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"Nowadays cybernetics has an increasing importance in the management of industrial and economical processes, in reducing the human effort and in increasing the special productivity of man's work, in the overall progress of mankind".

NICOLAE CEAUŞESCU

from the Message addressed by the President of Socialist Republic of Romania to the Third International Congress of Cybernetics and Systems

Cybernetic Economic Systems

I. THE CONCEPT OF CYBERNETIC ECONOMIC SYSTEM

Cybernetics based on the creative application of generally — valid truth has enriched the gnostic arsenal of contemporary science by new functions of systemic and forecast investigation upon phenomena and processes in nature and society.

Cybernetic-economic, an interdisciplinary science, approaching the phenomena and processes taking place in economy, in a systemic manner, has substantiated the concept of cybernetic-economic system.

Cybernetic-economic systems, qualitatively different from other classes of systems, contain as an essential element the *man's direct and conscious presence fulfilling the functions of deciding, commanding, checking and controlling.*

The higher is one of these systems in the hierarchy of cybernetic — economic systems, from micro — to macroeconomy the more complex are its functions, qualitatively different from those of the component elements.

The presence of the human factor as essential element of the optimal operation of cybernetic-economic systems gives them a dynamic, alert and permanently improving character.

The identification of those properties defining the cybernetic-economic systems of the conditions for optimal, balanced, proportional growth of these systems allowed the permanent expansion of the practical application of economic cybernetics.

In this way economic cybernetics becomes a science of how to manage the complex, dynamic, alert and permanently improving cybernetic-economic systems, in which man has a leading role in deciding and implementing the decision.

The cybernetic-economic systems represent large sets of ordered elements, mutually interconditioned within a more complex structure and which represent in a logic manner a unitary whole. They behave as a homogeneous entity having its own properties and functions, qualitatively different from those of the component elements.

According to this way of thinking, a section of an enterprise, a production unit, a research or development department, an industrial corporation, a department, a branch, a territorial unit (village, town, city, county) or the entire national economy are regarded as cybernetic-economic systems. Cybernetic—economic systems have levels of different complexity according to the area encompassed by processes and phenomena to which they are associated.

A characteristic of elements composing a system is the fact that they behave as parts with respect to the system which integrates them and as systems with respect to their own structure. In turn, each element of a cybernetic-economic system could represent a system to which other systems subordinate. One should point out that the distinction between the notions of system, subsystem and element is relative, since it depends upon the purpose of the analysis considering them. These concepts should be understood in a dialectic manner, starting from the thesis on the world unity, according to which all systems are, in fact, ensembles made of other systems, hierarchically organized and mutually interacting on.

In this way, economic cybernetics regards the goods production as a complex system, composed of numerous parts representing its subsystems: industry, agriculture, buildings, transport, goods circulation, other branches. These, in turn, represent complex systems composed of a multitude of other subsystems. For example, the industry subsystems are: extractive industry, electrical and thermal power industry, metallurgy, machine building, chemistry, light industry, food industry a.c.

From the same point of view a metallurgical corporation, for example, is regarded as a cybernetic-economic complex composed of numerous sections, workshops and workplaces, representing its subsystems. In turn, the corportation can be regarded as a subsystem of the metallurgical industry, this itself being a subsystem of the industry system.

It must be emphasised that not all the properties of a system are also properties of its elements. In this way the national economy, regarded as a complex cybernetic-economic system, behaves like a homogeneous and unitary whole and it does not result as a simple summation of its branches and subbranches. The national economy system has multiple properties which are not entirely found at its components.

The concatenation of the components of a system into a unitary whole makes this able to perform a multitude of activities which could not have been performed in isolation from its elements.

The cybernetic-economic systems as well as their composing elements are characterized by the diversity of activities taking place within them (production, research and development, technology, work force recruitment and training, forecasting, planning etc.).

The activities taking place inside each cybernetic-economic system are generated — and in turn, generate — by multiple flows of workforce, raw materials, energy, money, information etc. The ensemble of the flows received from the other components of the national economy is the *system input vector*. The results of the activity performed within each cybernetic-economic system have the aspect of similar flows which are directed towards the other components of the national economy system; the ensemble of these flows in the *system output vector*.

Fig. 1. shows the main types of inputs and outputs pertinent to a cybernetic-economic system and Fig. 2 is a vectorial representation of the same inputs and outputs; u denotes the input vector and y — the output vector.

The functional dependence between the input and the ouput vectors of a cybernetic-economic system underlines the structure and the efficiency of the activities performed by the cybernetic-economic system under analysis.

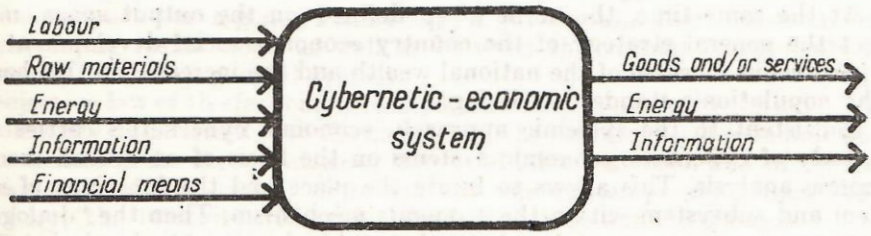

Fig. 1

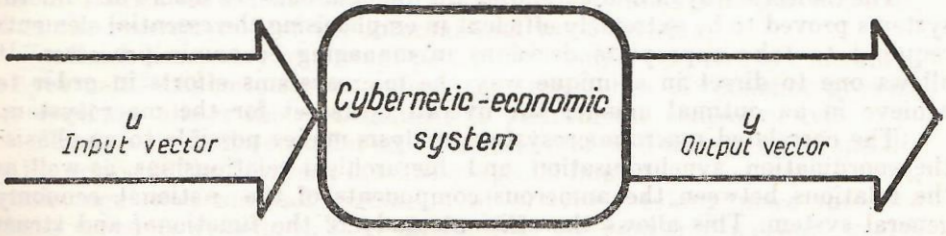

Fig. 2

If u is the input and y the output of a cybernetic-economic system, the pair

$$(u, y) \in U \times Y$$

is termed the *system activity*; U is the set of system inputs and Y the set of system outputs.

If the functional dependence between U and Y has the form

$$\Lambda: U \to Y$$

then Λ is called the *systems activity operator.*

One has to point out that the operator Λ of a cybernetic-economic system plays an extremely important part in elaborating the optimal growth models as well as in analysing the efficiency of the activities taking place within the cybernetic-economic systems.

If U and Y can be organized as normed vectorial spaces and the pair (u, y) is an activity of the cybernetic-economic model then the value of

$$Z(u, y) = \frac{\|y\|_Y}{\|u\|_U},$$

where $y = \Lambda u$ gives the efficiency of the activity (u, y). Here $\|\cdot\|_Y$ and $\|\cdot\|_U$ are norms defined on Y and U respectively.

Since U and Y are vectorial spaces with finite dimension one can use, apart from the usual Euclidian norm, other types, according to the purpose. The way in which these norms are defined is of major importance in building the economic-mathematical models of optimal growth processes. Thus, $\|\cdot\|_U$ defined on the input space must reflect the strategy of the efficient use of material and human resources, of the permanent reduction of the consumption of raw materials, energy and fuel.

At the same time, the norm $\|\cdot\|_Y$ defined on the output space, must reflect the general strategy of the country economic-social development, of the permanent increase of the national wealth and the increase, on this bases, of the population's standard of living.

Consistent to the systemic approach, economic cybernetics carries out the study of cybernetic-economic systems on the basis of an overall macro-economic analysis. This allows to locate the place and the functions of each system and subsystem within the economic mechanism. Then the "dialogue" macro-microeconomy can take place, thus achieving the symbiosis between the cybernetic analysis of macroeconomic and microeconomic systems.

The dialectic way of understanding the dialogue between macro and micro-systems proved to be extremely efficient in emphasising the essential elements required to take appropiate decisions in managing economic processes. It allows one to direct in a unique way the microsystems efforts in order to achieve in an optimal manner the overall tasks set for the macrosystem.

The correlated macro-microsystem analysis makes possible to emphasise the coordination, synchronisation and hierarchical relationships, as well as the relations between the numerous components of the national economy general system. This allows the efficient study of the functional and structural connections taking place within the national economy.

The foundation of the concept of cybernetic-economic system is based upon the analysis of its *connections*, *behaviour and functions* within the economic mechanism. These defining elements will be examined in what follows, together with their mathematical representations.

1. Connection. Feedback connection

The concept of connection and the objective law of the feedback are of fundamental importance in understanding the mechanisms governing the phenomena and processes taking place within the national economy system.

Economic cybernetics studies the properties of cybernetic-economic systems, having as main instrument the dialectic concept of connection, which expresses the links through which the system components are connected and interact.

The complex of connections which form between the components of a cybernetic-economic system represent the essential element which lends to it its unitary and homogeneous character. If the systems connections, i.e. the complex of interactions between its components disappear, it would become an amorphous mass of elements which would not form an unitary system.

Phenomena and processes in nature and society are coupled by multiple connections, being in a dynamic and continuos interconditioning.

The complex analysis of connections formed between the elements of the national economy system, analysis carried out in order to apprehend the laws of optimal, balanced and proportional growth is of capital importance, since it allows one to emphasize the place and the role of each component within the economic mechanism.

The concept of *feedback* helps a great deal in characterising the defining elements of a cybernetic-economic system.

The feedback has a general character; it governs all cybernetic-economic systems, acting inside them as well as between the various components of the national economy general system.

Objective law of the feedback acted permanently upon the evolution of the human society. Concurrent with the increase of the complexity of economic life, and as results of the accentuation of the social labour division and of the use on wider scale of the results obtained by the contemporary science and technology, the intensity with which the feedback acts is increasing.

The area on which the law of objective feedback acts becomes larger and larger at the level of the world economy general system, as result of the continuous diversification and increase of intensity of the links between countries, and of the accentuation of the international work division.

Feedback has a very important part in the complex process of controlling the cybernetic-economic systems along the trajectories of economic growth, since feedback allows the management to perform the control activity.

This is why, in the socialist economy, the profound knowledge of specific way for acting of the feedback law has a special importance for management, control, regulation and self-regulation of activities taking place into the national economy system, in their directing to the growth of national wealth and on this base, to nation's welfare.

The action of feedback on a cybernetic-economic system takes place through the interrelations between particular components of the output vector and the input vector. This can be obtained either directly (Fig. 3.) or through other cybernetic-economic systems (Fig. 4).

