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The System Concept in Economic Cybernetics

From the cybernetic standpoint, the utilization of the system concept in the science of management substantiates the fundamental concerning the essential functions of management.

1. CYBERNETICS AND ECONOMIC MANAGEMENT

The problem of management and economic organization improvement has recently become one of the most interesting research subjects. Owing to its complexity and its implications, this problem makes available to research workers, production organizers, various experts, as well as to the bodies for decision making and economic synthesis, a wide field allowing debates and analyses in order to tackle new concepts during the process of improving the mechanism of economic management and organization.

Starting with the significant mutations which are fundamentally converting the traditional economic environment, the conclusion has been reached, according to which the formulation of a new concept in enterprise management is required. In the opinion of many specialists, this is the most effective way of facing the future.

Among the concepts which have most recently been introduced in management science, are also those in the field of cybernetics.

In order to emphasize the relationship existing between cybernetics and management, assuming the acknowledgement of the thesis according to which these concepts can be extended to the economic area, the production units, the economic branches, or economy as a whole, are considered to be cybernetic systems, whose development is always caused by a management effort based on the feedback principle.

Out of the great number of concepts which are now ascribed to cybernetics, we consider that the concepts of *system*, *information* and *entropy*,

control and self-control, *activity* and *transfer function*, as well as of *feedback*, are particularly significant for economy.

Considering that the development of the cybernetic concept on economic management and organization involves the elucidation of some general factors associated to the application of the respective concept in the economic field, we dedicate the present paper to the idea of system.

2. THE CONCEPT OF AN INDEFINITE SYSTEM WHATEVER

Definition: a system is part of the objective reality which can be defined through the instrumentality of a transformation structure *). According to this definition, an indefinite system whatever $\mathcal{S}$ can be mathematically described by a structure of basic sets **A**, **B**, **C**, ... and a set of operators

If, however, at one time we wish to set apart this system, in order to examine it as an isolated entity, it can also be described as follows:

$$\mathcal{S} = \{X,\ Y \mid \mathbf{A}\} \tag{1}$$

where X is the set of input elements;

Y is the set of output elements;

A is the set of activities, functions of the system $\mathbf{A} = f, \varphi, \rho, \ldots,$ where $\alpha, \varphi, \rho \ldots,$ play the part of transformation operators.

It is well-known in automatics that the relationship between the input and output signals is featured in an indefinite case whatever, as

$$y = Ax \qquad A \in \mathbf{A}$$

and in special cases

$$y = Fx,\ y = Lx, \qquad y = Hx, \ldots$$

where F, L, H, ... are the integral (or serial) transforms of Fourier, Laplace, Hilbert, etc.

Meanwhile, we shall restrict ourselves only to pointing out the possibility offered by the assumption in the above definition, i.e. of considering that the activities pertaining to a real system may always be viewed as transformation operators; we shall see in later sections that this assumption allows the application of the system concept, like the other concepts of general cybernetics, to the field of economy; moreover — by using the symbolic computation — we will be able to describe the respective phenomena, as nearly as possible to their real content.

Further, depending upon the mutual relationship existing among the constituent elements of the systems structure, and by taking into account the time factor as well, we will be able to define the existence of the following *classes of indefinite systems:*

Systems not related to time or *constantly operational*

These are the systems where there invariably exists a constancy of the operation (the operational constancy).

$$\mathcal{S} = \{X,\ Y \mid A\}$$
$$x,\ y = f_\alpha(t) \tag{2}$$
$$A = A[t_0] = \text{operatorial constant}$$

*) It is to be pointed out that this is an attempt to define the concept of some indefinite system, so that it entitles us to introduce the concept of cybernetic system.

Time systems.

These are the systems where the operational conversion is always time-dependent:

$$\mathcal{S} = \{X,\ Y \mid A\}$$
$$x,\ y = f_\alpha(t) \tag{3}$$
$$A[t_1] \neq A[t_0]$$

Evolutionary systems.

