COGNITIVE APPROACH TO PROBLEM SOLVING
OF SOCIAL AND ECONOMIC OBJECT DEVELOPMENT

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Abstract: The basic technique of problem-solving is structurization of knowledge about object and its environment and construction of a cognitive model. The technique includes monitoring of dynamics of factors of the model (their tendencies), analysis of the model structure with the use of SWOT-approach, and modeling that permits to determine and solve semi-structured problems. The technique allows supporting of a vital control task that consists in goal setting of socio-economic object development, as far as solution of discovered problems turns into the system development control task. The application of technique is useful when designing a strategy of development of social and economic objects.

1 INTRODUCTION

Traditional methods of decision theory concentrate attention on processes of search of optimal solution amongst the fixed set of alternatives in order to achieve accurately set goals. Problem identification, goal setting, and alternatives generating issues, as a rule, stay apart.

In real situations of social and economic object (enterprises, cities, regions, states, etc.) control there often arises a task, which consists in the analysis of a situation in order to reveal a problem and the reasons of it's appearance.

Cognitive approach to SEO modelling is directed to development of formal models and methods that support the intellectual process of problem solving owing to taking into account the cognitive abilities (perception, representation, cognition, understanding, explanation) of control agents.

The Institute of Control Sciences of the Russian Academy of Sciences has developed the technique of problem solving of SEO development on the basis of cognitive approach to modeling.

Cognitive modelling is a research of SEO functioning and development by means of creation of a situation model on the basis of a cognitive map. In the model a cognitive map reflects the subjective representations of a problem or a situation, connected with SEO functioning and development.

2 THE TECHNIQUE OF PROBLEM SOLVING OF SEO DEVELOPMENT

2.1 Construction of Model of SEO Development

The model construction is based on the cognitive structurization of knowledge about object and its environment.

The purpose of structuring is revealing of the most essential factors describe a "boundary" layer of interaction of object and external environment, and establishment of qualitative relationships of cause and effect between them.

The cognitive structurization is finished by formalization of singled out knowledge that consists in generalization of essential information into a system of basic factors.

Analysis of a graph model of a situation associated with a cognitive map allows to reveal the structural properties of a situation. The basis of the model is a weighed digraph $G = (X, A)$, where X is a set of nodes that biuniquely corresponds to the set of basic factors, A is a set of arcs reflecting the fact of direct influence of factors. Each arc connecting some factor x_i with some factor x_j has the weight a_{ij} which sign depicts the sign of influence of the factor x_i on the factor x_j, and the absolute value of a_{ij}

depicts the strength of the influence. Thus, the cognitive map can be examined as a connectivity matrix A_g of the graph G.

When constructing a cognitive map of SEO development set of basic factors, X, is grouped in blocks relevant to external environment, X^{ext}, and an internal environment SEO, $X^{int} = X \backslash X^{ext}$. Besides determination of factors and influence between them the vector of initial factor trends, $X^{ext}(0) \cup X^{int}(0)$, is established.

The dynamic model is constructed to obtain a new knowledge of structure and dynamics of situations under research. On the basis of that model the one carries out scenario research with use of methods of computer modelling of self-development and controlled development of SEO (Maximov, 2001; Maximov and Kornoushenko, 2001; Avdeeva, et al., 2003; Makarenko, et al., 2004).

Behavior of factors in time is described by dynamic linear model

$$x_i(t+1) = x_i(t) + \sum_{j \in I_i} b_{ij}\left(x_j(t) - x_j(t-1)\right), \qquad (1)$$

where $x_i(t+1)$ and $x_i(t)$ – value of factor i in t+1 and t time points accordingly, i=1, 2, …, N; $x_j(t) - x_j(t-1)$ = $\Delta x_j(t)$ – increment of factor x_j in t time point, describing the rate of change (tendency) of x_j; b_{ij} – strength of influence of factor x_j on factor x_i, corresponding to matrix B element (B = A_g); I_i –set of numbers of factors directly influencing the factor x_i.

The input parameters are the initial rates of change of factors (initial tendencies), that describe a situation's history. Actually, values of factors are not fixed, i.e. dynamics of change of a situation is being simulated on the basis of factors' increments.

2.2 SWOT-Analysis on the Basis of Analysis of the Model Structure

Generally, SWOT-analysis is expert determination of strength and weaknesses of SEO, opportunities and threats of its environment, and estimation of their interaction. Results of SWOT-analysis are represented as a matrix "Window of opportunities".

The mathematical procedure of generation of matrix "window of opportunities" on the basis of analysis of structural features of SEO development cognitive map has been worked out. Thus, there is no necessity in regular attraction of experts with all accompanying procedures.

