POLSKA AKADEMIA NAUK
INSTYTUT BADAŃ SYSTEMOWYCH

PROCEEDINGS OF THE 3rd ITALIAN-POLISH CONFERENCE ON APPLICATIONS OF SYSTEMS THEORY TO ECONOMY, MANAGEMENT AND TECHNOLOGY

WARSZAWA 1977

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BIAŁOWIEŻA, POLAND
MAY 26—31, 1976

EDITED BY J. GUTENBAUM

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CONTROL PROCESS IN LARGE-SCALE ECONOMIC SYSTEMS IN PLANNED ECONOMY

INTRODUCTION

I would like to discuss rather not a control process at all but the specifics of a process being considered by the General Systems Theory as a control (or regulation) process applied in an economic system, specifically in a large-scale economic system operating under conditions of a centrally planned economy. Three terms used in the titel of this paper require from the conceptional point of view to be defined. They are respectively:

control process —
— large-scale economic system —
— planned economy conditions.

It requires, however, that first of all an economic system must be defined what will allow to give some interpretation of an operating large economic system in a given environment. My definition of an economic system is as follows:

An economic system means a system being intentional[1], consisting of at least two intentional subsystems, having common bunch of a tonomic objectives expressed in economic and social terms, which creates a hierarchical tree of goals and tasks using for this purpose the criterion of specialization to divide the system into subsystems, and supported by a communication system in which at least one of the subsystems works as a control process center.

BASIC ASSUMPTION AND DEFINITIONS

The main assumption for all considerations in this paper is based on J. Kornai theorem[2] and could be defined in the following way;,

Market or a planning system only are separately and exclusively not able to

[1] This term was used by R. Ackoff for a classification purpose in which five types of systems were defined in terms of behavioural theory of systems, MANAGEMENT SCIENCE, July 1971.

[2] J. Kornai, ANTI-EQUILIBRIUM, North-Holland Publishing Co. Amsterdam, 1971 Theorem 23.1.

manage a large economic system, highly compound with stochastic processes and behaviour. Both market and planning system are regulators operating in a way which is not enough complex. The effectiveness of a control process in economic systems requires, therefore, necessarily that both joint systems, market and planning will work together on a basis of a multistage information system and multi-level control process to improve the activities and responses of the economic system to the changing environment.

Now, assuming the co-operation between the market mechanism on the one hand and the mechanism of planned stimulators and indicators on the other hand as a joint process affecting the behaviour and development of each particular system in planned economy the three components mentioned above can be described and defined.

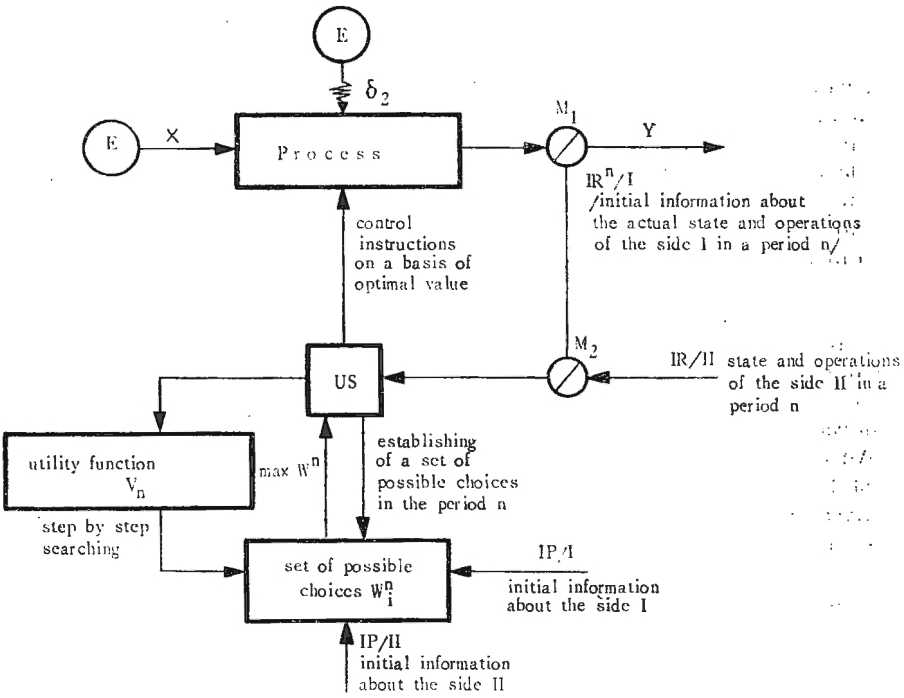


Fig. 1

1) the control process is related to a particular class of systems (see Fig. 1). It is called in this draft a game system operating on a basis of a searching and selecting procedure for the best solution from a set of feasible control processes. By a game system I mean an adaptive control system[3)]

