Kornoushenko E., Maximov V. (2001). Cognitive Model for Correction and Tactical Management of Enterprise Activity.
Proceedings of the IFAC Symposium on Modelling and Control of Economic Systems (SME 2001).

COGNITIVE MODEL FOR CORRECTION AND TACTICAL MANAGEMENT OF ENTERPRISE ACTIVITY

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Abstract: Qualitative method of correction and tactical control of enterprise activity is proposed. The basic accent is done on account an interference of enterprise parameters and interests of actors to be included in enterprise activity.

Keywords: Enterprise, goal, objectives, activities, Balanced Scorecard Collaborative, participant, interest of participant, cognitive model

1. INTRODUCTION

One of the most known and prevailing approach to complex systems control is based on the so-called the Balanced Scorecard Collaborative (BSC) (Missroon, 1999; Missroon, 2000; The eight key factors in evaluating Balanced Scorecard Systems, 1999). As is denoted in Missroon, (2000), "to develop an effective BSC, one must begin with enterprise vision (i.e., mission). Next, while keeping organizational structure in the mind, managers must decide which strategic objectives will lead to successful goal attainment. Managers then decide which strategic initiatives will assist the enterprise in meeting strategic objectives. Strategic initiatives are translated into specific tactical performance-driving activities. Finally, metrics are established for each activity. These become the enterprise performance measures. Now management has a framework of interrelated performance measurements".

Unfortunately, many managers consider Key Performance Indexes (KPIs) as isolated ones and don't take into consideration their interferences when making strategic and tactical decisions. Because of this some erroneous decisions are possible. It should be noted that KPI interferences aren't considered explicitly in the BSC.

Limitations of BSC (in our opinion) consist in the following:

- A choice of initiatives is realized with use of the direct relationships "cause-and-effect". The complex structure of indirect influences through chains of intermediate parameters is not taken into account;
- The interests of actors (structural divisions, personnel) realizing various phases of an enterprise activity (material supply, production cycle, selling, etc) aren't taking into consideration in any way in BSC. However, the coordination of actors' interests with strategic enterprise goals contains large opportunities for effective performance management.

In the approach for correction and management of enterprise activity to be offered in present work the basic accent was done on elimination of BSC limitations mentioned above, i.e.:

- Qualitative analysis of parameters interferences and representation these interferences as appropriate graph structure (cognitive card) is the basic stage of the approach;

- The required adjusting actions (corrections) are calculated by an algorithmic way as the solution of inverse dynamic problem;
- In obtaining solution of inverse problem the actors' interests are essentially taken into account;
- The solution of inverse dynamic problem specifies (at qualitative level) directions of proper ways to improve the effectiveness of the enterprise tactical activity from standpoint of its financial and economic parameters.

2. QUALITATIVE APPROACH FOR CORRECTION AND TACTICAL MANAGEMENT OF ENTERPRISE ACTIVITY

2.1 Basic factors interference graph

As a complex socio-economic system an enterprise involves various subsystems such as organizational, administrative, economic ones, etc. Each of these subsystems is characterized with some input and output material and financial flows. The key indexes of these flows will be called as basic factors. The basic factors set includes also key indexes of external environment influencing intensely on the enterprise activity.

Basic factors interference graph is defined as follows. Graph nodes correspond one to one to basic factors. Arc *(i, j)* drawn from node i to node j depicts the fact that the change of value of factor x_i induces directly the change of value of factor x_j. Arc *(i, j)* has a sign "+", while this direct influence is "positive" (i.e. an increase of the factor x_i induces an increase of factor x_j) , and a sign "-" in an opposite case.

To construct the basic factors interference graph, it is necessary to understand all peculiarities of the enterprise under consideration and all interconnections between its subsystems and to use also its account and management data. Each direct influence from some factor to another one is stated on the basis of:

- Corresponding economic or social well-known law,
- Empirical dependencies if these dependencies for given pair of factors were stated and verified,
- Expert conclusions.

Let us denote the basic factors interference graph as $G_1 (X_1 , A_1)$, where X_1 be the basic factor set, A_1 be the adjacent matrix (with taking the signs of arcs into account) of graph G_1 .