These are time systems characterized by the property of never returning to a state they once experienced.

$$\mathcal{S} = \{X,\ Y \mid A\}$$
$$x,\ y = f_\alpha(t)$$
$$A = A[t] \text{ and } A[t] = \Omega A[t_0]$$

We associate an efficiency function to the system

$$\psi = \psi(t)$$

Within this class of systems, we differentiate the following sub-classes depending upon the relationships existing between $\psi(t)$ and $\psi(t_0)$:

if $\psi(t) < \psi(t_0)$ we have decreasing systems;
if $\psi(t) = \psi(t_0)$ we have static systems;
if $\psi(t) > \psi(t_0)$ we have increasing systems.

We obviously have in all cases:

$$A(t_i) = \Omega A(t_{i-1}) \quad t_i \in (0, +\infty)$$

3. THE CONCEPT OF SYSTEM IN ECONOMIC CYBERNETICS

It is a well-known fact that, by definition, a cybernetic system is a system endowed with feedback.

It is further known that a class of systems $\mathcal{S}_1, \mathcal{S}_2, \ldots, \mathcal{S}_n$ having the transfer functions $A_1, A_2, \ldots, A_n$ associated together, make up also a cybernetic system, on condition that $\mathcal{S}_1 \cap \mathcal{S}_2 \cap \ldots \cap \mathcal{S}_n \neq \emptyset$.

Hence, the well-known basic property of cybernetic systems, according to which they can be decomposed in sub-systems which are mutually transmitting information — thus exerting a mutual influence — and which aim to achieve a process of self-adjustment for the system as a whole.

The above mentioned property is, in our opinion, the starting point on which the idea of extending the concept of cybernetic system to the economic activity is based. Our hypothesis is then that systems can be associated even if they have a heterogeneous structure. Indeed, by assuming the following definitions as being admitted:

Message = a specific form reflecting the objective reality;

Information = a group of messages allowing the featuring and conveying, through a material carrier, of some structural attributes of a system;

Entropy = the size of the quantity of information (the degree of undetermination of a system); it may be calculated by using the relations developed by Claude E. Shannon or H. Hatori.

The above hypothesis allows to consider that if **E** is a *system* with *economic* elements, represented through *time functions* (management, control production, dissemination and information, etc.) it is a cybernetic-economic system, whose basic operators can be defined as follows:

1. $\mathbf{E} \rightarrow \alpha(\mathbf{E})$, α = the operator of the system's management activity. This operator takes into account the possibility of the values determining the management operations, to be evenly approximated through superposed time functions.

2. $\mathbf{E} \rightarrow \rho(\mathbf{E})$, ρ = the operator of the system's control activity. This operator takes into account the effects of the information exchange on programming, control, monitoring, which can similarly be described through superposed functions.

3. $\mathbf{E} \rightarrow \varphi(\mathbf{E})$, φ = the operator of the system's production activities; the mathematical description can be achieved through many types of time functions which are the object of a vast economic research.

4. $\mathbf{E} \rightarrow \gamma(\mathbf{E})$, γ = the operator of the system's dissemination activities.

5. $\mathbf{E} \rightarrow \sigma(\mathbf{E})$, σ = the operator of the system's technical and information activities. The latter two operators are also the object of a great number of investigations in the fields of econometrics, informatics, scientics, operations research, etc.

On this basis, it can be assumed that some model of a cybernetic-economic system refers to a system operating on set **E** (input and output elements) with the previously defined basic operators. The symbolic expression of this model is:

$$\mathbf{E} = \{X,\ Y \mid \alpha,\ \rho,\ \varphi,\ \gamma,\ \sigma\}.$$

The existing relationships among the basic operators express the system's general activity, its organization, management and effectiveness as compared to production and circulation.