[3)] it was presented and defined at the first Polish-Italian Meeting in 1972, see CONTROL AND CYBERNETICS, vol. 3 (1974) No. 1/2 p. 15.

starting with very poor initial information equipped with a set of pattern choices in which the adaptation process is partly random. The initial information describes both sides taking part in the process (a game against the nature, the environment, the Planning Center, etc.) and the utility function allows the selection of the best solution from the set of choices.

2) by large economic system I mean a system participating in the gross product and the national income to this extend that the results of the collapsing of this system affect in a perceptible way the whole national economy.

3) by planned economy aspects I mean the relationship between enterprises (all economic systems) and the national economy (the planning center) based upon both parametric and administrative ways of formulating goals and tasks, limiting the resources, redistributing merchandises and funds, etc. It means the degree of decision centralization (higher levels) and the degree of freedom of decision-making in enterprises (lower levels).

STRATEGY OF DEVELOPMENT OF LARGE ECONOMIC SYSTEMS

A control process is a sequential, multi-stage process. Fig. 2 shows the components of a combined process of planning and control. At the moment t_0 (now) we have a given state of the system (S). It is a result of the process in the past. We have at the same time certain state of the environment. Now the leadership of the system has to perform many important activities. First of all it uses the prediction about the expected future state of the environment for the moment t_n.

Let say, it is a long-term prediction. Taking the expected future state in the environment (technological progress forecast, the expected sales conditions, the labour market situation, etc.) into account the system top-management

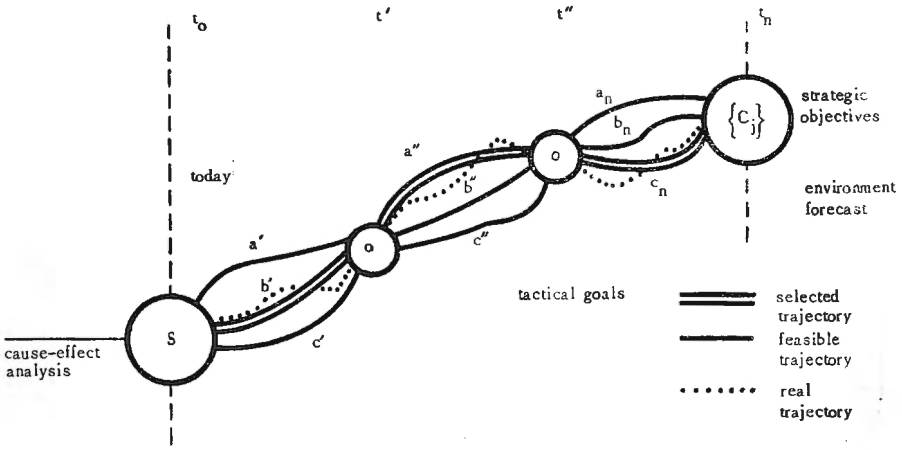
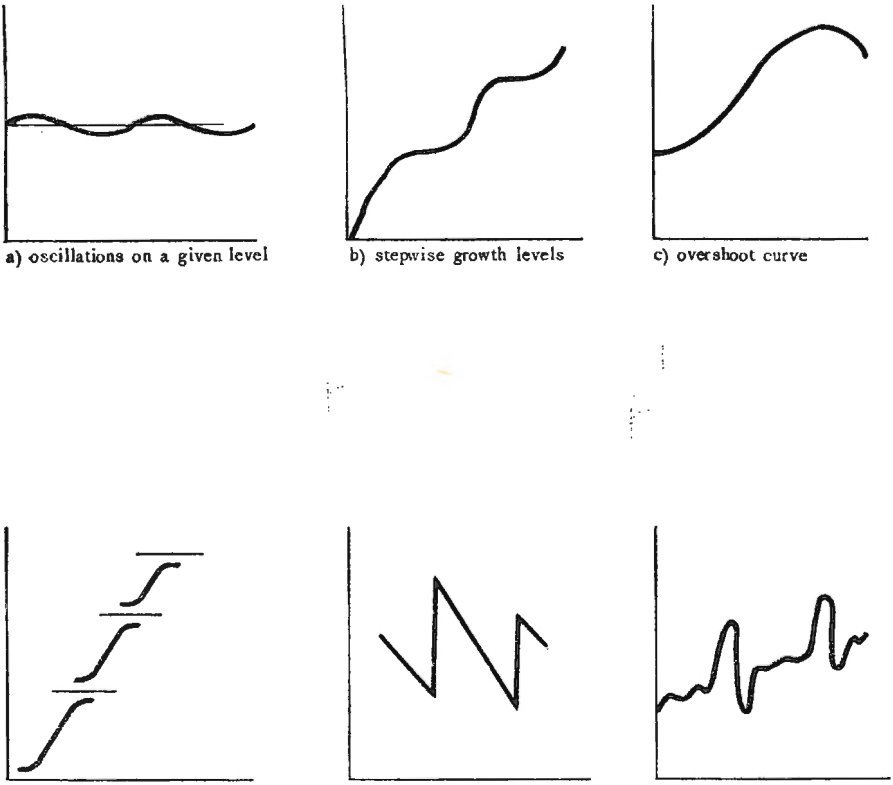