<u>*Assumption 1.*</u> The factor influence signs are invariable on the time horizon under consideration.

Naturally, the factor influence signs may vary in an enterprise activity. However, an allowance of assumption 1 enables to propose and to prove the qualitative (cognitive) approach to management of enterprise activity. At the same time the steps of qualitative approach, i.e. choice of strategic goals, initiatives, and activities are the same as in the BSC method.

2.2 The actors set

We will consider separate structural divisions (which according to expert opinion may affect severely on the enterprise activity) as actors. This implies that the basic factor set consists necessarily actors' factors as a subset.

Each actor to be the active participant in an enterprise activity has some goals at any time of his activity and some set of measurable KPIs is corresponds to each goal. Goal factors of the *k*-th actor at time *t* make some subset $Z_k (t)$ in X_1 . The *k*-th actor's goal at time *t* is a vector $z^*_k (t) = (z^*_{k1} (t), z^*_{k2} (t),\dots, z^*_{kn} (t))$ with prescribed values of its coordinates from $Z_k (t)$ to be the most desirable to the *k*-th actor at time *t*. This goal may be consider as strategic or tactic one depending on degree of mutability of external and/or internal conditions for an enterprise activity. A choice or change actor's goal depends on many non-formalized reasons: changeable actor's interests, his prognosis of future enterprise state, etc.

The actor's attitude to alteration of its goal factors at time *t* is represented as signed vector $R_k (t) = (r_{k1} (t), r_{k2} (t),\dots, r_{kn} (t))$, where each coordinate $r_{ki} (t)$, $i = 1,\dots,n$ is defined as

- +1(-1), while its increase is considered by the actor as event to be favorable (adverse) to him,
- 0, while the change of this coordinate is indifferent for the actor.

We will say that vector $R_k (t)$ defines the *k*-th actor interests at time *t*. Interests of some actors may coincide or may be partially or completely contradictory at time *t*. Therefore the administration's problem is to attain such state of affairs when interests of all actors to be privy to enterprise activity make agree in the best way with global goals of enterprise stable evolution. In the framework of qualitative approach such coordination of actors interests is represented as minimization as far as possible the number of unmatched coordinates in vectors of their interests when these vectors are compared with the administration's interest vector.

Actors to be active elements influence severely on enterprise activity by means of various admissible actions. In the framework of qualitative approach some set of so-called control factors from X_I is corresponded to each actor. The k-th actor's control factors are "the leverages" which the k-th actor may use directly to influence on enterprise activity. In the basic factors interference graph this "leverage" using is represented as direct change of control factor value. These changes are transferred via chains of "intermediate" factors to another factors and so on. As a result, an initial state of enterprise will run some trajectory in factor phase space. By analogy with BSC, we may say that a choice and concrete change of k-th actor's control factors may be interpreted as his initiatives to achieve his goals (objectives).

2.3 A qualitative model of the enterprise activity

To construct a qualitative model of the enterprise activity, first of all it is necessary to define the notion "a state" of model. A choice of appropriate definition for "state" isn't well-defined because it depends on completeness of information to be obtainable to an analyst. We accept the following assumptions.

Assumption 2. a) Let Δt be the length of some time intervals such that current information about the enterprise activity is disposable to the analyst at boundary points of these intervals only. The value of Δt may be equal to one day, one week, one month, etc.

b) At any time some "reference" value may be correlated to any basic factor and current value of this factor is compared with this "reference" value. Current qualitative state of this factor is defined as some function of current value of this factor and corresponding "reference" (for example, planned) value. Such function may be relative deviation from planned value (from moving average, etc). Some scale is chosen for representation the factor qualitative values.

c) Difference of factor qualitative value at time t is defined in a natural way as $\Delta x(t) = x(t) - x(t-1)$, where $x(t)$ is the qualitative value of factor x at time t.

Assumption 3. The basic factor interference graph is the same from the standpoint of any actor (i.e. all direct influences from some factor to another one are known to each actor).