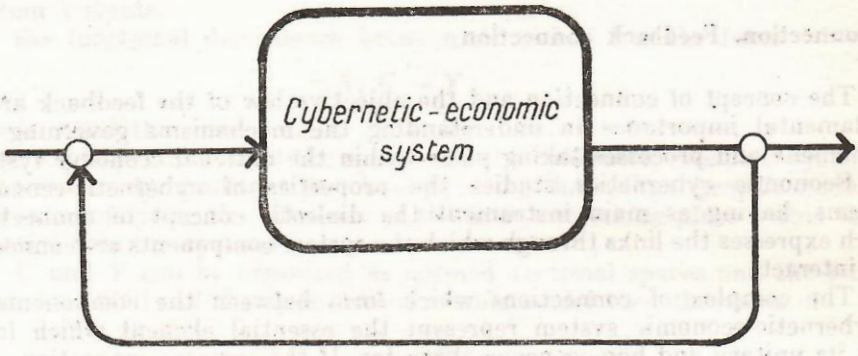

Fig. 3

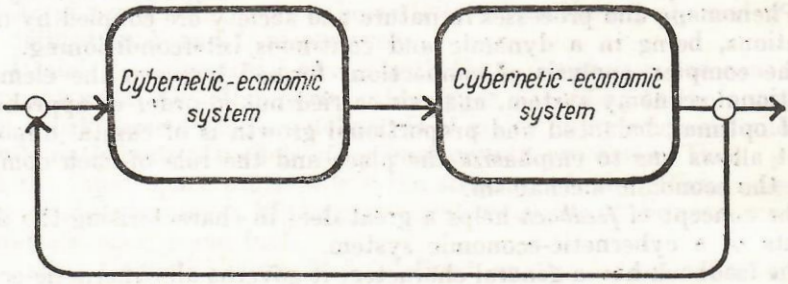

Fig. 4

Obviously, the two types of feedback can take place simultaneously (Fig. 5).

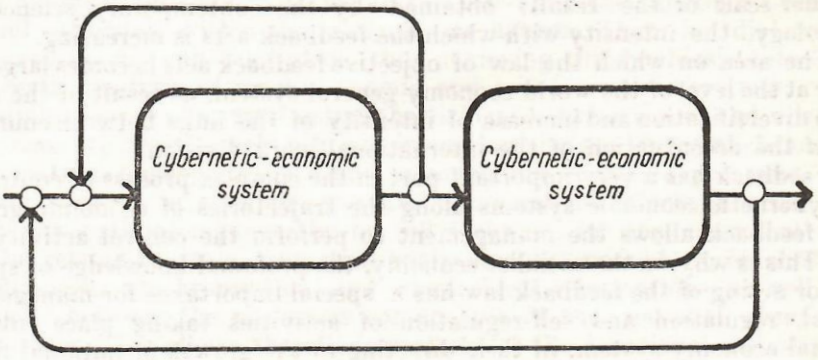

Fig. 5

The feedback plays an important part in the complex process of controlling all the components of the national economy general system in order to achieve the optimum of social economic development. In this way, based on the analysis of the output vector of each cybernetic-economic system and subsystem, the decision element checks the way in which the planned tasks are fulfilled, and if errors occur, takes the suitable control action in order to reset the system on the planned trajectory (Fig. 6).

In order to express through a mathematical relation the *controlling mechanism* based on *feedback* one will denote by Λ the system activity operator.

The decision element analyses the output vectory y of the cybernetic-economic system and compares it with the planned tasks, denoted by $\tilde{y}$ If unwanted differences between the two vectors exist the decision element takes the control action $R(y)$. Thus, if $\|y - \tilde{y}\| > \varepsilon$ then the control decision $R(y)$ is taken.

In this case the system input vector becomes $u + R(y)$ and the output vector is

$$y = \Lambda(u + R(y))$$

Assuming that Λ^{-1} exists one obtains

$$\Lambda^{-1}(y) = u + R(y)$$

and thus

$$\Lambda^{-1}(y) - R(y) = u$$

$$(\Lambda^{-1} - R)(y) = u$$

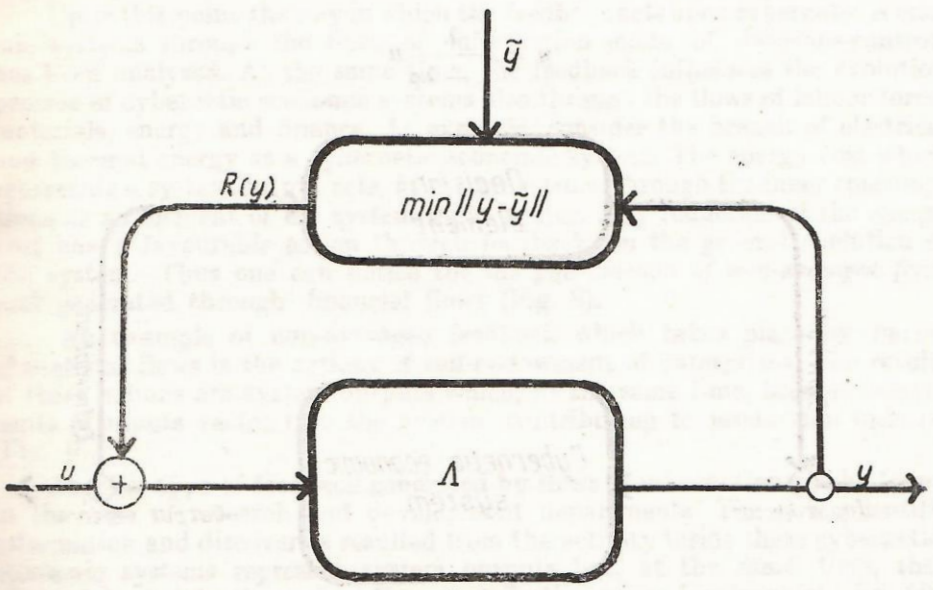

Fig. 6

Assuming that the operator $\Lambda^{-1} - R$ has an inverse, y is given by

$$y = [\Lambda^{-1} - R]^{-1}(u)$$

and, finally

$$y = [E - \Lambda R]^{-1} \Lambda(u)$$

Therefore the control through feedback operator (Fig. 7) has the expression:

$$\hat{R} = [E - \lambda R]^{-1}$$

The *control law based on feedback* is:

$$y = \hat{R}\lambda(u)$$

When the system input and output are scalars and the operators Λ and R are multipliers, i.e.

$$\Lambda(u) = \lambda u, \quad R(y) = \rho y$$

then the control through feedback operator becomes

$$\hat{r} = \frac{1}{1 - \lambda\rho}$$

r is also known as *feedback multiplier.*

The control law based on feedback can be written as

$$y = \frac{\lambda}{1 - \lambda\rho} u$$

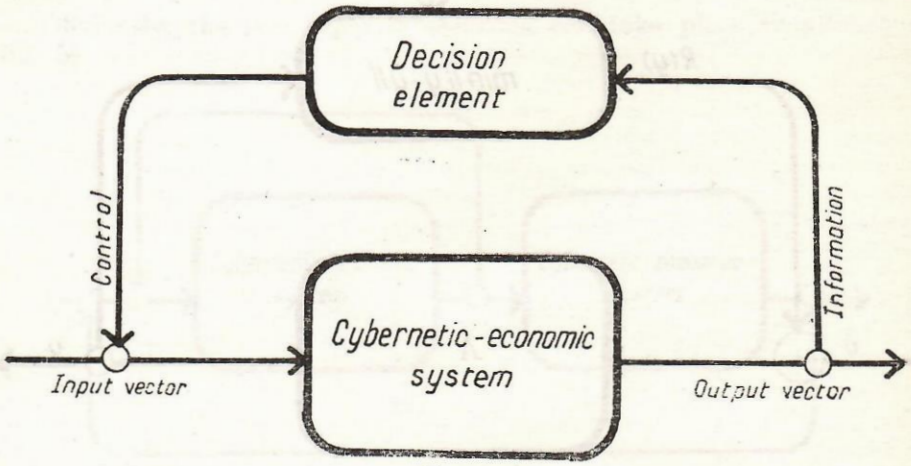

Fig. 7

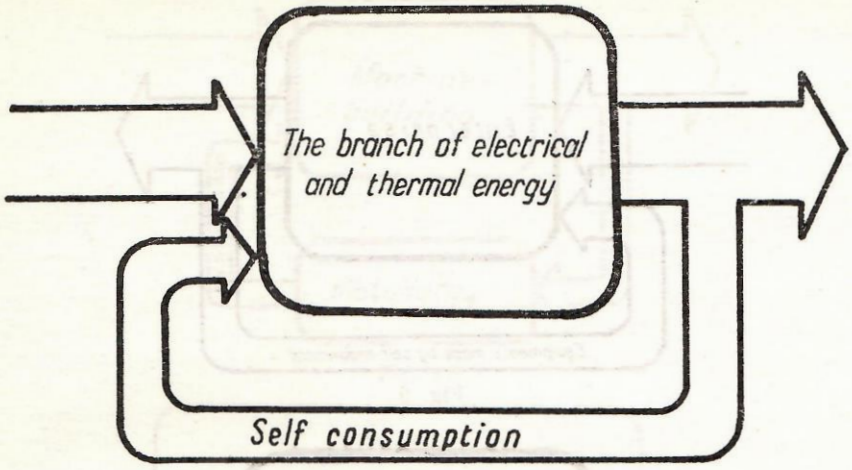

Fig. 8

If λ and ρ are matrices, the control law based on feedback becomes

$$y = [E - \lambda\rho]^{-1}.\ \lambda u$$

or

$$y = [E + \lambda\rho + (\lambda\rho)^2 + (\lambda\rho)^3 + \ldots].\ \lambda u.$$

It has been assumed that the eigenvalues of $\lambda\rho$ are inside a circle of unit radius.

Up to this point the way in which the feedback acts upon cybernetic-economic systems through the flows of information made of decisions-controls has been analysed. At the same time, the feedback influences the evolution process of cybernetic economic systems also through the flows of labour force, materials, energy and finance. As example, consider the branch of electrical and thermal energy as a cybernetic-economic system. The energy cost which represents a system output acts, at the same time, through the inner consumptions as an element of the system input vector. Any reduction of the energy cost has a favourable action through feedback, on the general evolution of the system. Thus one can notice the *the phenomenon of non-averaged feedback* generated through financial flows (Fig. 8).

An example of non-averaged feedback which takes place by means of material flows is the actions of self-endowment of enterprises. The results of these actions are system outputs which, at the same time, become components of inputs vector into the system, contributing to production increase (Fig. 9).

Another type of feedback generated by flows of information can be found in the case of research and development departments. The new scientific information and discoveries resulted from the activity inside these cybernetic-economic systems represent system outputs but, at the same time, they are feed back into the system thus contributing to its development (Fig. 10).