Fig. 2

set up bunch of strategic objectives (it means the required state of the system itself in a given time t_n). After the vector $\{C_k\}$ of objectives is expressed in quantitative terms the intermediate goals for interval periods t' t'' ... have to be formulated (c). These are tactical objectives. Usually, there are many possibilities to reach the intermediate goals. In other words there are many different trajectories leading from one set (bunch) of tactical goals to the next one. That is the area of application of operations research and other optimization methods to find the best way to pass the distance between each set of intermediate goals on the way to the strategic objectives. The chosen way (or trajectory) is illustrated in the Fig. 2 through double lines. Now arises the problem of regulation. The system starts to move ahead. The question is now to observe and to measure the deviations of the system (or its parts) from the trajectory b' in the first period, a'' in the second one, and c^n in the last one. I hope the scheme demonstrates clearly the relations in the decision-making process among all components and factors of an operating and developine system toward



a) oscillations on a given level
b) stepwise growth levels
c) overshoot curve
d) logistic growth with moving saturation levels
e) arhythmic supplementing of a given level of something
f) oscillations interrupted through boom jumps

Fig. 3

goals. There is another final conclusion of great significance for an effective adaptive process of control. The control process includes the following elements:

1) strategic objectives setting-up (and modifications),
2) policy decisions dealing with tactical, intermediate goals related to the resources being available and expected to be available in the future,
3) evaluation of all feasible trajectories and establishing of criteria of choice
4) choice of the trajectory for each period,
5) establishing of regulating standards and a measurement system of deviations,
6) activities leading to decrease and eliminate deviations.

DYNAMIC APPROACH AND SYSTEMS BEHAVIOUR

The behaviour of an economic system and in particular the behaviour of subsystems (production, sales, supply, stocks, capital, employment, productivity, etc.) is usually in agreement with some patterns of behaviour. In Fig. 3 the most often appearing patterns are shown. It is, therefore, easy to predict the behaviour of many subsystems because the reactions of those subsystems are rather routinized. The deviations occur seldomly.

Fig. 4 illustrates the interfaces and interactions between some subsystems presenting a model of flows of real and regulation processes. An operating economic system can be presented in a dynamic way using the flow channels