A qualitative model of the enterprise activity from standpoint of k-th actor has the form

$$x(t+1) = x(t) + A_{I\,m}\,\Delta x(t) + B_k\, u_k(t), \qquad (1)$$

$$z_k(t) = C_k(t)\, x(t), \qquad (2)$$

where elements of matrices B_k and $C_k(t)$ indicate the numbers of control factors and goal factors of k-th actor at time t correspondingly and $u_k(t)$ be the control vector, i.e. vector of forced changes of control factors to be done by k-th actor at time t. Matrix $A_{I\,m}$ is obtained from transposed matrix A_I in a following way: each element $a_{i\,j}$ of transposed A_I is divided by factor $(s_i + \varepsilon)$, where s_i be a number of non-zero elements of i – th row of A_I and $\varepsilon > 0$ - some small value to assure the stability of the resulting matrix A_{Im}.

It is necessary to note that some constraints may be imposed on qualitative factor admissible values. Particularly, the most frequent constraint is non-negativity of qualitative values, i.e.

$$x(t) \geq 0. \qquad (3)$$

It follows evidently from (1) that each point in phase space of the enterprise activity is characterized qualitatively by its coordinates and current movement direction.

Cognitive model (1)-(3) is a structured and simplified dynamic description of enterprise activities interferences. It is unlikely that its equations represent directly the time dependencies between various factors even in qualitative form. However, the signs of influences from any factors to another ones may hold true on chosen horizon. It is the assumption that enables one to use this model and in its framework to find the direction of action of each actor, i.e. signs of control factor disturbances to be done by actor subject to current situation state and actor's goal. Then keeping these direction signs in the mind, the actor may choose admissible initiative (scenario) and calculate the consequences of his actions. It is such possibility that enables one to say about practical availability of proposed model.

2.4. Choice of control vector at time t by k-th actor

Let $x(0)$ and $\Delta x(0)$ be an initial qualitative state and its difference correspondingly and let absolute values of current differences considerable less than corresponding coordinate values. While any actor doesn't disturb any control factor, we obtain subject to (1):

$$x(t) = x(0) + (\sum_{k=1}^{t} A_{1m}^{k})\Delta x(0).$$

In view of stability of the matrix A_{Im} the series $\sum_{k=1}^{t} A_{1m}^{k}$ is convergent. Therefore one may consider some finite number of initial summands, say, N, where N be total number of basic factors. So, the initial state $x(0)$ is transferred to time-independent state x_{t-i}

$$x_{t-i} = x(0) + (\sum_{k=1}^{N} A_{1m}^{k})\Delta x(0) \qquad (4)$$

in view of (4). If values of k-th actor's goal coordinates in vector x_{t-i} are closed to corresponding ones in k-th actor's goal vector $z^*_k(t)$, the actor suppose that a situation evolves in "right" direction and he hasn't to intervene in its evolution. But in opposite case he has to change the direction of evolution with use of appropriate control vector.

Assumption 4. We consider that:

a) By virtue of the fact that cognitive model is very approximate, periodic correlation of its state with current qualitative values of basic factors of the enterprise activity is necessary. Such correlation is realized at times to be referred as correction ones (and be denoted by t with star);

b) Forced changes of coordinates of k-th actor's control vector are pulsed ones and are put in correction times only;

c) Between two correction times an influence from each factor is transferred to any factors connecting to it;

d) Each actor changes his goals more rarely in comparison with distance between two adjacent times of correction.

Let $x(t^*)$ be corrected state of the model. Subject to (1)-(2) and (4) the vector $z_k(t^*+\Delta t)$ of the k-th actor's goal coordinates at time $t^*+\Delta t$ is defined as

$$z_k(t^* + \Delta t) = C_k(t^*)x(t^*) + C_k(t^*)(\sum_{k=1}^{N} A_{1m}^{k})\Delta x(t^*) + C_k(t^*)(\sum_{k=0}^{N} A_{1m}^{k})B_k u_k(t^*). \qquad (5)$$

Let us denote

$$C_k(t^*)(\sum_{k=1}^{N} A_{1m}^{k}) = W_1(t^*)$$

$$C_k(t^*)(\sum_{k=0}^{N} A_{1m}^{k})B_k = W(t^*)$$

$D_k(t^*) = z^*_k(t^*) - C_k(t^*)\,x(t^*) - C_k(t^*)\,W_1(t^*)\,\Delta x(t^*)$,

where $z^*(t^*)$ be the k-th actor's goal vector at time t^*.