The essence of the procedure of SWOT-analysis is the following.

Analyzing a situation of SEO development, it is possible to put forward various hypotheses about desirable dynamics of any factor of the model. So, the parameter "attitude to factor dynamics" (AFD) is brought in for each factor of the model. If dynamics of a factor is positive (negative) AFD is equal 1 (–1). If it is difficult to evaluate the factor dynamics its AFD is equal 0. The set of AFD vector on some set of model factors reflects desirable change of a situation in SEO.

Let's designate through $R^{ext}(X^{ext})$, $R^{int}(X^{int})$ vectors of AFD of factors of the external and internal environment, where $X^{ext} \cup X^{int} = X$; $X^{ext}(0)$, $X^{int}(0)$ – vectors of initial trends accordingly.

While the situation evolves each factor is being influenced not only by "neighbouring" factors, but also by more "distant" ones and these indirect influences are transferred through chains of the appropriate factors and graph arcs that connect them. Set of influences both direct, and indirect to which each factor in a situation is subject, is described with the use of concept of transitive closure of a cognitive map of the situation.

To determine the transitive closure it will suffice to consider N terms in a power series of matrix B, where N - the order of matrix B, i.e. number of basic factors in a cognitive map of a situation. Then the transitive closure of matrix B is estimated by matrix:

$$Q = E_N + B + B^2 + \dots + B^N \cong (E_N - B)^{-1} \qquad (2)$$

When constructing a matrix "Window of opportunities" opportunities and threats of the environment, strengths and weaknesses of SEO are determined on the basis of observation of the dynamics of model factors and estimations of their integrated influence on desirable dynamics of factors $R^{ext}(X^{ext})$ и $R^{int}(X^{int})$. The significance of strengths and weaknesses of SEO is determined as well.

Let us introduce the basic definitions.

Definition 1. If the initial trend of the internal environment factor, $x_i^{int}(0)$, is negative, i.e. does not correspond to a desirable direction of change (AFD), the given factor is regarded as a weakness of functioning and development of SEO, otherwise (the trend is favourable) - as a strength of object. The weaknesses determine internal threatening trends to SEO development, and strengths - internal favourable trends.

Using a terminology of SWOT-analysis, we shall designate X^{st} – a subset of factors–strengths of SEO, X^w – a subset of the factor–weaknesses of SEO, $X^{st} \cup X^w \subset X^{int}$.

Definition 2. The initial factor trend from X influences positively on desirable dynamics of the factor from X if the following is fair

$$sign(x_i(0)q_{ij}) = r_j(x_j),$$

where q_{ij} – (i,j) element of a transitive closure matrix Q, which determines integrated influence of i factor on the j factor; $q_{ij}=0$ if x_i does not influence x_j.

If AFD of some factors are given equal to zero $(r_j(x_j) = 0)$ such factors are excluded from the analysis (integrated influences on them of other factors are not taken into account).

The following definitions follow from definition 2.

Definition 3. The factor of an environment x_i^{ext} is neutral for X^{int}, if the initial trend of this factor does not influence $(q_{ij}=0)$ the desirable dynamics of all factors of the internal environment of SEO, X^{int}.

Definition 4. The factor of environment x_i^{ext} characterizes the opportunity for SEO development if the factor is not neutral and its initial trends does not negatively influence (through the appropriate integrated influences) the desirable dynamics of all factors of internal environment of SEO, $R^{int}(X^{int})$. In other words the initial trend of factor x_i^{ext} promotes SEO development in a desirable direction.

Definition 5. The trend of the environment factor x_i^{ext} threatens the SEO development, if it negatively influences (through the appropriate integrated influences) desirable dynamics even of one factor of internal environment $x_j^{int} \in X^{int}$.

Using a terminology of SWOT-analysis, we shall designate X^{op} – a subset of factors–opportunities for SEO development, X^{th} – a subset of factors–threats to SEO development, $X^{op} \cup X^{th} \subset X^{ext}$.

Definition 6. The internal environment factor, x_i^{int}, is neutral for X^{ext}, if the initial trend of the factor does not influence $(q_{ij}=0)$ the desirable dynamics of the environment factors X^{ext}.

Definition 7. The internal environment factor, x_i^{int}, promotes strengthening of the opportunity of environment x_j^{op} if x_i^{int} is not neutral and its initial trend favourably influences (through the appropriate integrated influence) the desirable dynamics of the factor x_j^{op}. Otherwise x_i^{int} promotes decrease of the opportunity of environment.

Definition 8. The internal environment factor x_i^{int} promotes parrying of threats of environment x_j^{th} if x_i^{int} is not neutral and its initial trend favorably influences (through the appropriate integrated influence) the desirable dynamics of the factor x_j^{th}. Otherwise x_i^{int} promotes strengthening of threats of environment.

