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

Redaktor techniczny
Iwona Dobrzyńska

Korekta
Halina Wołyniec

POLSKA AKADEMIA NAUK
INSTYTUT BADAŃ SYSTEMOWYCH

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

BIAŁOWIEŻA, POLAND
MAY 26—31, 1976

EDITED BY J. GUTENBAUM

WARSZAWA 1977

Redaktor techniczny
Iwona Dobrzyńska

Korekta
Halina Wołyniec

PREFACE

The present volume comprises the papers from the 3rd Italian-Polish Conference which was held in [illegible] [illegible] to 13. The conference organized by the Centre of Control Systems and Computation of the Italian National Research Council in Rome and the Institute for Organization, Management and Control Sciences of Polish Academy of Sciences and the Ministry of Science, Higher Education and Technology in Warsaw was the third conference of this type.

The first one took place in Kraków (Poland) in [illegible], the second in Pugnochiuso (Italy) in [illegible].

This conference, like both the previous ones, gathered the leading representatives of many scientific centres from Italy as well as from Poland, representing also the different aspects of the systems analysis applied to the economic, management, data processing and technological systems.

From the past such meetings enrich the exchange of views and experiences between the specialists from both countries what is the facilities advantageous to both sides. Above the scientific part, the communication of the systems and control theory specialists with the econometricians contributes to the essential development of the quantitative methods and the particularly applicability of large complex systems.

The meaning of such meetings, however, goes far beyond that what is happening during the conference because the established contacts are also fruitful in form of common scientific research works and — last but not least — form the friendly links between the scientists of both countries which last for years.

The proceedings of the conference were divided into three parts:

1. Optimization and Control Theory;
2. Systems Theory in Economics;
3. Technological, Management and Information Systems.

While the first two parts are of rather homogeneous character, the third part contains the papers concerning the different types of models — for the economic, technological, management and data processing systems.

A. Straszak
J. Owsiński
Systems Reseerch Institute,
Polish Academy of Sciences, Warsaw

SYSTEMS ANALYSIS APPROACH TO INTEGRATIVE ORGANIZATION, PLANNING AND MANAGEMENT FOR THE DEVELOPMENT OF THE REGION

WHY REGION?

Spectacular emergence of regional problems in politics and economy, as well as - consequently - in science occured some time ago; we do not try to be unique with this respect. After a period of "coping with" or "finding the way round" a region, politicians, economists, and scientists have begun the serach for positive solutions. It is obvious, however, that it is the growing complexity of socio-economic situations which has brought about the necessity of finding these solutions. To solve the new, complex problems of regions we have, therefore, to utilize new, powerful methods, first to understand the problem and then to determine feasible or optimal alternatives.

Growth of importance of regional problems results from development of production means (growth in volume and speed of performance), transportation and communication, increase in geographic density of economic activities, and specialization of these activities. In order to understand the mechanisms that have brought about regional problems, let us consider the following thought process (Exhibit 1): The most prominent and distinct socio-economic large systems today are **national systems.** From an economic and organizational point of view these systems can be divided into **subsystems** to which we refer as **sectors of economy**. Here we shall use the word "sector" in a general sense, meaning by it all these national subsystems which have maximal "vertical" hierarchical stretch; this may range from a central authority (e. g. ministry or large corporation headquarters) to a great number of bottom-level, site--ascribed units (e. g. individual enterprises). It is easily noted that in the last few decades such sectors have greatly changed their character. From **sets of dispersed, isolated units** carrying out their activities in relative separation, they have become **highly interconnected hierarchical system**, sensitive to changes in individual elements. Also the flows between the sectors have increased both in volume and in speed, and what is particularly important here, the average geographical reach of flows originating from one point has rapidly grown. If we add to the above mentioned phenomena the fact that geographic density