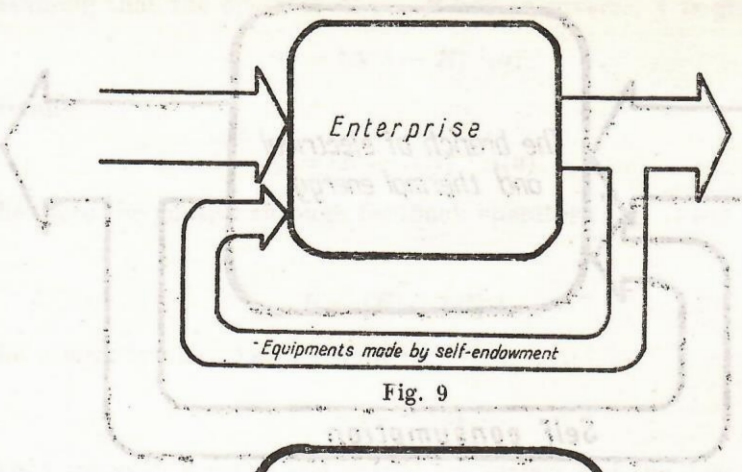

Fig. 9

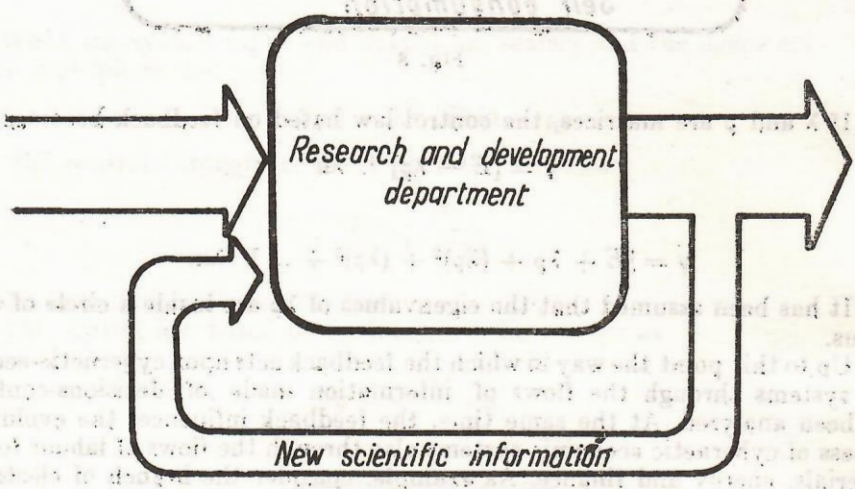

Fig. 10

In order to illustrate the phenomenon of *non-averaged feedback* generated by material flows, we consider the case of two great components of national economy's general system: the branch of machine building and metalurgical one. The achievement by the branch of machine-building of some equipments of high technicity for the metalurgical branch will allow the possibility of this one to get products of higher and technical quality. These, in their turn, will allow an improvement and increase of activities taking place into the machine-building branch. (Fig. 11).

In order to illustrate the combined way in which feedback acts one considers a company inside which two systems are coupled: the coal extraction system and the system producing electrical and thermal power for internal needs (Fig. 12).

The cost of energy has a direct effect on the system through the inner consumption, but at the same time, through the delivered electrical and thermal energy, it influences also the cost of coal extraction. Since a part of

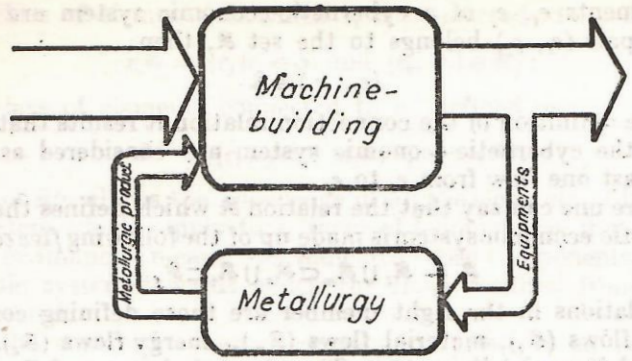

Fig. 11

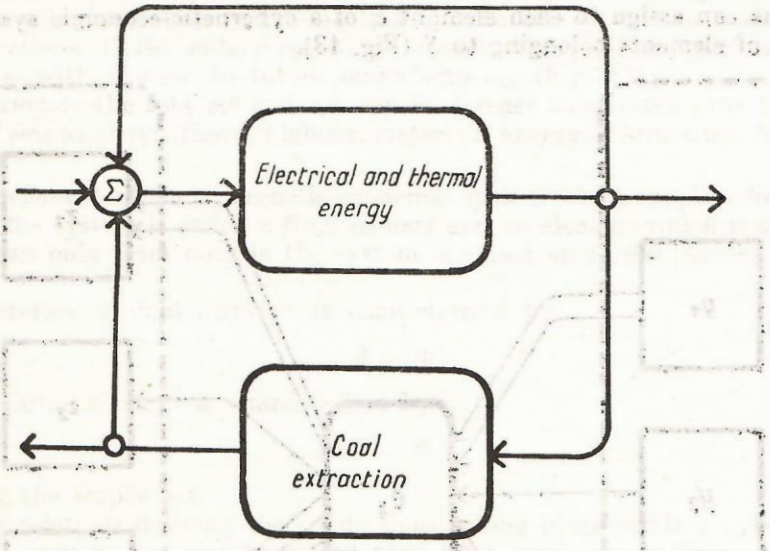

Fig. 12

coal production is used to produce energy, the influence of *non-averaged feed-back* upon the system producing electrical and thermal power is emphasised.

The *connection description*, the description of the links and the interrelations between the components of a cybernetic-economic system, can be achieved by using the set theory, the matrix calculus or the graph theory.

If S is the set of elements composing a cybernetic-economic system:

$$S = \{e_1, e_2, \ldots, e_n\}$$

then the connections specific to the systems are given by the set $\mathcal{R}$ which is a subset of the Cartesian product $S \times S$.

The set

$$\mathcal{R} \subseteq S \times S$$

is formed as the *connection definition-relation* pertinent to the cybernetic-economic system.

Two elements e_i, e_j of a cybernetic-economic system are connected if the ordered pair (e_i, e_j) belongs to the set $\mathcal{R}$, then

$$(e_i, e_j) \in \mathcal{R}$$

From the definition of the connection relation it results that the elements e_i and e_j of the cybernetic-economic system are considered as connected if there is at least one flow from e_i to e_j.

From here one can say that the relation $\mathcal{R}$ which defines the connections of the cybernetic economic system is made up of the following *five connection sets*:

$$\mathcal{R} = \mathcal{R}_l \cup \mathcal{R}_m \subset \mathcal{R}_e \cup \mathcal{R}_i \subset \mathcal{R}_f$$

where the relations in the right member are those defining connections for labour force flows ($\mathcal{R}_l$), material flows ($\mathcal{R}_m$), energy flows ($\mathcal{R}_e$), information flows ($\mathcal{R}_i$) and financial flows ($\mathcal{R}_f$). Therefore, each type of flow generates a *connection structure.*

One can assign to each element e_i of a cybernetic-economic system two classes of elements belonging to S (Fig. 13).

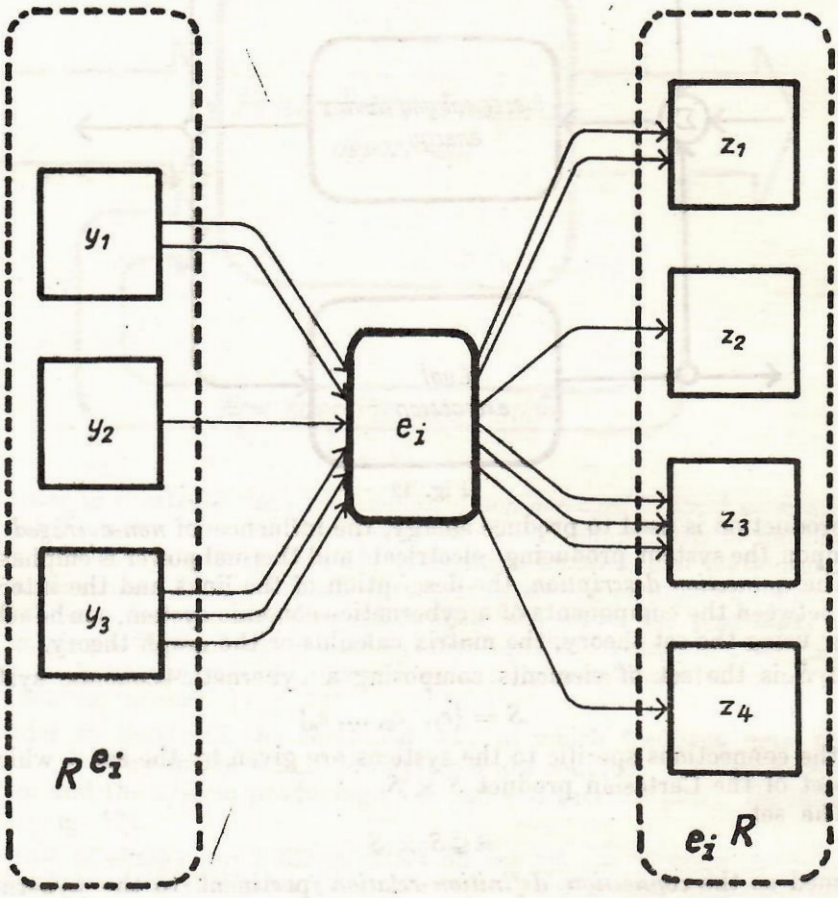

Fig. 13

— the class of elements to which e_i is connected, defined as

$$e_i\mathfrak{R} = \{e_j \mid e_j \in S \text{ and } (e_i, e_j) \in \mathfrak{R}\};$$

— the class of elements connected to e_i, defined as

$$\mathfrak{R}^{e_i} = \{e_j \mid e_j \in S \text{ and } (e_j, e_i) \in \mathfrak{R}\}.$$

The set of $\mathfrak{R}^{e_i}$ allows the knowledge of all the elements of the cybernetic-economic system which supply to e_i flows of labour force, materials, energy, information or financial means. $e_i\mathfrak{R}$ indicates those components of the cybernetic-economic system towards which the flows resulted from the activity of e_i are directed.

When the analysed cybernetic-economic system is an enterprise, and its components are the workshops or production sections, then the set R^{e_j} will be made up of all production sections which supply raw materials, semi-finished, sub-ensemblies, etc. to section e_i. The set $e_i^{\mathfrak{R}}$ will be made up of those sections of the enterprise which receive the products performed by section e_i with a view to future manufacturing (Fig. 13).

Obviously the sets $\mathfrak{R}^{e_i}$ and $e_i\mathfrak{R}$ can be further subdivided into the five types of sets as above (flows of labour, materials, energy, information, financial means).

An element of the cybernetic-economic system which supplies flows only outside the system is called a *final element* and an element which is supplied with flows only from outside the system is called an *initial element* of that system.

Therefore a final element is characterised by

$$e_i\mathfrak{R} = \Phi$$

and an initial element is characterised by

$$\mathfrak{R}^{e_i} = \Phi$$

Φ being the empty set.

The relations defining the connections taking place inside a cybernetic-economic system can also be represented by a *connection matrix.*

The elements of the connection matrix

$$\alpha = \| \alpha_{ij} \|_{n \times n}$$

are defined as follows;

$$\alpha_{ij} = \begin{cases} 1 \text{ if } e_i \text{ and } e_j \text{ are connected} \\ 0 \text{ otherwise.} \end{cases}$$

One can define five types of connection matrices:

$\alpha_l = \| \alpha_{ij}^l \|$ — the connection matrix based on the flows of labour force;
$\alpha_m = \| \alpha_{ij}^m \|$ — the connection matrix based on the flows of materials;
$\alpha_e = \| \alpha_{ij}^e \|$ — the connection matrix based on the flow of energy;
$\alpha_i = \| \alpha_{ij}^i \|$ — the connection matrix based on the flows of information;
$\alpha_f = \| \alpha_{ij}^f \|$ — the matrix based on the flows of financial means.

Two elements e_i and e_j of a cybernetic-economic systems are connected if at least one of the elements;

$$\alpha_{ij}^{l},\ \alpha_{ij}^{m},\ \alpha_{ij}^{e},\ \alpha_{ij}^{i},\ \alpha_{ij}^{f}$$

is nonzero.

In order to illustrate, we shall suppose an entreprise having seven sections, the connections among these sections being shown in Fig. 14.