On the basis of definitions 1-8 SWOT-analysis comes to the following stages:

1. Building of cognitive map of SEO development with extraction of external X^{ext} and internal blocks of factors. Vector of initial trends of factors $X^{ext}(0)$ and $X^{int}(0)$ is set.

2. AFD for each factor $R^{ext}(X^{ext})$, $R^{int}(X^{int})$ is set.

3. Strengths and weaknesses for each object (X^{st} and X^w) are found on the basis of the vector $X^{int}(0)$.

4. Matrix of transitive closure Q (2) is used to build

− matrix "Window of opportunities ext-int" on the basis of which opportunities X^{op} and threats X^{th} of environment and their importance (how great is their influence on factors of internal environment) are determined, $X^{op} \cup X^{th} \subset X^{ext}$;

− matrix "Window of opportunities int-ext" with the purpose of determination of internal opportunities of SEO that can neutralize the threats of environment X^{th}, and also the problems connected with possible negative influence of SEO on environment X^{ext};

− matrix "Window of opportunities op-th". The analysis of interferences between opportunities and threats allows to reveal opportunities which promote parrying of threats;

− matrix "Window of opportunities st-w" for revealing the latent internal opportunities allowing to remove weaknesses of SEO due to advantages.

As a result of the analysis all factors are being grouped into the following classes: S (Strengths), W (Weaknesses), O (Opportunities), T (Threats). Factors inside of each class are being ranked according to the force of their favourable (unfavourable) influence on the factors of another class. This procedure lets us estimate the importance of strengths and weaknesses, opportunities and threats for SEO development.

2.3 Structure and Goal Analysis of SEO Development

When setting the goals of a SEO development a decision maker doesn't always manage to trace if the goals he has set are inconsistent, i.e. reaching of a goal will prevent from reaching of another one. Inconsistency of goals can also be influenced by the chosen ways of their reaching.

Thus, it is very important to reveal the contradictions already at the stage of goal setting.

The technique of the structure and goal analysis of SEO development. allows to determine integrated (direct and all possible indirect) influences of one factor on the other and due to it to reveal

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inconsistencies between goal and control factors. The structure and goal analysis also allows to determine the most effective controls.

Thus, the structural analysis of cognitive model of a situation development under control consists of the following stages:

Stage 1 - analysis of goals (coordinates of a vector of goals) on mutual consistency in order to answer the question "whether the vector of goals (fixed or unfixed) is inconsistent, i.e. whether the reaching of any of goals (coordinates in a vector of the given goals) will prevent from reaching of other goals?"

When the consistent vector of goals is formed the desirable integrated change of any of goal factors will not result in undesirable integrated change of other goal factors in a vector of goals.

Stage 2 - check of a consistency of the set of control factors with the given vector of goals, i.e. whether the change of the value of any control factor (with the help of the appropriate control) will promote reaching of some goals in a vector of goals and at the same time prevent from reaching of other goals of a vector of goals.

Stage 3 - estimation of efficiency of influence of control factors on all coordinates of the vector of goals. Such estimation is useful when choosing the most effective control factors the changes of which with the help of the selected control actions will provide the purposeful development of a situation.

Formally, the parameter of efficiency is determined as absolute value of the sum of coefficients of influence of the given control factor on the goal factors multiplied by AFD of the goal factors.

2.4 Scenario Modelling

Scenario research (Maximov, 2001; Maximov and Kornoushenko, 2001; Avdeeva, et al., 2003; Makarenko, et al., 2004) allows to develop various variants of SEO development in view of arising trends (favourable and negative) of environment.

Scenario consists of a set of factor trends describing a situation at the present moment, desirable goals, a set of activities that are used upon the running of a situation, and system of observable parameters (factors) illustrating behaviour of processes.

Self-development of a situation represents evolution of an initial condition of a situation in SEO. Results of such modelling answer the question: what can take place of the existing trends of SEO development are preserved?

Controlled development of a situation is determined by the chosen goal of control.

On the basis of results of SWOT- and Structure and goal analysis we form the set of vectors of goals of SEO and vectors of controls that reflect possible strategy of secure SEO development.

The combination of the stages described above enables one to diagnose and define problems in SEO development and find ways of its solution and form well-founded goals and strategy of SEO development.

3 CONCLUSIONS

The result of application of the technique is the project of strategy of SEO development in the form of goals and main ways of its reaching. Goal-setting issues from forecasting and analysis of problems. Cognitive model, which is used in the basis of the technique, gives an opportunity to use monitoring data and quickly correct models with the purpose to analyzing new problems.

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