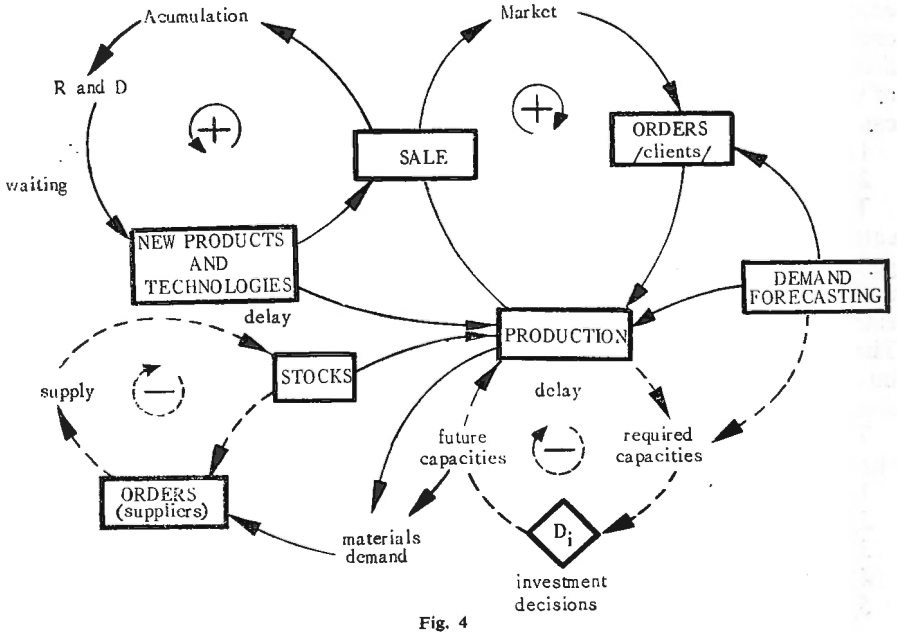


Fig. 4

(arrows) and feed-backs ("+" means the positive and "−" the negative feed-back). Usually, positive and negative feed-back create a pair of loops. The positive feed-back means in an economic system the increase or growth, the negative causes the stabilization on a given level. If the power of both feed-backs is the same we get the state of equilibrium. The temporary domination of one of this kind of feed-backs means that the system goes up to reach a new level of development (new capacity, new products, new market position, etc.) or that the system is in a stable situation.

What I want to stress is that each system in every situation can be shown and interpreted in this way and that it is a very effective method to analyze the behaviour of a system by analyzing the pairs of operating feed-backs. This kind of analysis allows the dynamic modelling of a system and in the next step simulating of the behaviour of it. The three most significant components of the behaviour analysis are (similarly to Forrester dynamic approach): level of something, flow, and decision.

THE ROLE AND FUNCTIONS OF PLANNING IN PLANNED ECONOMY

Investigating the history of development of socialist countries we could conclude that the central planning system can be more or less centralized. The centralization went up and down dependently upon actual policy, the level of development of each particular economy, and the coplexity of the national economy and the environment. The rapid increase of international trade and exchange or for example the energy crisis require different degree of centralization to avoid some negative phenomena. In any case, however, the transfer of tasks formulated in the national economic plan (annual, five-year plan, etc.) can be divided into two parts:

1) direct imperative indicators (non-parametric management system),
2) indirect standards (parametric management system).

The greater is the number of indirect standards in the whole set of indicators, coefficients, standards, and tasks the more decentralized is the management system of the national economy. But each economic system operates under uncertainty. It is a system with probable reactions to the internal and external disturbances. It is, more generaly concluding, a cybernetic system. The main role of planning is on this background the translation of the strategy into an operating system. For this reason it is by nature an iterative approach and a hierarchical structure of many procedures.

There are five most significant and essential requirements related to the functions of a planning system. They are as follows:

1) flexibility (given freedom of choice),
2) complexity (interfaces),
3) hierarchy (multi-level planning and control processes),
4) continuity of both processes,
5) adaptability (parametric and structural).

As I said before a plan consists usually of two parts; one with directly addressed figures and the second with parameters affecting in an economic way the activities of economic systems (associations, companies, enterprises, etc.). The power of each direct and indirect parameter (I will use rather the term standards which is I think more adequate to the role and function of the planning system) is of course different. Now arises the problem how to allocate the standards in a multi-level control process? I will try to answer this question because it is one of the most sophisticated and most important problems to make planning and control process more effective.

MULTI-LEVEL CONTROL PROCESS

In Fig. 5 the decomposition of a control process is shown. The notation $i = 1, \ldots m$ means the level of real processes being under control. The notation $j = 1, \ldots n$ means the number and position of a control center on an i-th