From the analysis of the connections among sections, it results that the considered system has an initial-element (element 1) and two final elements (elements 6 and 7). The production connections which are formed among the seven sections may be synthetized into the following connection matrix:

$$L = \begin{Vmatrix} 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{Vmatrix}$$

2. The functions, the behaviour and the structure of a cybernetic-economic system

By approaching the study of the systems in order to control them in an optimal manner along the trajectories of economic growth, economic cybernetics analyses their functions within the economic mechanism, the tasks they have to fulfill in order to achieve a fast, balanced and proportional development of the ensemble of the national economy general system.

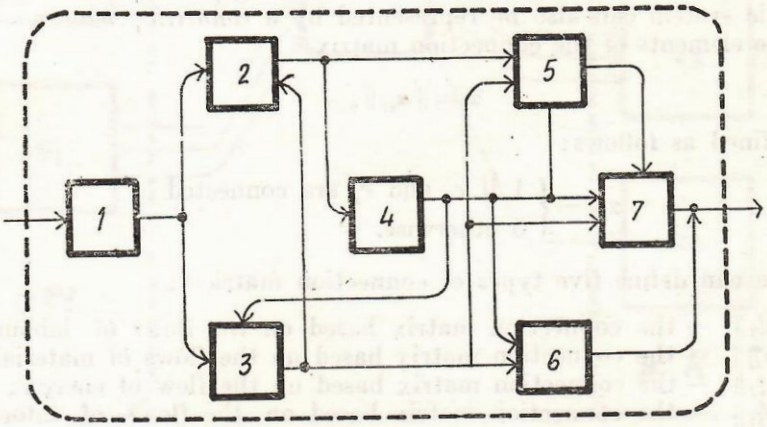

Fig. 14

The *function* is an essential quality of any cybernetic-economic system and it focuses the attention upon the multiple connections between it and the other components of the national economy general system.

Therefore, the analysis of the function pertinent to each cybernetic-economic system must be carried out in a systemic way, tightly connected to the ensemble of the other systems of the national economy, which represent the *environment* of the analysed system.

If Σ is the general system of the national economy, the environment of a cybernetic-economic system $\mathcal{S}$ is defined as

$$\mathcal{A}_{\mathcal{S}} = C_{\Sigma}\ \mathcal{S} = \Sigma \backslash \{\mathcal{S}\}$$

The flows of labour force, materials, energy, information and financial means entering a cybernetic-economic system represent, in fact the action of the environment upon the system. In turn, each system acts upon its environment through the output flows, directed towards the various components of the national economy general system.

The cybernetic analysis of the phenomena and processes taking place under the general system of the national economy shows that the *functions* of each cybernetic-economic system within the economic mechanism is characterised by the way of converting the input flows into output flows, by their intensity and the way in which they are directed towards the components of the system environment. The function is the vectorial sum of the intensity of the flows of labour, materials, energy, information and financial means entering the system and of the system external *behaviour*, i.e. the way of converting the input flows into output flows.

The external, as well as the internal (i.e. the way of changing the system states) behaviour of the cybernetic-economic system are strongly influenced by its *structure*, which represents the dialectic unity between its components and the flows generated between them.

It results that the structure of a cybernetic-economic system is characterised by

$$\{S, \mathcal{R}\}$$

which implies the knowledge of the elements of the set above and of the definition relation of the system connections, i.e. of its connection matrix.

When analysing the functions, the behaviour and the structure of cybernetic-economic systems one has to take into account their strong dynamic characteristic, which results from the action of the objective laws governing the society development as well as from conscious human action. The dynamic properties concern the overall system, the connections between its elements as well as the interdependence relations with the other components of the national economy system.

We have to point out that the alert rate of technical progress characteristic to the contemporary period and the intensification of the connections between the systems of national economy as a result of deepening the labour international division, are factors stressing the dymanic character of cybernetic-economic systems.

The science of cybernetics, based on a thorough analysis of the dynamic properties of the national economy system components showed that these properties encompass all the aspects defining the cybernetic-economic system, i.e. its functions, structure and behaviour. The understanding of these dynamic properties is essential for a proper foundation of decisions regarding the management of cybernetic-economic systems. Based on the afore-mentioned analysis one can identify the optimal evolution of the connections between the system elements, this creating the circumstances necessary to act along the lines which ensure the successful achievement of the scheduled tasks.

The emphasis placed upon the major part played by the understanding of the dynamic properties of cybernetic-economic system in its optimal management requires to define the concept of system *dynamic structure*.

In order to achieve this the elements of the connection matrix defining the structure of a cybernetic-economic system have to be considered as time-dependent. Therefore, one can write the matrix characterising the system connections at time t as

$$\alpha_t = \| \alpha_{ij}^t \|_{n \times n}$$

where

$$\alpha_{ij}^t : T \to \{0,1\}$$

The elements α_{ij}^t of the connection matrix are defined as

$$\alpha_{ij}^t \begin{cases} 1 \text{ if the elements } e_i \text{ and } e_j \text{ are connected at time } t; \\ 0 \text{ otherwise.} \end{cases}$$

T denotes the time period along which the analysis takes place.

Therefore, the concept of dynamics of a cybernetic-economic system structure is defined by the sequence of the pairs

$$\left\{ S_t,\ \alpha_t \right\} \begin{matrix} t = T \\ t = 0 \end{matrix}$$

When approaching the dynamic structure of a cybernetic-economic system one defines the class of the elements to which e_i is connected at t as:

$$e_i \mathcal{R}_t = \{ e_j \mid e_j \in S_t,\ \alpha_{ij}^t = 1 \}$$

Therefore e_i is *stable connected* to the element e_j if

$$e_j \in e_i \mathcal{R}_t \quad (\forall) t \in T,$$

which means that

$$\prod_{t \in T} \alpha_{ij}^t = 1$$

If

$$\alpha_{ij}^{t-1} = 0 \text{ and } \alpha_{ij}^t = 1$$

then a new connection formed at time t.

In order to quantify the *degree of coupling* of the element e_i within the system at the moment t one can use the figure

$$\bar{\alpha}^t_{i,.} = \frac{\sum_{j=1}^{n} \alpha^t_{ij}}{n}$$

If $\bar{\alpha}^t_{i,.}$ is an increasing function of t it reflects an increase of the number of connections of the element e_i with the other components of the cybernetic-economic system, increase which could be generated by the growth of its activity within the system.

The analysis of Romanian economy in the last decade, outlines a very big number of branches and economic sectors whose connections to other components of national economy system have been continuously increased as a result of growing and diversification of production. We recall to this end, the electronic, electro-technical, mechanical industry, etc., which have generated flows of products to a higher and higher number of economy's branches and sub-branches.

The final elements of a cybernetic-economic system are characterized by the relation:

$$\bar{\alpha}^t_{i,.} = 0$$

If $\bar{\alpha}^t_{i,.} = 0$ and $\bar{\alpha}^{t+1}_{i,.} > 0$.

It results that the element e_i ceassed at the moment t to be final element for the system it contains.

The class of the components connected to the element e_i at time t is defined as

$$\mathfrak{R}_i^{e_i} = \{e_k \mid e \in S_t,\ \alpha^t_{ki} = 1\}$$

If the element e_k is stable connected to the element e_i:

$$\prod_{t \in T} \alpha^t_{ki} = 1$$

The degree of connection of the system components to the element e_i at time t is quantified by the relation:

$$\bar{\alpha}^t_{.,i}\ i = \frac{\sum_{k=1}^{n} \alpha^t_{ki}}{n}$$

For the initial elements of a cybernetic-economic system the following relation holds:

$$\bar{\alpha}^t_{.,j} = 0$$

In other words, there is no other system component connected to it at time t.

If the figure $\bar{\alpha}^t_{.,i}$ increases in time, this reflects the increase of the number of components connected to the element e_i, which can be due to the increase of the importance within the system.

Thus, in case of Romanian economy, at the same time with the creation of car industry as a component of economy, very many elements of this have been connected to the new industry within the co-operation process.

So, the specializing and diversifying process of production in several branches lead to increase of cooperation in production, this fact representing an important factor which leads to growth of the coupling degree of the components of a cybernetic-economic system.

The degree of the structure complexity of a cybernetic-economic system at time t can be quantified by the figure:

$$|\alpha_t| = \frac{\sum_{i=1}^{n} \bar{\alpha}^t_{i,.}}{n^\circ} = \frac{\sum_{i=1}^{n} \bar{\alpha}_{,i}}{n^\circ} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} \alpha^t_{ij}}{n^2}$$

The value n^2 represents the maximal number of connection which can be formed within a cybernetic-economic system which contains n elements. This corresponds to the case in which each system element is connected to all system elements.

In general

$$|\alpha_t| < 1$$

For example, in case of cybernetic-economic system shown in Fig. 13, including seven components, the complexity degree of its structure is given by:

$$|\alpha| = \frac{\sum_{i=1}^{7}\sum_{j=1}^{7} \alpha_{ij}}{7^2} = \frac{13}{49} = 0.265$$

The dynamic increase of the figure which quantifies the degree of complexity of a cybernetic-economic system could show in general, an increase and a diversification of the production inside the system.

The analysis of cybernetic general system of Romanian economy as a whole, of its several branches and subbranches as: machine-building, chemistry, etc., outlines the continuous increase of the mentioned figure.

One should underline that the figure on the degree of complexity of the national economy system can be calculated based on the branches, by using the information contained by the first quadrant of the model.

The state variable vector has an important part in identifying and representing the *dynamic behaviour* of cybernetic-economic systems. The analysis of each cybernetic-economic system allows one to establish those parameters which can be used to identify at each moment of time its position within the national economy system, as well as the development level of the system under consideration. These parameters are the components of the state vector.

A very large number of state variables required to characterize cybernetic-economic systems is specific to such systems. The state variables identification in cybernetic-economic systems is an extremely complex problem. It requires a good practical knowledge of the fine structure of the system under analysis, of its type of organization, of its structure and functions

within the economic mechanism. Therefore, when identifying the state vector characterising a system one should bear in mind that the intensities of the flows of labour, materials, energy, information and financial means, hence of the connections within the system, are determined by the level of the *exchange of activities* taking place between its elements.

The paramount part in the performance of all the activities of a cybernetic-economic system is played by man characterised by his working capacity. The activities taking place in most cybernetic economic systems are work processes.

As it has already been pointed out, each cybernetic-economic system is characterised by two aspects of its behaviour: internal and external, dialectically connected.

The *internal behaviour* of a cybernetic-economic system is the objective way in which the state vector change under the action of the input flows.

The state of a cybernetic-economic system at a given moment of time represented by the state vector $x(t)$, depends on one hand, on its previous states $x(\tau)$ $(\tau < t)$ and, on the other hand, on the input flows acting inside the time interval $[\tau, t]$.

The following notations are made:

L, M, E, I, F — the set of flows of labour, materials, energy, information, financial means;

$\mathcal{U}_{\mathcal{S}}$ — the space of input vectors of the system $\mathcal{S}$.

One can write that

$$\mathcal{U}_{\mathcal{S}} \subseteq L \times M \times E \times I \times F$$

Let $\Gamma_{\mathcal{S}}$ be the class of functions

$$\Gamma_{\mathcal{S}} = \{\gamma \colon T \to \mathcal{U}_{\mathcal{S}}\},$$

where T is the time interval along which the system is analysed.