In this context we consider that in transposing the concept of cybernetic system to the economic field, the follwing definition can be taken into account: *A cybernetic system is an aggregate of interacting elements comprising human beings, objects of labour and equipment, whose activities of handling, processing and control of materials, information, energy and human activities aim at achieving a previously established program determined by a management effort based on the principle of feedback.*

By keeping the basic feature of cybernetic systems, the economic systems can be dissociated in subsystems, which mutually transmit activities and information affecting each other and aiming at achieving a self-adjustment process.

The most simple system (irreducible system) can be regarded as being the working space, where the most organic combination of the three basic elements is accomplished.

This cybernetic system best emphasizes the distinction to be made between the *carrying out* and the *management functions*, which are mainly aiming to work out and provide a predictive development (evolutionary) program for the respective sub-system.

By extending the dissociation of the system's functions in the two categories, to the complex (reducible) systems, it is possible to consider that each function is associated to a set of activities, according to relation:

$$\mathcal{S} = I \cup E$$

Where $\mathcal{S}$ = the structure of all activities belonging to the system;
I = the sub-structure of adjustment activities;
E = the sub-structure of carrying out activities;

The adjustment sub-structure I contains activities of the following type:

internal → internal
external → internal

Thus, depending on the type of performances (finalization), the adjustment sub-structure refers to the *internal* character of structure $\mathcal{S}$. The carrying out sub-structure **E** contains activities of the following type:

internal → internal
internal → external

Depending upon performances, the carrying out sub-structure refers to the *external* character of structure $\mathcal{S}$, the inner connections referring only to the operation proper.

4. THE IDENTITY CRITERION, ADJUSTMENT AND EFFICIENCY FUNCTIONS OF ECONOMIC SYSTEMS

In agreement with the previous definitions, it follows that any economic system is included in the class of evolutionary systems, which can be described at any time (t) through conversion structures, such as:

$$\mathbf{x} = \{\mathcal{A} \mid \cup, \cap, \times, \wp, f \ldots\}$$
$$\mathcal{A} = \{A_1, A_2, \ldots, A_n\}$$

where

$$n = n(x) \quad n < \aleph_0$$

If A_i stands for a set of numbers X_{ij}, then $X_{ij} \geqslant 0$

In structure **x**, we specifically discern a sub-structure $\tilde{\mathbf{x}}$, the numerical sub-structure of X representing the numerical

$$\tilde{\mathbf{x}}(t_0) = \{\tilde{\mathrm{A}} \mid \cup, \cap, \times, \wp, f \ldots\}$$

i.e.

$$\tilde{\mathrm{A}} = \{\tilde{A}_1, \tilde{A}_2, \ldots, \tilde{A}_n\}$$

Similarly, we can consider another production process

$$y = y(t_0)$$

at the time t_0, defined through structure

$$\mathbf{y} = \{\mathrm{B} \mid \cup, \cap, \times, \wp, f \ldots\}$$

where

$$\mathrm{B} = \{B_1, B_2, \ldots, B_n\},$$
$$n < \aleph_0$$

(In fact $n(x) = n(y) = n$ is not a constraint or a particular case, although some sets A_i or B_i may be void).

Similary

$$\tilde{\mathbf{y}}(t_0) = \{\mathbf{B} \mid \cup, \cap, \times, \wp, f \ldots\}$$

is the numerical sub-structure of $\mathbf{y}\ (t_0)$, defined analogously to $\mathbf{x}\ (t_0)$; obviously

$$\widetilde{B}_j = \{y_{1j}, y_{2j}, \ldots, y_{mj}\} \text{ with } y_{kj}\} \geqslant 0$$

If we reduce production processes to manufacturing stages bestowing them *homologous structures*, then, according to the structure theory, we can write:

If process $X\ (t_0) \sim$ process $Y\ (t_0)$ and process $Y(t_0) \sim$ process $Z\ (t_0)$, and relation $X\ (t_0) \sim Z(t_0)$ results, we can reach the following conclusion:

Production processes may be described through homologous structures *only if they belong to the same manufacturing stages.*

By further applying the equivalence formulas of sets to homologous structures, we can write: where card A = card B = card C, and where sub-structures $\mathbf{X}$, $\mathbf{Y}$, $\mathbf{Z}$: $\mathbf{X} \sim \mathbf{Y} \sim \mathbf{Z}$ are obviously homologous.