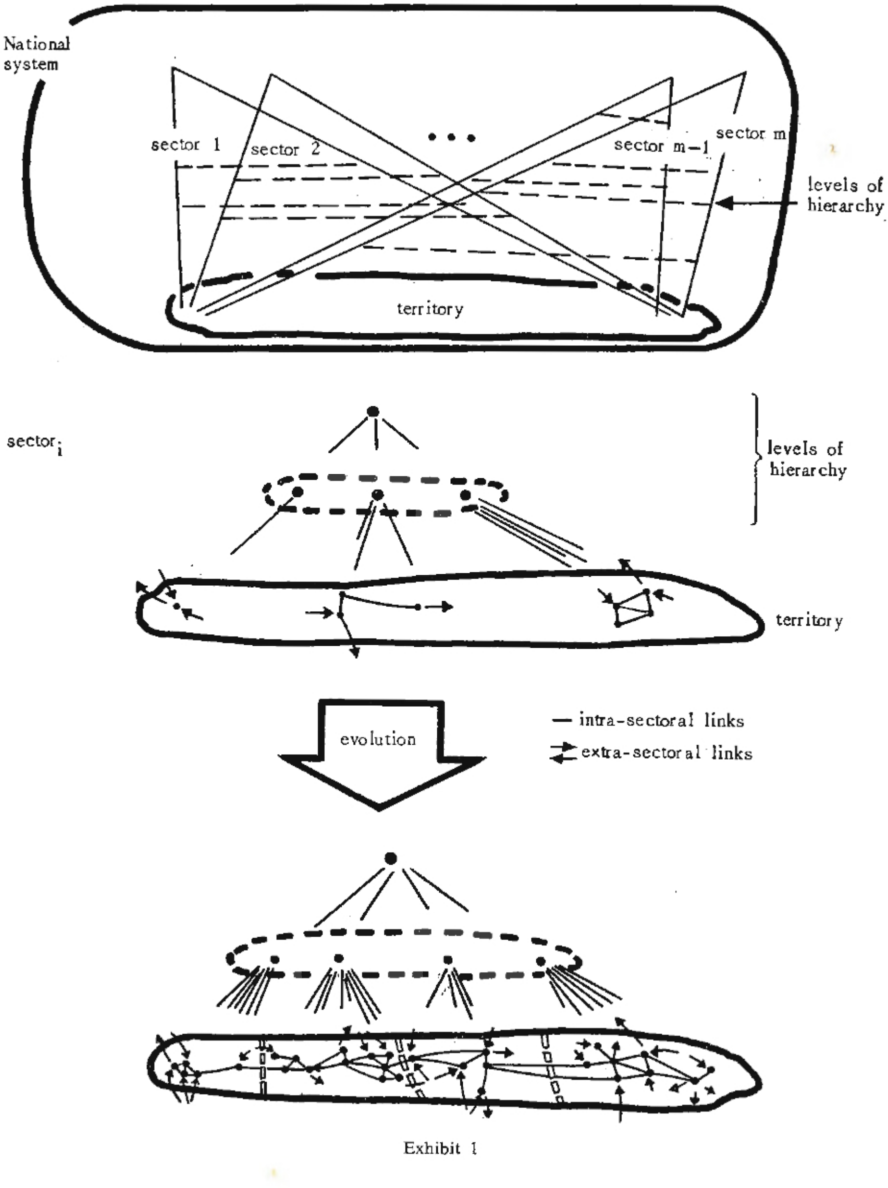

National system
sector 1
sector 2
sector m-1
sector m
levels of hierarchy
territory
sector$_i$
levels of hierarchy
territory
evolution
intra-sectoral links
extra-sectoral links

Exhibit 1

of socio-economic activities has grown as well, we see why it may be said0. that individual **territorial units** entered into contact with entire sectoral, and thence national systems, and gradually **became inherent elements** of these complex systems. It not only means that the territorial elements are greatly dependent on other parts of the system, but also that these other parts depen on appropriate territorial elements. However, the importance of such percept-ion appears, not exclusively, as it may seem, for already developed territories and regions. For each new, virgin area developed there exists a complex of potential interlinkages with other parts of national systems; therefore such new areas cannot be considered separately from other national systems.

We have stated, then, that territorial units achieve nation-wide importance in as much as the activities carried out within these units affect the whole national system (through the progress in transportation, communication and specialization) and become affected in the complex array of interdependencies framework. To further complicate this picture, we must add that there exist national subsystems which deal directly with the geographic dimension of national socio-economic systems, e.g. the administrational system.

Having thus roughly described a new, complex situation (qualitatively new, but resulting from quantitative changes within the system), we shall now present some of the problems and opportunities which can emerge:

— Coordination. The need for coordination has two sources: first of all, the interests of many sectors (often conflicting, e.g. the quest for land) in one territorial unit, and second ly the matching of sectoral (i.e. national-level) interests with local ones expressed by population. Coordination problems must be solved through establishment of adequate mechanisms on the lowest territorial level of sectors and on each level of their hierarchy.

— Regionalization. Appropriate breakdown of geographic space for sectoral and administrational purposes is one way of facilitating the task of coordition; at the same time it is a self-standing planning and management problem (e.g. in the design of hierarchical structures of organizations).

— Development. Everything that happens in social and economic spaces, happens also in geographical space. Suppose that we want to undertake a development venture which is somehow geographically located. Then, in view of all the complex of interests and interdependencies which potentially or currently relate to the area to be developed, in order to obtain the best (perhaps only feasible) results we are obliged to take into consideration all of these interests and interdependences, all the systems they constitute, as one whole. This is the starting point of an integrative approach to development. We are obliged to make an effort in the direction of integration, because our intuition will no longer tell us (with adequate accuracy) about the possible effects of isolated actions taken within one subsystem or element on the whole system.