The internal behaviour of a cybernetic-economic system, thus the specific way of passing from one state into another, has the aspect

$$\varphi \colon D \to X,$$

where

$$D \subset T \times T \times X \times \Gamma$$

and X is the state space of the cybernetic-economic system.

The state vector of the cybernetic-economic system at time t is given by

$$x(t) = \varphi(t,\ \tau,\ x(\tau),\ \gamma_{[\tau,\ t)}),$$

where $\gamma_{[\tau,\ t)}$ is the ensemble of the input flows of the system in the time interval $[\tau, t)$. φ reflects in a correct fashion the internal behaviour of the system if it has the following properties:

a) $\varphi(t,\ t,\ x,\ \gamma) = x \quad \forall x \in X$ and $t \in T$

b) $\varphi(t,\ t_1,\ x_1,\ \gamma_{[t_1,\ t)}) = \varphi(t,\ t_2,\ \varphi(t_2,\ t_1,\ x_1,\ \gamma_{[t_1,\ t_2)}),\ \gamma_{[t_2,\ t)})$

$$\forall x_1 < X,\ t_1 < t_2 < t$$

c) if $\gamma^1, \gamma^2 \in \Gamma$, $\gamma^1_{[t_1,\ t)} = \gamma^2_{[t_1,\ t)}$

then

$$\varphi(t, t_1, x, \gamma^1_{[t_1, t)}) = \varphi(t, t_1, x, \gamma^2_{[t_1, t)}).$$

Therefore, the *internal behaviour* of a cybernetic-economic system is described by the triad

$$(\mathcal{U}_{\$}, X, \varphi)$$

The external behaviour of a cybernetic-economic system is characterized by the way of transforming the input flows into output flows, by means of which it acts upon other components of national economy, from an economic cybernetics point of view, the external behaviour is a emphasis of the ensemble of activities and processes taking place within the system, i.e. of those regarding the production, distribution, circulation, consumption etc.

The external behaviour of a cybernetic-economic system is characterized by the vectorial function

$$\xi: T \times T \times X \times \Gamma \to \psi_{\$}$$

where $\psi_{\$}$ is the output flows space. Therefore, the intensity of the system output flows corresponding to a segment of input flows $\gamma_{[\tau, t)}$ is given by the vectorial relation

$$y(t) = \xi(t, \tau, x(\tau), \gamma_{[\tau, t)})$$

Since the external behaviour shows the way in which the flows of labour materials, energy, information and financial means are converted into output flows, it represents an essential element based on which the efficiency of all the activities taking place inside the system is evaluated.

The *external behaviour* of a cybernetic-economic system is given by the triad

$$(\mathcal{U}_{\$}, \psi_{\$}, \xi).$$

The *overall behaviour* of a cybernetic-economic system is given by the dialectic symbiosis between its internal and external behaviour.

Mathematically, the behaviour of the cybernetic-economic system is characterised by the pair of vectorial functions

$$\{\varphi_{(t)}, \xi_{(t)}\}_{t \in T}$$

and also by the sets $U_{\$}$ and $\psi_{\$}$.

There is a strong interdependence between a system behaviour and structure. The behaviour of a cybernetic-economic system is strongly influenced by its structure, i.e. by the connections made inside it. On the other hand the external behaviour of a cybernetic-economic system, while showing the way in which the input flows are converted into output flows, emphasises in fact the action of the system under analysis upon the other components of the national economy general system.

Thus light is thrown on the strong connection existing between the external behaviour of a cybernetic-economic system and its functions within the economic mechanism.

The mathematical representation of the functions of a cybernetic-economic system require the identification of the ensemble of the components of

the national economy system with which the system under analysis is connected through its final elements.

Let ${}_{\mathcal{S}}\mathcal{R}^{t}_{\Sigma}$ be the set of all components of the national economy connected with the cybernetic-economic system $\mathcal{S}$ at the moment t and let $R^{t,\mathcal{S}}_{\Sigma}$ be the set of components connected to it.

From the point of view of economic cybernetics the *functions* of the system $\mathcal{S}$ within the economic mechanism at the moment t is described as

$$\{{}_{\mathcal{S}}R_{\Sigma},\ R^{t,\mathcal{S}}_{\Sigma},\ \mathcal{U}_{\mathcal{S}}\ \psi_{\mathcal{S}},\ \xi\}.$$

An analysis leads to the conclusion that a cybernetic-economic system is characterised by the following elements:

$$\{S,\ \mathcal{R},\ {}_{\mathcal{S}}\mathcal{R}_{\Sigma},\ \overset{\mathcal{E}}{\mathcal{R}}_{\Sigma},\ \mathcal{U}_{\mathcal{S}},\ X,\ \psi_{\mathcal{S}},\ \varphi,\ \xi\}.$$

They allow to describe the following system characteristics:
— the internal structure: $\{\mathcal{S},\ \mathcal{R}\}$
— the behaviour: $\{\mathcal{U}_{\mathcal{S}},\ X,\ \psi_{\mathcal{S}},\ \varphi,\ \xi\}$
— the functions: $\{{}_{\mathcal{S}}R_{\Sigma},\ R^{\mathcal{S}}_{\Sigma},\ \mathcal{U}_{\mathcal{S}},\ \psi_{\mathcal{S}},\ \xi_{4}$.

Therefore, *a cybernetic-economic system is defined by the dialectic interaction between its structure, behaviour and functions within the economic mechanism* (Fig. 15).

The analysis carried out on the defining characteristics of a cybernetic-economic system creates the conditions required to examine in detail the national economy general cybernetic system, its components, its functions, the

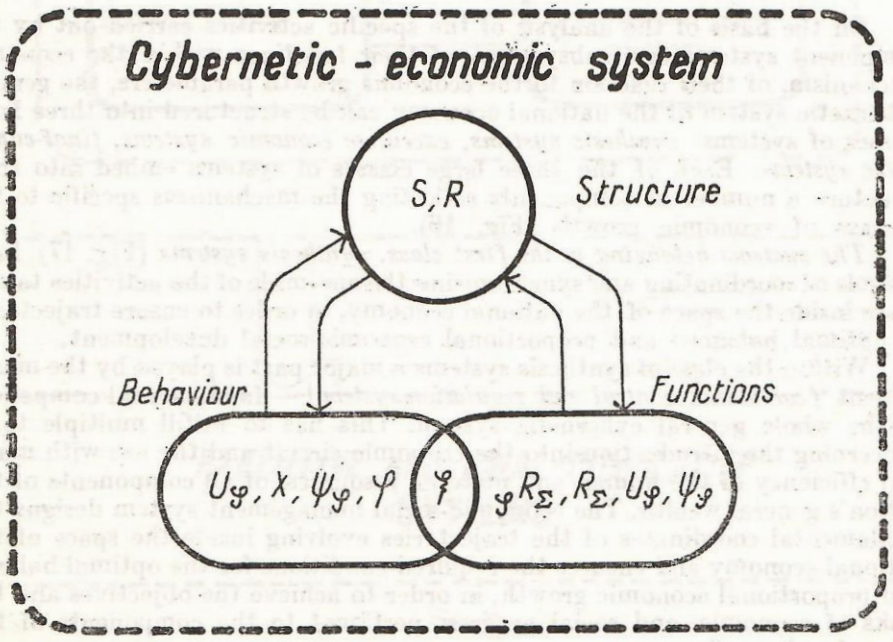

Fig. 15

connections taking place within the economic mechanism thus, obtaining essential elements necessary to scientifically understand the phenomena and processes taking place in economy, in order to give a proper foundation to the decisions on optimal, balanced, proportional growth.

II. THE GENERAL CYBERNETIC SYSTEM OF THE NATIONAL ECONOMY. FLOW TOPOLOGY AND FLOWS MAP

The unitary character of the national economy, the complexity of its structure and the multiple feedforward and feedback connections created inside it represent the main attributes defining the concept of cybernetic-economic system of the economy as a whole.

The general cybernetic system of the national economy development has as components all the systems and subsystems evolving within the space of the national economy.

The structure of the general cybernetic system of the national economy development is extremely complex, having a large number of components grouped into hierarchical structures, both on vertical (company, product, group of products, subbranch, branch, up to the level of the national economy) and on *horizontal* in territorial profile (villages-towns).

In analyzing the general cybernetic system of social-economic development, it is necessary to take into consideration the fact that these are an entity with specific properties which are not totally reformed to each element.

1. System topology

On the basis of the analysis of the specific activities carried out by the component systems and subsystems, of their functions within the economic mechanism, of their reaction to the economic growth parameters, the general cybernetic system of the national economy can be structured into three large classes of systems: *synthesis systems*, *executive economic systems*, *final-cumulative systems.* Each of the three large classes of systems embed into their structure a number of components reflecting the mechanisms specific to the process of economic growth (Fig. 16).

The systems belonging to the first class, *synthesis systems* (Fig. 17) have the role of coordinating and synchronising the ansemble of the activities taking place inside the space of the national economy, in order to ensure trajectories *of optimal balanced and proportional economic-social development.*

Within the class of synthesis systems a major part is played by the management *(command, control and regulation system)* — fundamental component of the whole general cybernetic system. This has to fulfill multiple tasks concerning the introduction into the economic circuit and the use with maximal efficiency of the human and material resources, of all components of the nation's general wealth. The economic-social management system designs the fundamental coordinates of the trajectories evolving inside the space of the national economy and ensures the required conditions for the optimal balance and proportional economic growth, in order to achieve the objectives and the tasks of economic and social progress pertinent to the components of the general cybernetic system.