These definitions allow us to formulate the *process identity* criterion:

Several processes are identical if and only if the sets of determined structures are equipotential (one-to-one correspondence) and the homologous constituent parts, i.e. A_i, B_i, $\widetilde{A}_j$, $\widetilde{B}_j$ *... are also in one-to-one correspondence.*

Starting from the equivalence criterion of processes thus described, it will be possible to subsequently define the concept of *adjusted process.* We consider two systems $\mathscr{X}$ and $\mathscr{Y}$, and assume that after a certain time interval $T = |\, t_1 - t_0 \,|$, some changes take place in structure $\mathbf{X}$.

We shall assume for the moment that structure $\mathbf{Y}$ remains unchanged during this time interval. We shall obviously have:

$$\mathbf{X}(t) \not\equiv \mathbf{Y}(t) \quad \text{but} \quad \mathbf{Y}(t) = \mathbf{Y}(t_0)$$

This is possible even if card A = B, as x_{ij}, y_{ij} and we don't know even if there exists a relation between these elements.

If, however, we admit that $X\ (t_0)$, then we can make the basic assumption that between $X\ (t)$ and $Y\ (t_0)$ there exists a relationship whose significance will be established.

In order to determine if there is any relationship between these processes, we shall start from the homology of structures.

Since the cardinals of the sets and sub-sets associated to structures $\mathbf{X}$ and $\mathbf{Y}$ remain invariant, the problem to be solved is connected with the state of elements x_{ij} and y_{ij}; it is clear that

$$x_{ij}(t) = y_{ij}(t) \text{ for } t \in [0,\ t_0],$$

however,

$$x_{ij}(t) \neq y_{ij}(t) \text{ for } t \in (t_0,\ t_1);\ 0 < t_0 < t_1.$$

These differences can be explained on the basis of the *identity criterion*, by considering that, as a matter of fact, it is the same process which has, however, progressed in time. Thus, if among the elements of structures $\mathbf{X}(t)$, $\mathbf{Y}(t)$ there is an evolutionary-historical relation, we can introduce operators for each pair of elements in one-to-one correspondence: $y_{ij} = \Omega_{ij} \times X_{ij}$, operators Ω_{ij} being defined on the parts of numerical sub-structures.

Consequently, the control function is defined by the ability of the system to change its structure through conversion operators , keeping the fundamental elements it had at time $t_1 < t_2$.

From the cybernetic viewpoint, *the concept of controlled production process is included in the system concept.* In the economic field, this situation comprises *all production phenomena represented in a specific vector space* $R^n \times n$ *with an evolutionary property.* The above property expresses the fact that during a certain time interval (t_1, t_2) the process structure changes, according to certain programming previously established.

As to the *efficiency function of a system* it is to be noted that, as shown in structure X, a sub-structure $\mathbf{S}$ is specifically distinct, which is a numerical sub-structure of system $\mathscr{X}$ activities, representing the numerical sets:

$$A_\alpha = \{x_{1\alpha},\ x_{2\alpha},\ x_{3\alpha},\ , \ldots, x_{m\alpha}\}$$

The numerical sub-structure of system $\mathscr{X}$ activities is in turn solved in two numerical sub-structures:

$$I = (x_{1\alpha},\ x_{2\alpha} \ldots x_{m\alpha} \ldots)$$

$$F = (y_{1\alpha},\ y_{2\alpha} \ldots y_{m\alpha} \ldots)$$

Between these two sub-structures of the activities structure, the following relationships exist: card I + card $\mathbf{E}$ = card A,

$$\psi = \frac{\| A \| - \| I \|}{\| A \|}$$

By analyzing this function ψ, we derive the fact that is an *efficiency function*, since it shows the way in which the system responds to the adjusting activity, and simulatneously expresses the relationship between adjustment and efficiency.