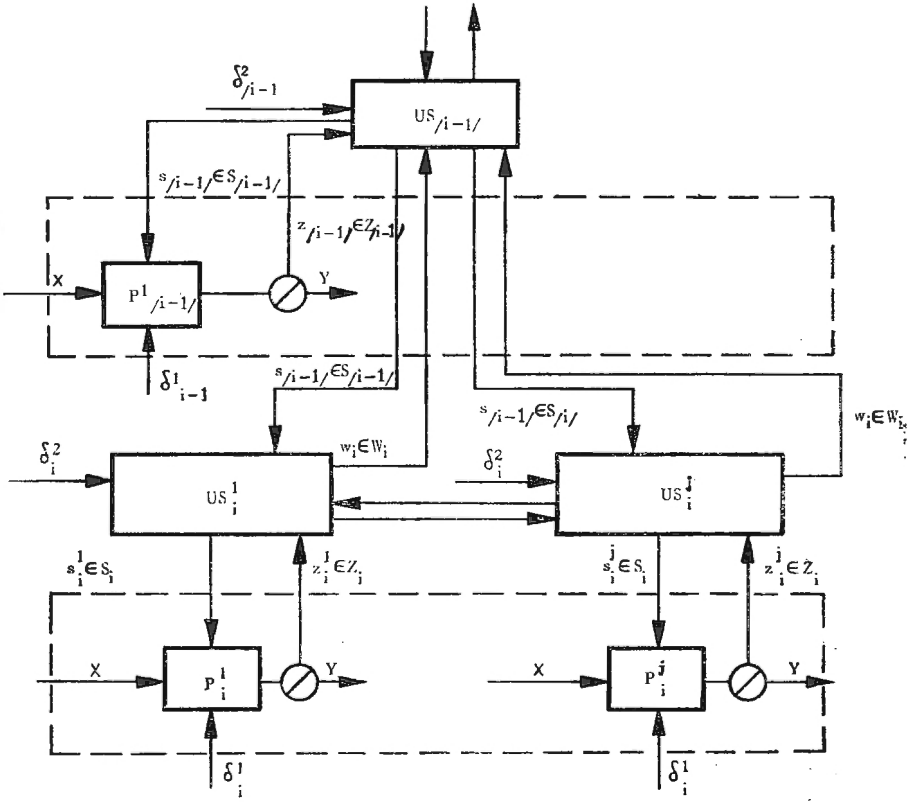


Fig. 5

level of an adaptive control process. P_i^j means the j-th real process on the i-th level and US_i^j the control center keeping the real process under control. S_i means a set of control signals (up-down) and Z_i is a set of feed-back signals (information) going down — up. The set of higher level aggregated information is noted by W_i (going from down — level "i" up to the level (i—1)). The draft illustrates the decomposition of control centers and values which allows to keep the control process as near as possible to the real processes being under control. The higher level center performes the function of a co-ordinator of the whole control process on a basis of a package of alternative regulation solutions. Usually, it is not possible to integrate the control process on one level because there is not one single, total criterion of quality. The higher level control process keeping under control all local control centers would in an other case require the establishing of a polioptimal control assignment. The decomposition of a control model seams to be in most cases a more effective solution. But many local criteria require the introducting of a co-ordinator.