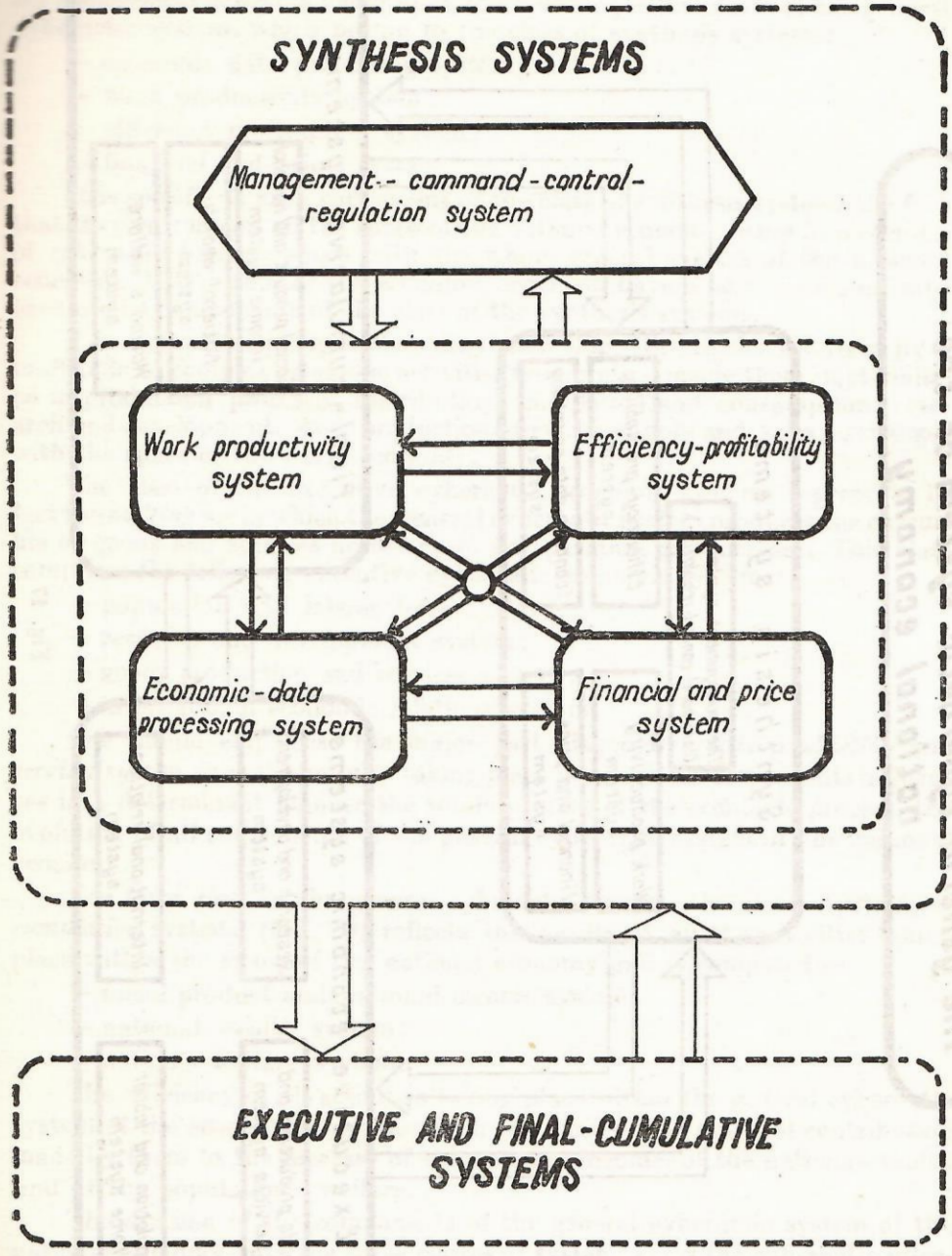
SYNTHESIS SYSTEMS
Management - command - control - regulation system
Work productivity system
Efficiency-profitability system
Economic-data processing system
Financial and price system
EXECUTIVE AND FINAL-CUMULATIVE SYSTEMS

Fig. 16

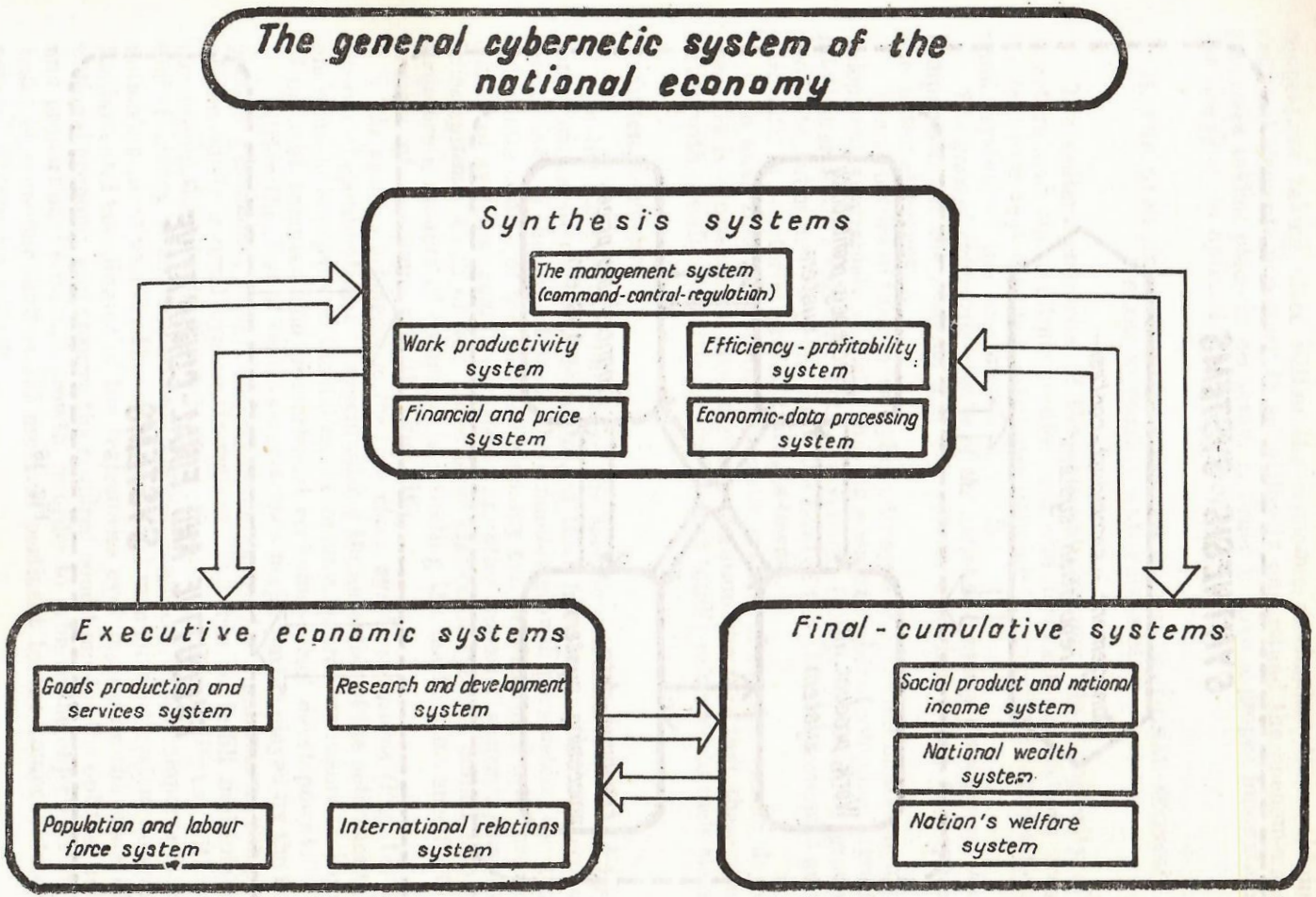
The general cybernetic system of the national economy
Synthesis systems
The management system (command-control-regulation)
Work productivity system
Efficiency - profitability system
Financial and price system
Economic-data processing system
Executive economic systems
Goods production and services system
Research and development system
Population and labour force system
International relations system
Final - cumulative systems
Social product and national income system
National wealth system
Nation's welfare system

Fig. 17

In fulfilling the important tasks of management command and regulation *the management system* is based upon the following components of the general cybernetic system, which belong to the class of synthesis systems:

— economic data processing system;

— work productivity system;

— efficiency-profitability system;

— financial and prices system.

It is specific to each component of the class of synthesis systems the fact that they encompass all the space of the national economy being in a relation of *cybernetic homomorphism* with the whole general system of the national economy. All the cells of the economic organism have a correspondence into each of the components of the class of the synthesis systems.

The systems belonging to the second class (Fig. 18) are characterized by a multitude of complex economic activities taking place inside them, materialized in production processes, distribution, circulation and consumption, research and development, goods production, services, supply and sales, exchanges with the space of the world economy.

The class of the executive cybernetic economic systems represents in fact the *melting pot* in which the general cybernetic system produces the ensemble of goods and services necessary to its operation and increase. This class comprises the following executive cybernetic economic systems:

— population and labour force system;

— research and development system;

— goods production and services system;

— international economic relations system.

One should emphasise the major part played by *goods production and services system* since the activity taking place inside all its components influences in a determinant manner the whole process of the economic process, the evolution of all components of the general cybernetic system of the national economy.

The third class of the general cybernetic system, the class of the *fina cumulative* systems (Fig. 19) reflects the results of all the activities taking place within the space of the national economy and is composed of:

— social product and national income system;

— national wealth system;

— nation's welfare system.

The efficiency of all activities taking place within the general cybernetic system of the economy is appraised on the basis of the national contribution made by them to the increase of the national income, of the national wealth and of the population's welfare.

The division of the components of the general cybernetic system of the national-economy, into the three classes of systems cases the cybernetic interpretation of the complex phenomena and processes taking place inside the space of the national economy.

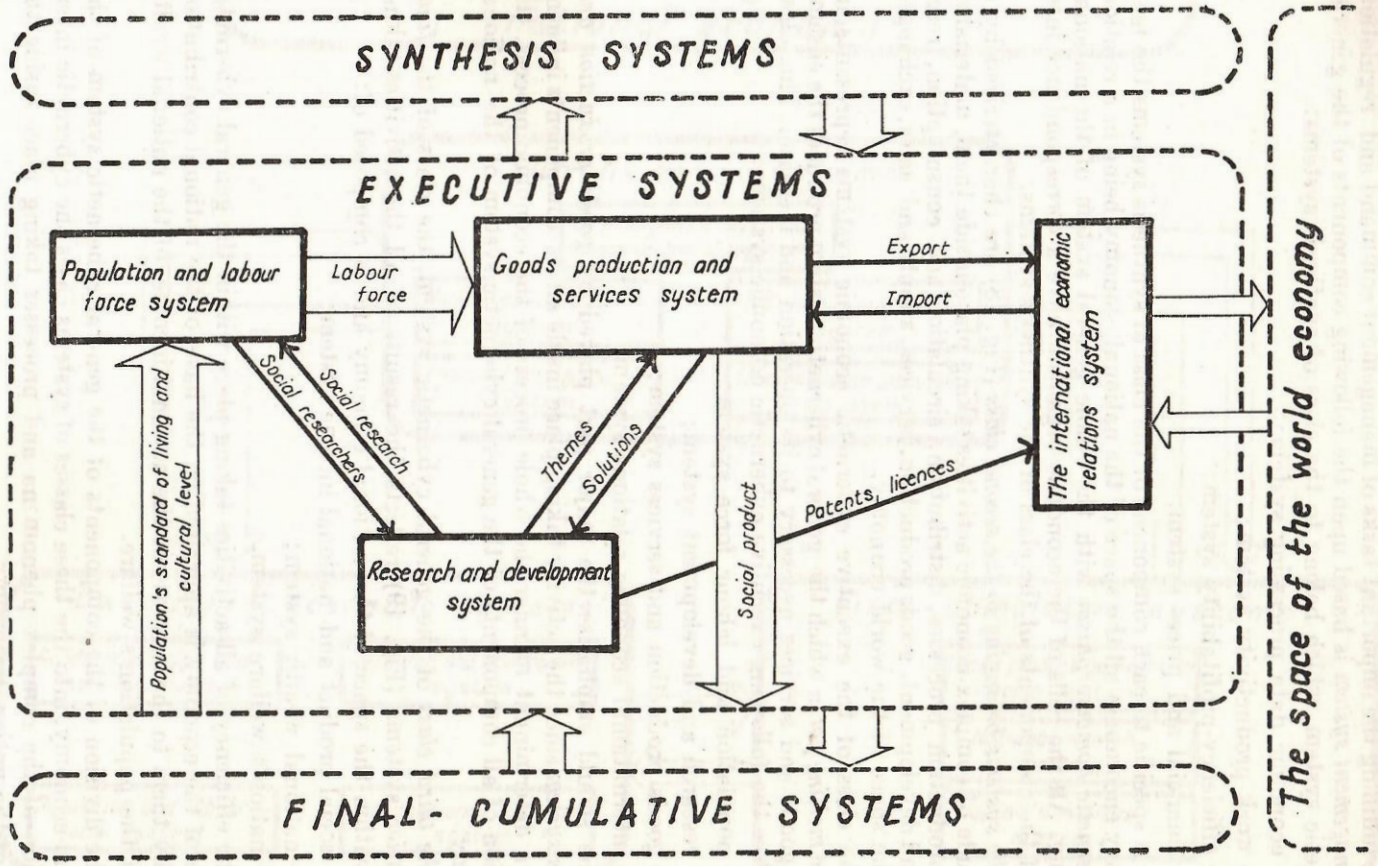
SYNTHESIS SYSTEMS
EXECUTIVE SYSTEMS
Population and labour force system
Labour force
Goods production and services system
Export
Import
The international economic relations system
Social researchers
Social research
Themes
Solutions
Patents, licences
Population's standard of living and cultural level
Research and development system
Social product
FINAL - CUMULATIVE SYSTEMS
The space of the world economy