In economy, the eficiency functions have always the following aspects:

$$\psi_\lambda = \psi_\lambda (n_\alpha,\ v_\beta,\ p_\gamma, \tau),$$

where

N = the set of manufactured objects, numerically represented by $n_\alpha \in N$

V = the set of vatriables showing the relative investment for the products in N, $v_\beta \in V$

P = the set of variables showing the relative cost of products in N, $c_\gamma \in P$

$\tau = t_1 - t_0$ = the recovering time of investments in V.

The efficiency function previously described shows that the most favourable case will be obtained if, and only if, the time interval during

which the system operates undisturbed is maximal (higher than, or at most equal to, the investment recovering term). This situation assumes the existence of a constant balance between the actual capacity of the productive unit and the quantity of products which is to be scheduled for the respective time period. This balance takes into account, as an esential element, the possible utilization of feedback during the entire production process.

In fact, such a view involves the compliance with the following primary condition:

$$K_u \cdot C \geqslant [N]_0^T$$

where K = efficiency coefficient
C = production capacity
N = production accomplished
T = reference time interval

5. CONCLUSIONS

The above reasoning leads to the statement of the hypothesis that, by extending the concept of cybernetic system to economy, the latter will comprise in its field the sum total of industrial processes as well as the elements causing the inner adjustment, that is their time progress.

From the cybernetic point of view, the utilization of the system concept in management science substantiates the thesis regarding the essential functions of management, among which the planning or predictive function, as well as the directing and control function are listed. At the same time, this concept involves the flexibility of the respective functions, the exclusion of rigidity, each program allowing, within certain limits, the possible self-adjustment of the system, and if necessary an adjustment of the program, such as to permit the system to respond more effectively and in the desired direction to the possible inner disturbances brought about by the functions of some other systems to which it is connected.

This fundamental can be quantitatively substantiated, as the limits within which a self-adjusting process has to be ensured depend on the value of the respective system's entropy, a problem not tackled, however, in this article.

The theory of modelling and economic process simulation is still young, hence the idea of self-adjustment viewed as an objective requirement in the evolutionary movement of economic phenomena is often disregarded, being replaced by the program with fixed minimal limits, the possibility of exceding them being admitted as much as possible.

In our opinion, the management phenomenon based on cybernetics must combine within a system the means of production, manpower and the labour objectives, based on a previously established production program, developed under an extremely wide scope and using a system of internal-internal, internal-external and external-internal connections, allowing the good performance of the self-adjustment functions of therespective system.

REFERENCES

1. BETHEL, LAWRENCE, L.: *Industrial Organization and Management.* Mc. Graw-Hill, Book Company, New York, 1956.
2. BEER, STAFFORD: *Management Science.* A Books Limited, London 1967.
3. BEER, STAFFORD: *Cybernetics and Management.* The English Universities Press Ltd., London, 1959.
4. BOURBAKI, N.: *Topologie générale.* Herman, Paris, 1951.
5. BONNIAN, J. and ROBINSON, V.: *An Investigation of Graph Simulation Computer.* The University of Chicago, the Institute for Computer Research, No. 14, August 1/1967.
6. CHAUFFIGNAL, L.: *La Cybernétique.* Press Universitaires de France, Paris, 1963.
7. CHORAFAS, D.N.: *La simulation mathématique et ses applications*, Dunod, Paris, 1966.
8. ELMAGHRABY, S.E.: *The Design of Production Systems.* Mc. Graw-Hill, New York, 1966.
9. FISHBURN, PETER C.: *Decision and Value Theory.* John Wiley & Son, New York, 1964.
10. GHIAŞU, SILVIU: *Aplicaţii ale teoriei informaţiei.* Editura Academiei R.S.România, 1968.
11. LANGE, OSCAR: *Introducere în cibernetica economică.* Editura Ştiinţifică, Bucureşti, 1967.
12. MĂNESCU, MANEA: *Preocupări cu privire la tehnica de elaborare a metodelor cibernetice în economie.* „Revoluţia ştiinţifică şi tehnică contemporană".
13. MAZUR, MARIAN: *Cybernetyczna teoria ukladow.* Samodzieluych, Warszawa, 1966.
14. MOISIL, GR.C.: *Elemente de logică matematică şi de teoria mulţimilor.* Editura Ştiinţifică, 1968.
15. NICOLAU, EDMOND and POPOVICI ALEXANDRU: *Cibernetica sistemelor discrete.* Editura Ştiinţifică, Bucureşti, 1966.
16. POUDEROUX, N.: *L'Entreprise et son avenir.* "Hommes et techniques", No. 264, 1966.
17. REITSMA and SAGALIN, I.: *Correlation Measures — Information Storage and Retrieval* Department of Computer Science, Cornell University, Ithaca, New York, December, 1967.