Subject to (5) we have

$$W(t^*)\,u_k(t^*) = D_k(t^*). \qquad (6)$$

We find the solution of equation (6) with use of least squares method. The normal solution of (6) is

$$u_k(t^*) = W^+(t^*)\,D_k(t^*), \qquad (7)$$

where $W^+(t^*)$ be the pseudoinverse matrix for matrix $W(t^*)$.

The solution (7) will be called as the inverse problem solution. The solution (7) indicate:

- Which control factors are to be taken into account by the k-th actor at time t^*;
- To what extent and in which direction the actor should change each chosen factor to approach to his goal vector $z^*_k(t^*)$.

While each actor calculates his control vector, it is assumed that he knows and uses complete structure of the graph G_1 and his actions don't depend on actions of other actors. If some actors act on the same control factor, its resulting change is an algebraic sum of changes to be induced by each actor.

3. REALIZATION OF ACTOR'S CONTROLS – THE GRAPH HIERARCHY.

The solution in form (7) of the inverse control problem may be interpreted, as the answer to question *what*, i.e. which actor's control factors should be changed to bring nearer the actor's goal at time t. Then one is to settle the question *how*, i.e. which concrete actions should an actor make to change his control factor in accordance with (7).

Let us supposed that each "concrete" action (to be considered as "a cause") be interpreted as corresponding change(s) of some factor(s) belonging to some set X_2 of "concrete" factors. "Consequence" of this cause consists of change(s) of some control factor(s) in X_1. Moreover, this "consequence" may include also changes of another factors in X_2, which aren't control factors from X_1. So, the concrete action choice problem in X_2 is analogical to control factors choice problem in X_1 and is solved with use of graph $G_2(X_2, A_2)$ (the lower level graph) to be constructed analogically to graph $G_1(X_1, A_1)$ (the upper level graph). In graph G_2 the set X_2 is an union of a set of "concrete" factors and the set of control factors from X_1 and A_2 is an arcs set representing the interference of factors from X_2. The goal set and the control factors set are defined for each actor in G_2 as well as in G_1. It should be noted that the actor's goal factors set in X_2 is his control factors set from X_1.

The following variants of graph G_2 are possible:

a) Set X_2 consist of the control factors of G_2 and G_1 only and graph G_2 is a set of unconnected pairs "cause – and – effect". In other words, there is the only control factor in X_1 for any control factor in X_2 such that a change of control factor in G_2 induced a change of only corresponding control factor in G_1 (to be the corresponding goal factor in G_2). This is the simplest case of realization of controls (7) obtaining from graph G_1.

b) Elements of set X_1 to have been included in X_2 are the control factors only. In this case inverse control problems in graphs G_1 and G_2 may be solved independently, i.e. at first in G_1 and then in G_2 . In addition, any actor's action to be the inverse control problem solution in G_2 will bring nearer (in the framework of specified assumptions) his goal at time t* in G_1, while other actors are idle. In other words, in this case there is *transitivity of goal attainment* from lower to upper level in graph hierarchy.

c) Set X_2 includes the control factors from X_1 and some other factors from X_1. In this case the inverse control problem is to be considered in the same way on the union of graphs G_1 and G_2. For more details specific consideration is needed.

In these cases the result of simultaneous actions of all actors may be obtained by modeling only.

Some situations are possible when the graph hierarchy is to be continued, i.e. consideration of graph G_3, G_4 ,… of lower levels is needed.

Mathematical Basics of Construction the Graph and Computer Models for Complicated Situations may be seen in Maximov V. and Kornoushenko E. (*In: this issue)* and on http://www.ipu.ru/labs/lab51/51_home.htm

4. CONCLUSION

Conceptual approach to a choice of actions by actors with accordance to their interests was considered. This question is related closely with a problem of an enterprise activity control. Some basic notions using in proposed approach are the same as in BSC-methods. But underlying difference is confined in that here actors influence to an enterprise activity is token in account and actors actions to be realized to bring nearer their goals are defined by algorithmic way as solutions of corresponding inverse control problems.

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