Fig. 18

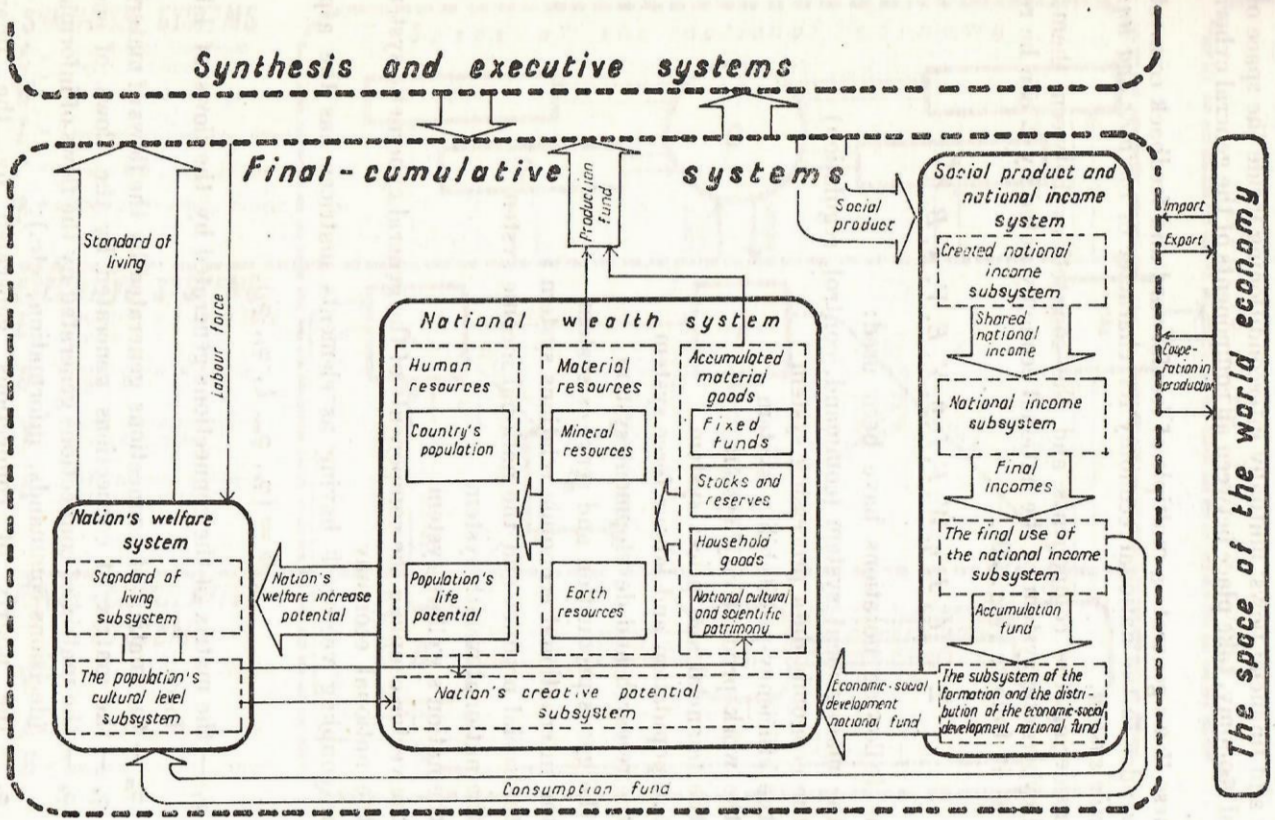
Synthesis and executive systems
Final - cumulative systems
Production fund
Social product
Social product and national income system
Created national income subsystem
Shared national income
National income subsystem
Final incomes
The final use of the national income subsystem
Accumulation fund
The subsystem of the formation and the distribution of the economic-social development national fund
Import
Export
Coope-ration in production
The space of the world economy
Standard of living
labour force
National wealth system
Human resources
Country's population
Material resources
Mineral resources
Earth resources
Accumulated material goods
Fixed funds
Stocks and reserves
Household goods
National cultural and scientific patrimony
Nation's welfare system
Standard of living subsystem
The population's cultural level subsystem
Nation's welfare increase potential
Population's life potential
Nation's creative potential subsystem
Economic-social development national fund
Consumption fund

Fig. 19

2. The main connections. The flows map

Multiple and complex networks of labour force, materials, energy, information and financial flows, mutually interconditioning inside the space of the national economy, take place between all components of the general cybernetic system.

These flows generate a multiple of feedforward and feedback connections which render to the national economy its character of *complex and unitary cybernetic system.*

Considering the components and the connections between them, the general cybernetic system of the national economy noted by Σ can be represented as it follows (Fig. 20).

$$\Sigma = \{C, J. \eta, W, F, L, \theta, Y, E, V, A, B, \Phi\}$$

The following notations have been used:

C — the management system (command, control, regulation)
J — the economic data processing system
η — the efficiency-profitability system
W — the work productivity system
F — the financial and prices system
L — the population and labour force system
θ — the research and development system
Y — the goods production and services system
E — the international economic relations system
V — the social product and the national income system
A — the national wealth system
B — the nation's welfare system
Φ — the vector coupling the components of the general cybernetic system of the national economy

The coupling vector Φ having as elements matrices has the aspect:

$$\Phi = (\varphi_e, \varphi_m, l., \varphi_i, \varphi_f)$$

where: φ_l — the matrix of the connections generated by the flows of labour force;
φ_m — the matrix of connections generated by the flows of materials;
φ_e — the matrix of connections generated by the flows of energy
φ_i — the matrix of connections generated by the flows of information (decisions-commands, information, etc.);
φ_f — the matrix of connections generated by the financial flows.

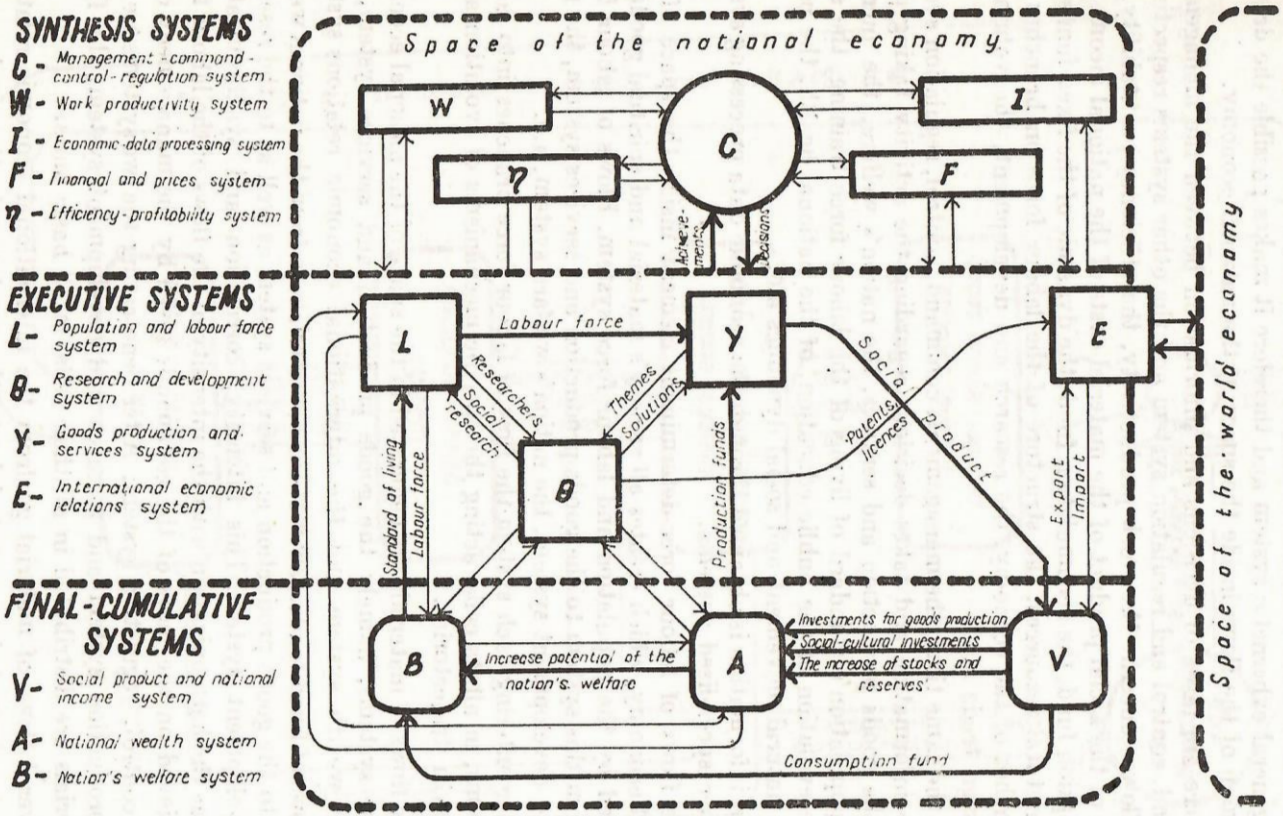
SYNTHESIS SYSTEMS
C - Management - command - control - regulation system
W - Work productivity system
I - Economic-data processing system
F - Financial and prices system
η - Efficiency - profitability system
EXECUTIVE SYSTEMS
L - Population and labour force system
B - Research and development system
Y - Goods production and services system
E - International economic relations system
FINAL - CUMULATIVE SYSTEMS
V - Social product and national income system
A - National wealth system
B - Nation's welfare system
Space of the national economy
Space of the world economy
W
C
I
η
F
Achievements
Decisions
L
Y
E
B
Labour force
Researcher's
Social research
Themes
Solutions
Social product
Potential licences
Export
Import
Standard of living
Labour force
Production funds
B
A
V
increase potential of the nation's welfare
Investments for goods production
Social-cultural investments
The increase of stocks and reserves
Consumption fund

Fig. 20

The knowledge of the coupling vector Φ allows the identification of the feedforward and the feedback connections formed between the components of the general cybernetic system and therefore it makes possible the drawing of the map of the flows inside the space of the national economy.

There are flows of decisions and information between the management, command, control and regulation system and the other systems respectively. These flows concern: the work productivity, the efficiency-profitability, the volume of the social product of the material costs of the national income, the consumption fund, the accumulation fund, the dynamic of the fixed funds, the use of natural resources, the structure of the labour force on branches and subbranches of the economy, the research and development, the volume of the foreign trade a.o.