LE CONCEPT DE SYSTEME DANS LA CYBERNETIQUE ECONOMIQUE

Ayant pour fondement la théorie mathématique des structures, on démontre qu'un processus de fabrication X peut être, toujours, considéré comme étant un système possédant une structure de transformation qu'on peut exprimer de façon symbolique:

$$\mathcal{S} = \{X,\ Y \mid \mathbf{A}\}$$

où X, Y représentent les ensembles qui attestent les liaisons du système sous la forme: externe interne, interne-externe, et $\mathbf{A} = \{A_1, A_2, ..., A_n\}$ représente l'ensemble des activités internes internes, ou bien la capacité du système de réaliser des activités pratiques.

On met en formule le critère de l'équivalence des processus et on introduit la notion de processus dirigé

$$\mathcal{S}[t_\alpha] = \Omega_\alpha \mathbf{S}[t_{\alpha-1}],\ t_\alpha \in [0, +\infty]$$

où $\mathbf{S}[t_\alpha]$ représente la structure de transformation du système au moment t_α, $\mathbf{S}[t_{\alpha-1}]$ représente de façon analogue, la structure de transformation au moment $t_{\alpha-1}$, et Ω_α est la structure de transformation de l'opération relative à l'évolution du système.

Les exemples de classes de sytèmes cybernétiques appartenant à l'économie et les méthodes au moyen desquelles se réalise leur simulation mathématique, cités dans l'article, ont pour but la direction et l'orientation optimes des processus de production et économiques.

КОНЦЕПЦИЯ СИСТЕМЫ В ЭКОНОМИЧЕСКОЙ КИБЕРНЕТИКЕ

На основе математической теории структур доказывается, что процесс фабрикации X можно всегда считать системой с такой структурой изменения, которая может быть выражена символически:

$$\mathcal{S} = \{X, Y \mid \mathbf{A}\}$$

где X, Y являются множествами, доказывающими связи системы вида: внешняя — внутренняя, внутренняя — внешняя, $\mathbf{A} = \{A_1, A_2, ..., A_n\}$ является множеством деятельностей внутренней — внутренних, или способностью системы развернуть эффективные деятельности.

Формулируется критерий эквивалентности процессов и вводится понятие регламентированного процесса

$$\mathcal{S}[t_\alpha] = \Omega_\alpha \mathcal{S}[t_{\alpha-1}], \quad t_\alpha \in [0, +\infty]$$

где $\mathcal{S}[t_\alpha]$ представляет структуру изменения системы в момент t_α, $\mathcal{S}[t_{\alpha-1}]$ аналогичным образом представляет структуру изменения в момент $t_{\alpha-1}$, а Ω_α представляет структуру изменения операции, отнесенную к эволюции системы.

Примеры класса кибернетических систем взятые из экономики, и методы реализации их математического симулирования приведены в статье с целью оптимального руководства и управления производственными и экономическими процессами.