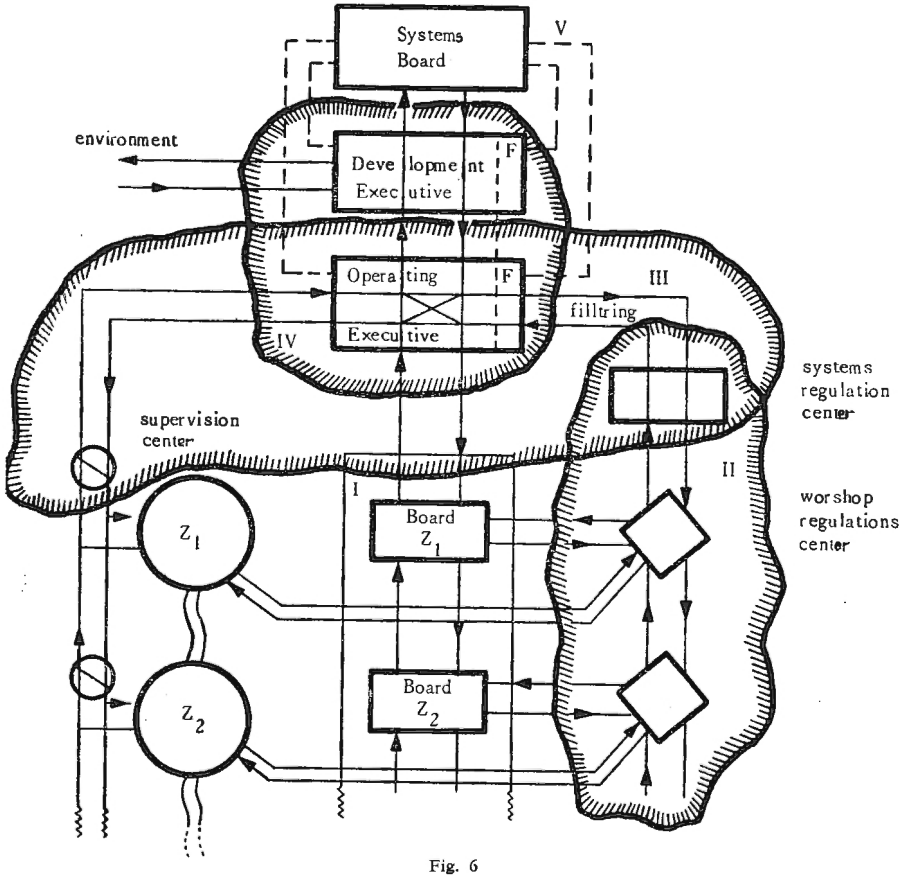


Fig. 6

The hierarchical multi-level structures create many analytical problems, e.g.:

a) establishing of criteria for dividing of the real and regulation processes into subprocesses (*P* and *US*),

b) formulating of local criteria, local optimization of tasks, and standards for the control process,

c) formulating of the criterion of the general control process and describing the co-ordination function,

d) defining and setting up the master set of decisions and the subsets of local, decentralized decisions.

After the general structure of a multi-level control process has been considered it is now possible to present a more practical model. It is a model and structure of a multi-level economic system. It is shown on the Fig. 6. The lowest two or sometimes three levels work as selfregulated subsystems. This assumption is in full agreement with Proof. Beer's statements[4]. It is a typical structure of a large system in which real processes are performed by final product factories as well as co-operating factories and units specialized in transportation, distribution, etc. On the other hand regulation processes are performed by many centers and specialized units (technological, marketing, etc.).

ALLOCATION OF STANDARDS

The proper allocation of standards in a multi-level structure of an economic system is one of the most difficult problems in an economic control process. The structure of allocated standards is shown in Fig. 7. The set of standards N_{ij} is divided into subsets for each i-th level which consists of j-th elements each. I assume that the number of standards is not smaller than the number of goals and control centers. Each area covered by a goal requires at least one standard because in other case it would be not possible to measure deviations and to start the regulation process.

The question is, however, yet open how to allocate the standards. By standards I mean here parameters expressed in economic terms and used to affect in an indirect way the behaviour of a system. In this light the most influencial economic parameters are, now-a-days, in the Polish national economy as follows:

— prices (highly centralized, however, in recent two, three years more and more left to the enterprise decisions,
— income and turnover tax rates,
— duty tariffs (of increasing importance because of GATT membership),
— wages per unit of time or product,
— rates of currency exchange,

[4] S. Beer, BRAIN OF THE FIRM, Penguin Press, London, 1972.