At the same time, the management, command, control, regulation system receives information and takes decisions regarding the activity taking place inside the goods production and services, the nation's welfare, the increase of the population's standard of living of the labour force training, the state and the evolution of the public education, of the national health, the population's natural movement and social dynamics a.o.

This information is obtained through the economic data processing system and other specialised systems.

The flows of labour force-determinant element inside the space of the national economy, which creates all society's material and spiritual goods-are generated by the population and labour force system. Flows of labour force stem from this system to the goods production and services system, the research and development system, the nation's welfare system, a.o.

After entering each system the flow of labour force branches into all its subsystems, in all its cells, acting the specific mechanisms of evolution along the growth trajectories.

The flows of materials are generated in the space of the national economy by three systems, namely the goods production and services system, the national wealth system and the international economic relations system.

Flows of fixed funds, raw materials, materials go from the national wealth system to the goods production and services system as well as to the research and development system. This intensity, correlation and synchronization, as well as the harmonization with the intensity of the flows of the labour force are achieved on the basis of the commands given by the management command, control, regulation system. After penetrating the two systems, i.e. the goods production system and research and development system, the flows of materials are distributed in all their cells, in all basic units.

Several flows of material go from the international economic relations system, i.e. imported raw materials, to the goods production and services system and to the research and development system. In general, they play

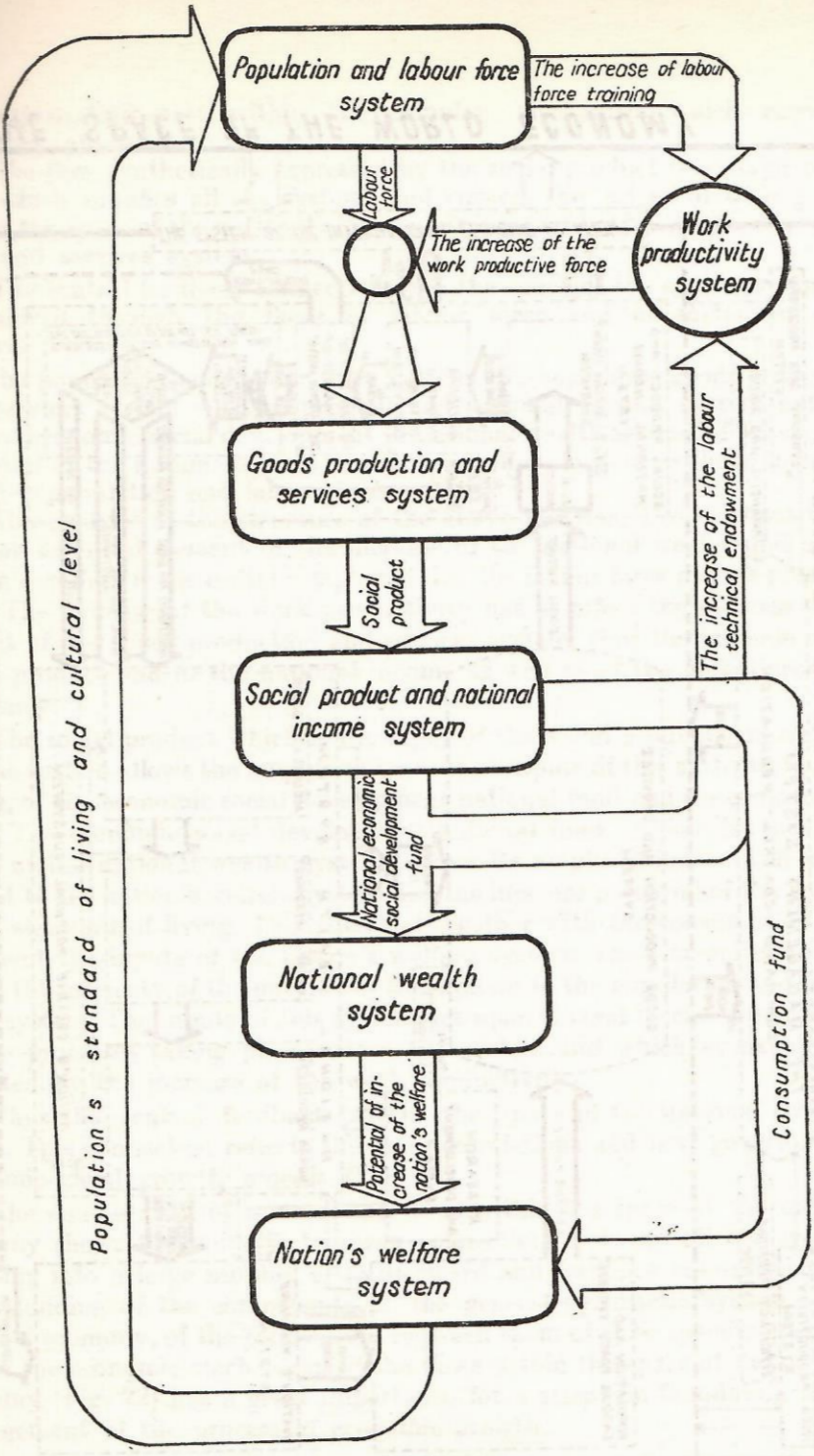
Population and labour force system
The increase of labour force training
Labour force
Work productivity system
The increase of the work productive force
Goods production and services system
Social product
The increase of the labour technical endowment
Social product and national income system
National economic social development fund
National wealth system
Potential of increase of the nation's welfare
Consumption fund
Nation's welfare system
Population's standard of living and cultural level

Fig.21

THE GENERAL CYBERNETIC SYSTEM OF THE NATIONAL ECONOMY

- THE FLOWS MAP -

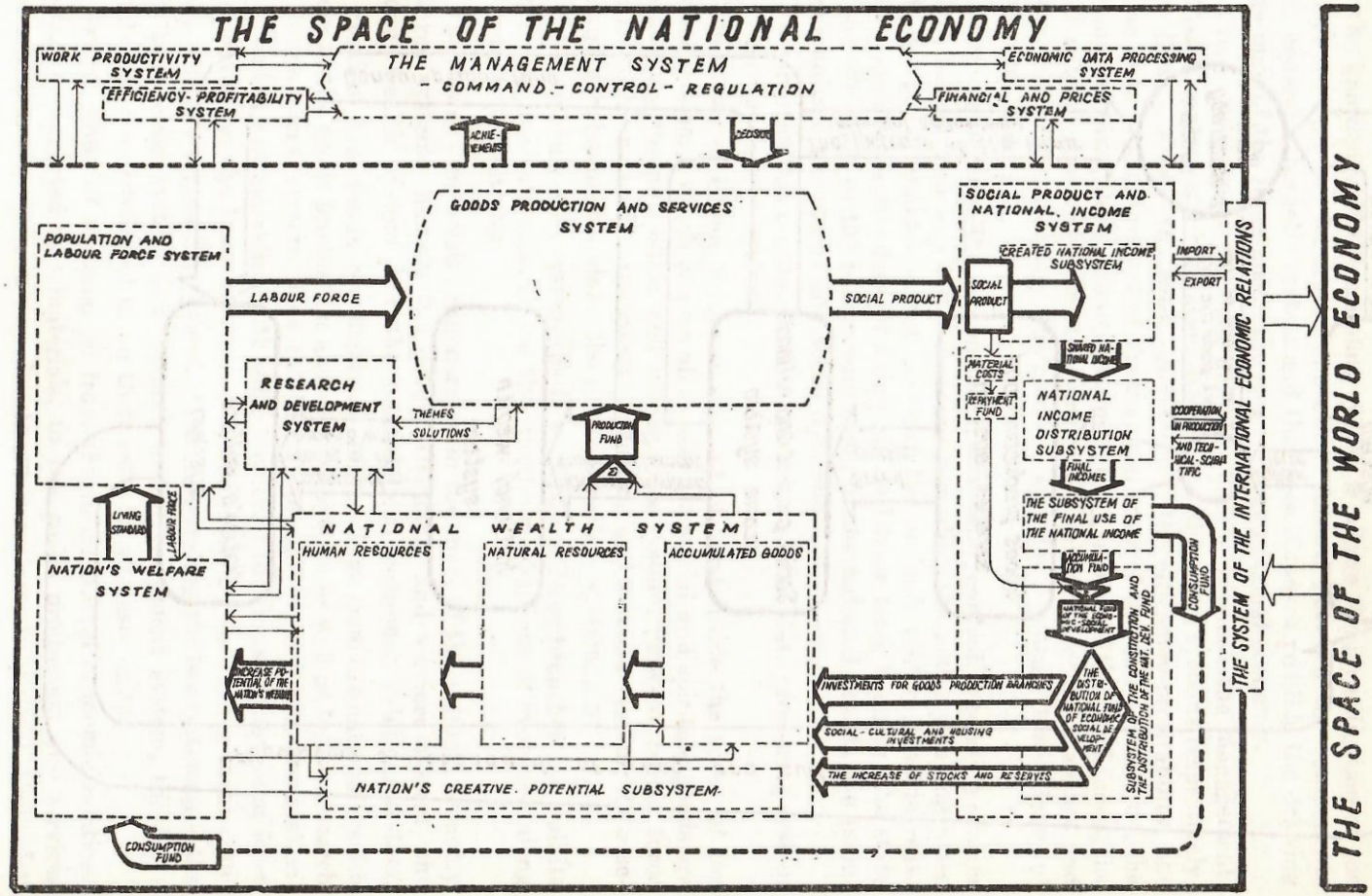

Fig. 22

a compensating part within the complex mechanism which correlates the flows intensities.

The flow synthetically expressed by the social product is a major macro flow which supplies all the systems and ensures the prices of their growth within the space of the national economy. It is generated by the goods production and services system.

The central feedback connection over the space of the national economy is achieved through the flows of labour force and of materials as it follows:

the population and labour force system → labour force goods production and services system → social product and national income system national fund of economic social development → national wealth system → the increase potential of the nations welfare → nation's welfare system → the standard of living → population and labour force system.

The analysis of the structure of the above mentioned connections shows that an essential element of the increase of the national wealth and of the nation's welfare is the initial component, i.e. the labour force and its productivity. The increase of the work productivity has as effect the increase of the output of the goods production and services system, thus the increase of the social product and of the national income as well as of the global economic efficiency.

The social product which is the input of the social product and national income system allows the amplification of the outputs of this systems, in other words, of the economic-social development national fund and the consumption fund. The economic social development national fund, which is the main input of the national wealth system, allows its amplification as well as the output to the nation's welfare system, i.e. the increase potential of the population's standard of living. This potential together with the consumption fund represent the inputs of the nation's welfare system. Their magnitude determines the intensity of the outputs of this system to the population and labour-force system. The inputs of this system act upon several mechanisms specific to the processes taking place within the system and which eventually are reflected by the increase of the work productivity.

Thus the central feedback within the space of the national economy closes. This connection reflects the main correlations and laws governing the economic-social growth process (Fig. 21).

The enumeration of some of the flows within the space of the national economy shows the multiple two-way connections between all the systems, resulting into a large number of feedforward and feedback connections. The understanding of the components of the general cybernetic system of the national economy, of the connections between them of their specific operation within the economic mechanism, of the flows within the space of the national economy (Fig. 22) has a great importance for a scientific foundation of the management of the process of economic growth.

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