	0.65
4	Dark apartment	0.59	0.5	0.42	0.35
5	Marital status: single	0.3	0.36	0.35	0.37
6	Marital status: married	0.4	0.41	0.42	0.47
7	Marital status: widow	0.1	0.09	0.08	0.07
8	Marital status: divorced	0.2	0.16	0.15	0.11
10	Daily dream: 7 or more hours	0.6	0.66	0.68	0.7
11	Daily dream: less then 7 hours	0.4	0.34	0.32	0.3
12	Good family relations	0.45	0.47	0.49	0.55
13	Irrelevant family relations	0.2	0.22	0.23	0.25
14	Conflict family relations	0.35	0.31	0.28	0.2
15	Good relations at work	0.43	0.46	0.5	0.58
16	Satisfied relations at work	0.22	0.2	0.18	0.15

17	Negative relations at work	0.35	0.34	0.32	0.27
18	Smoking	0.8	0.7	0.62	0.6
19	Alcohol addiction	0.78	0.77	0.75	0.73
20	Active style of life	0.7	0.71	0.72	0.8
21	Passive style of life	0.3	0.29	0.28	0.2
22	Monthly income UAH 50-100	0.35	0.3	0.28	0.12
23	Monthly income more then UAH 100	0.65	0.7	0.72	0.78

The functions of the social-ecological zone correspondence f_{At11}(vi) to the fuzzy set A_{tl1} characterizing ecological factors are represented in the table 2.

Table 2. The functions of the social-ecological zone correspondence fAt11(vi) to the fuzzy set Atl1 characterizing ecological factors

t	Ecological factor, ct21	f_{At12} (v1)	f_{At12} (v2)	f_{At12} (v3)	f_{At12} (v4)
1	Carbon monoxide	0.72	0.63	0.63	0.58
2	Nitric oxide	0.8	0.77	0.76	0.72
3	Ammonium hydrate	0.7	0.7	0.62	0.57
5	Manganese	0.7	0.68	0.64	0.6
6	Tin	0.79	0.79	0.78	0.72
7	Tetraethyl	0.8	0.78	0.73	0.7
8	Formaldehyde	0.8	0.78	0.76	0.73
9	Nickel	0.76	0.7	0.7	0.67
11	Cobalt	0.82	0.8	0.78	0.69
12	Chlorous hydrogen	0.68	0.65	0.6	0.58
13	Chrome	0.81	0.8	0.69	0.65
14	Aluminium	0.67	0.65	0.62	0.6
15	Noise	0.79	0.75	0.72	0.7

The importance of social factors preventing the increase of expenses on treatment of the blood system diseases in 2003α_{t127} is represented in the Table 3

Table 3. The importance of social factors preventing the increase of expenses on treatment of the blood system diseases in 2003

t	Social-economical factor, ct	α_{t127}
1	Dry apartment	1.059
2	Sunny apartment	1.061
3	Marital status: single	0.972
4	Marital status: married	0.968
5	Marital status: widow	0.968
6	Daily dream: 7 or more hours	1.063
7	Good family relations	0.968
8	Irrelevant family relations	1.054
9	Good relations at work	0.990
10	Active life	0.858
11	Monthly income more then UAH100	1.039

The importance of ecological factors influencing expenses on treatment of the blood system diseases in 2003α_{t117} is represented in the Table 4.

Table 4. The importance of ecological factors influencing expenses on treatment of the blood system diseases in 2003 α_{t114}

T	Ecological factor, ct	α_{t117}
1	Carbon monoxide	1.038
2	Nitric oxide	1.028
3	Ammonium hydrate	0.942
4	Manganese	1.015
5	Tin	0.809
6	Tetraethyl	1.018
7	Formaldehyde	1.033
8	Nickel	1.037
9	Cobalt	0.921
10	Chlorous hydrogen	1.041
11	Chrome	0.966
12	Aluminum	1.043
13	Noise	1.068

The meanings of the integrated social-economical x_{i27} and ecological x_{i17} factors for the blood system diseases calculated by means of the Computer System and monthly expenses are represented in the Table 5.

Table 5. The meanings of the integrated social-economical xi27 and ecological xi17 factors for the blood system diseases

I	Social-ecological zone	X_{i17}	X_{i27}	$[y_{i7}^-, y_{i7}^+]$
1	**SEZ1**	**0.341**	**0.183**	**[301.9, 304.9]]**
2	**SEZ2**	**0.381**	**0.203**	**[295.9, 298.9]**
3	**SEZ3**	**0.412**	**0.212**	**[292.8, 295.7]**
4	**SEZ4**	**0.433**	**0.232**	**[289.8, 292.7]**

By means of the method of consecutive including the structure of the model of expenses for blood system diseases treatment has been built

$$[\hat{y}_7(\vec{x}_7)]=[\hat{y}_7^-(\vec{x}_7),\ \hat{y}_7^+(\vec{x}_7)],$$

where $\hat{y}_7^-(\vec{x}_7)=\min_{\vec{b}7p\in\Omega}$ ($b_{07}p + b_{17}px_{17}x_{27}$); $\hat{y}_7^+(\vec{x}_7)=\max_{\vec{b}7p\in\Omega}$ (b07p + b17px17x27).

The meanings of the coefficients $\vec{b}_7$ (p-the number of the coefficients meanings) are represented in the table 6.

Table 6. The meanings of the coefficients $\vec{b}_7$

p	1	2	3	4
b_{07}	**317.529**	**322.169**	**322.211**	**329.280**
b_{17}	**-248.829**	**-322.924**	**-302.263**	**-393.762**

To check the adequacy of the model the comparison of the real interval meanings [y_{i7}] and predicted ones [$\hat{y}_{i7}$] has been hold. If x117=0.341, x127=0.183 then [y_{27}(x117, x127)]=[301.95, 304.97], [$\hat{y}_{i7}$ (x117, x127)]= [301.95, 304.97]. If x217=0.381, x227= 0.203, then [y_{27}(x217, x227)]= [295.9, 298.81], [$\hat{y}_{27}$(x217, x227)]= [295.9, 298.81]. If x317= 0.412, x327= 0.212 then [y_{37}(x317, x327)]= [292.8, 295.73], [$\hat{y}_{37}$(x317, x327)]= [292.8, 295.73]. If x417= 0.433, x427= 0.232 then [y_{47}(x417, x427)]=[289.75, 292.65], [$\hat{y}_{47}$(x417, x427)]= [289.75, 292.65]. Since the calculated meanings of the expenses pass through the all intervals of the experiment (table 5) the model is adequate.

Modeling enterprises economic activity influence on social and ecological environment by means of the Computer System has been used during the state ecological examination of the projects of maximum admissible throws for the range of enterprises of Ternopil (Ukraine). The models of expense on eleven classes of diseases have been built during the examination (1, 6).

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