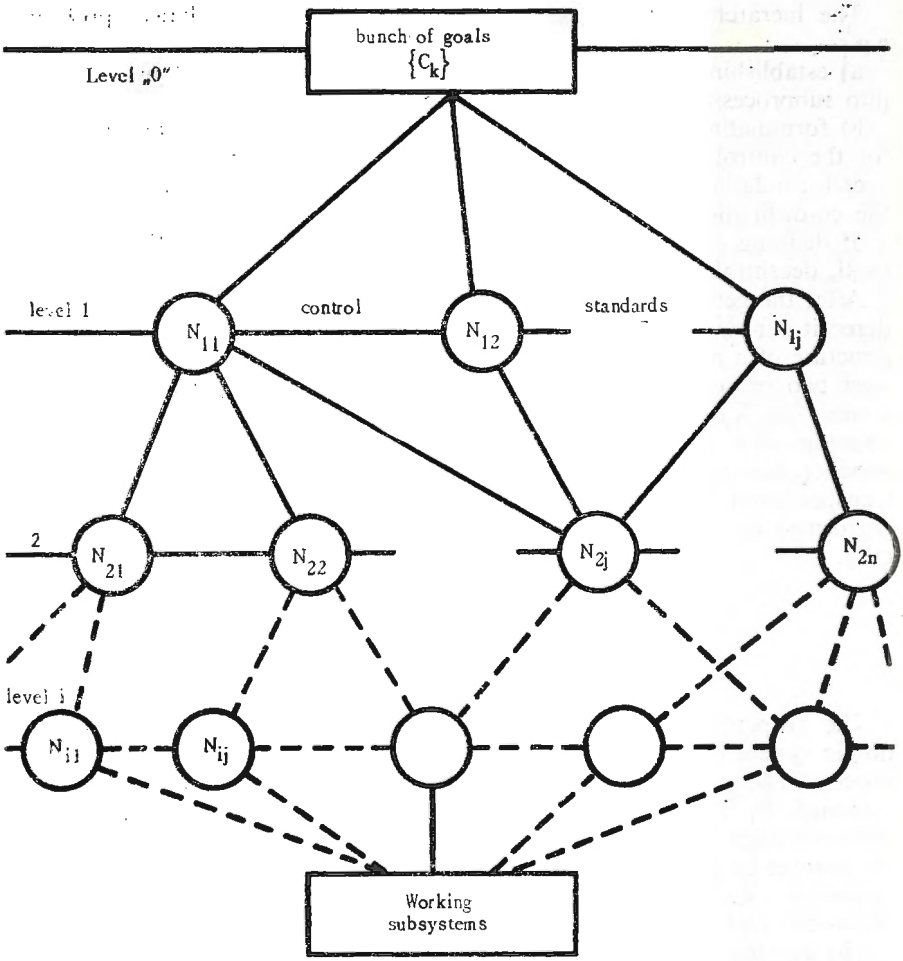


Fig. 7

— fix capital bank rate,
— bonuses and grants,
— net profit payment to the budget.

The list is an example only and is open. All these parameters force the economic systems to make decisions taking into account the economic results and consequences. The rentability, the value of gross and net profit, the productivity, selling and cost all these more or less aggregated values depend and are strongly influenced by this standards. The stock-on-hand level, cash-flows, etc. are internal standards and factors as well as social standards (work con-

ditions, social benefits, attitudes and stimulating systems, etc.). The value of each standard and the changes of these values in accordance with the actual policy following the changing environment and internal structural changes of the system are the subject of the decision-making process. To make a decision means from this point of view to:

1) set up objectives and goals,

2) develop the hierarchical tree of goals and tasks (followed, of course, by the tree of responsibilities),

3) select the optimal or feasible trajectory for each period of time,

4) list all standards and to fix the value of these standards where the value is not given from outside,

5) build a model of the control proces including a measurement system (where, how, when, what to measure, and to whom to transmit the data).

I would like to suggest a procedure for the evaluation of the power of each standard. The matrix approach can be used to find the relations and the power of standards.

standards	N_1	N_2	. . . . .	N_s	$\sum^{s} R$
N_1	0	${}_1R_2$	. . . . .	${}_1R_s$	${}_1R$
N_2	${}_2R_1$	0	. . . . .	${}_2R_s$	${}_2R$
⋮	⋮	⋮	0 .	⋮	⋮
N_s	${}_sR_1$	${}_sR_2$	. . . . .	0	${}_sR$
$\sum^{s} R$	x	x	. . . . .	x	$\times$

Fig. 8

This square matrix is used to compute the total value for each N_j (the sum in rows) and to prepare a list of standards starting with the greatest value and going down to the smallest one. The greater is the sum of matrix element values, the greater is the power of the standard and the influence upon other standards. The only problem remaining to be solved is, however, to evaluate the value of each particular pair of standards. I use, usually, three-digit scale. The digit "0" means there is no relation between the analyzed standards. Digit 2 means strong influence of one standard on the other and digit 1 means a perceptible influence. Using the notations "i" and "j" (at this moment we do not know the allocation of standards in a *i*-th level structure), and R to note the relationship, it is possible to present the relations in the following way:

$$
{}_iR_j = \begin{cases} 0 & \text{for } i = j \\ 0 & \text{for } i \neq j \text{ if there is no relation} \\ 1 & \text{for } i \neq j \text{ and } \left[\frac{N_i'}{N_i} \Big/ \frac{N_j'}{N_j}\right] > 1 \\ 2 & \text{for } i \neq j \text{ and } 0 < \left[\frac{N_i'}{N_i} \Big/ \frac{N_j'}{N_j}\right] < 1 \end{cases}
$$

where N' means the change of the value of the standard (increase or decrease). Perceptible influence can be in some cases proportional and consequently strong influence could mean more than proportional change of a standard being affected by the other analyzed control standard.

Having the total value for each standard we are able to locate them within a multi-level structure. The greater is the sum the higher is the level.

The presented approach is not a precise tool to allocate the standards in an optimal way. Nevertheless, it allows to make the first step in this direction. The second step is based on experimentation routine which could be applied after the standards are temporary settled on all feasible levels.

CONCLUSIONS

The more compound is an economic system the more compound is the process of control. From the theoretical as well as practical viewpoints we do not know a satisfactory way to generate an optimmally effective control process. We agree in this judgment fully with Majminas[5]. Multi-level control systems are, therefore, the only way to make the control process effective in a satisfactory degree. This approach requires some autonomy of subsystems within large, very compound probabilistic social and economic systems. I am here in agreement with J. Kornai[6]. In this case the selfregulation mechanism of particular subsystems can help the system to keep real processes under control. The variety of the most sophisticated control systems is not great enough comparing with the variety of states and reactions of a large system. But autonomy means a need for decentralization in the decision-making area and the parametric planning and managing of the whole national economy. Planning means the formulation of objectives, the policy of resources aquisition, allocation, and use. A control system means, in contrary, an effective performance of tasks and the proper use of resources by each subsystem of a large economic system. The planning process is in practice the problem of top-down translation of goals, global plans, and procedures. Very important

[5] J. Majminas, PROCESY PLANOWANIA W GOSPODARCE NARODOWEJ (The Planning Processes in the National Economy) PWE Warsaw — 1974, § 3.3 and 3.4.
[6] Op. cit. Chapter 13.

is for these reasons the methodological aspect of planning. The problems of language, iterative routines, horizon of time, aggregation level, scope and interfaces among different plans are very attractive questions for a Theory of Planning[7]. An adaptive planning approach and model should be based on the R. Ackoff's assumption. The model has to be equipped with a mechanism of flexible, fast and adequate reactions to situations and opportunities being unexpected before the system starts to work[8].

We are all in socialist countries searching for an effective method to incorporate in the planning system some models and control processes with this degree of adaptivity which is necessary to meet the changing environment. We are searching for an adaptive model, adaptive in two ways; first by manipulating with parameters and secondly by restructuring of a largescale economic system to meet new opportunities amd to react in a proper way to unexpected situations.

The research goes in two main directions. The one field is related to the question of the proportions and interfaces between the predictive (or descriptive) part of a plan and the imperative one. This includes the problems of autonomy, decentralization, selfregulation, equilibrium of a system and many other highly sophisticated questions. The other area is dealing with different profile of an adaptive plan. In this case the two main parts of a plan are called: declarative (describing the final states of a system in a given time) and a procedural part. It is the methodological aspect of a planning process.

The questions how to build an adaptive plan and how to incorporate it in an adaptive control process are still open.

SUMMARY

First of all the characteristics of an adaptive model is discussed. Both basic models are described, namely by adaptive parametric models and by adaptive structural models. The first are able to response to the environmental changes by changing their own parameters, the other of models by changing the structure of the system. Secondly the the main dimensions of a correctly constructed model are presented: the aggregation level, the scope, and the horizon of time of a model. The presentation of a modelling approach for large economic systems deals with three elements of a control process: the stability, feed-backs, and with variety of states. On this basis the scheme of a multi--level control process is developed and interpreted. The next paragraph is devoted to some important aspects of the Planning Theory. The role and functions of the planning process and the plans are discussed: mainly the flexibility, complexity, adaptivity, hierarchy of planning, continuity, and the multi-level

[7] See J. Emery, PLANNING AND CONTROL MacMillan Co., 1969, Chapter 5.
[8] R. Ackoff, A CONCEPT OF CORPORATE PLANNING, Wiley, 1970, Chapter 1.

structure of both planning and control processes. Finally the following two problems are emphasized and described in some details: the question of decomposition of a control process in large systems and the general rule consisting of three crucial steps in control process designing:

— objectives setting-up (bunch of goals),

— control standards assigning and their allocation in a multilevel large economic system,

— the use of regulation procedure to eliminate deviations.

Instytut Badań Systemowych PAN
Nakład 300 egz. Ark. wyd. 25,0. Ark. druk. 23,75. Papier druk. sat. kl. III 80 g 61×86. Oddano do składania 8 X 1976 Podpisano do druku w sierpniu 1978 r. Druk ukończono w sierpniu 1978 roku

CDW — Zakład nr 5 w Bielsku-Białej zam. 62/K/77 J-124