One more clarification is needed before we close this section. We have deliberately not defined what we mean by "region"; and throughout the text we often utilized the term "territorial unit". As we understand it, "region" has precisely the meaning given to it by the purpose of a given socio-economic system analysis. It is obvious, however, that all the quasi-reasoning presented here is significant only if entities referred to as "regions" are themselves complex socio-economic systems and are placed somewhere "in the middle" of the appropriate (administrative?) national hierarchy. The "territorial units" should, then, consist of more than one dwelling, more than one enterprise, etc. so that conclusions on, e.g. multi-interests, may apply.

The regional (or territorial, or spatial) problems of national socio-economis systems in advanced countries have therefore come to the forefront. We would like to propose one way of helping to solve these problems.

SYSTEMS ANALYTIC APPROACH

The science, and art, of systems analysis can be regarded as a consistent, methodic approach to: 1) indentification of basic elements of a given organization, process or phenomenon, 2) establishment of relations among these elements, and 3) synthesis and analysis of a model reproducing relevant features of the systemic behaviour of the system analyzed. (We are not insisting on any particular form of model-see W. Orchard Hays [1976] — the only requirement is that it be explicit). These three essential initial steps lead to the next phase in which certain real-world action is performed (design, policy decision, etc.). Definitions may vary, depending on different specific applications in view (see, e.g. Hoag [1956], p. 4); but more detailed considerations always reveal the necessity of including all of the above steps (Hoag [1956] p. 5., Quade [1963], p. 9).

It is obvious that the individual system's definition (boundaries, elements, relations), and hence the model itself, largely depends on the character of our research, i.e. on the systemic features analyzed. If, once the boundaries of the system are established, we want to synthesize the inside of the black--box thus created, basing on its input/output series, then the dimensions of the input/output data and our background thinking when delimitating the system will have decisive impact on the form of the model — e.g. mathematical formula — we obtain. The main aim of the analyses is to recognize the mechanism of the systems functioning in order to duplicate some of its features or to affect it in some desirable way (anticipation or future behaviour and then policy-making based on it, "organization" of the system, both on real and abstract levels; e.g. design of "classification systems" for given sets of objects, etc.). We are looking, then, for such models that can reproduce the real-world behaviour of our concern as accurately as is necessary for the above purposes.

It is possible, especially for single, well determined purposes, to construct models of much lower dimensionality, or variety than their real-life objects, and to apply them sucessfully to the aforementioned purposes. When this situation does not take place, a very important problem arises; one of reconciliation and integration of various approaches to and aspects of the system during the modelling, analysis, and utilization stages. The question thus posed, though directly pertaining to modelling activity, is closely related to problems of integration in regional development planning and management. The model which includes all relevant aspects and perceptions of the system would be a powerful tool in real-life integration. In the case of very large, complex, socio-economic systems we are, in fact, faced with a multitude of analyses and respective modelling efforts dealing with the same or various facets of the system. A solution to the problem of integration can then be provided in two ways:

1) construction of one general, comprehensive model which includes in its logical structure, possibly all existing theories explaining behaviour of given subsystems of the system or its subsequent aspects; or

2) interconnection of existing models as elements of a certain system, which is itself the model of a large and complex real system.

Up to now, very few integrative analysis and modelling efforts have been undertaken for systems of regional or national scale, Most of those that have been, however, tend to utilize the first approach mentioned, with some subdivision into subsystems or models, but with the same philosophy observed throughout the entire model (e.g. Aganbegyan et al [1971] or other models such as Inforum or Wharton). In some cases, use is made of some individual "external" model to provide necessary projections for other parts of the overall model (see Hinote [1976], SEAS). Ultimately this synthesizing approach is the ideal one, for it implies the elaboration of a comprehensive model that incorporates all the aspects of real socio-economic processes into one homogeneous system structure; i.e. a kind of general theory of complex socio-economic systems, like general field theory in physics (an example can be given by the the Mesarovic and Pestel [1974] model based on Norm, Organization, and Causal strata for representing regional subsystems of the world system and their inter-relationships). A number of approaches to complex systems analysis and optimization exists, resulting from various scientific backgrounds of proponents and from various objectives of analyses, among them multilevel control systems approach (Mesarovic et al. [1968]), Cybernetic CNS approach (Beer [1972], and others. To date, however, these approaches have provided only very general, chiefly descriptive results, and have not covered all relevant features of the systems analyzed. One of the difficulties lies within the bard task of integration of existing, well-proven partial theoreis, so as to form one general theory. This very fact of existence of distinct theories and models thereof explaining clear-cut sets of phenomena implies a second way of proceeding in the complex system's model construction: This consists in projecting all available models which satisfy certain quantifiability assumptions into a rough system's structure, in establishing adequate connections between models thus placed, and in the analysis of the system of models thus created. As far as we know, no consequent research in this field has been undertaken. The scientific community is, however, on the threshold of such projects (e.g. project LINK), with the increase in number and importance of comparative model studies and their significant reflection at IIASA (Charpentier [1974], [1975], Foell [1975], and Global Modelling Project works).

The philosophy underlying the system of models approach is esentially the same as for any other system analysis. If the equations describing an individual element's behaviour "in itself" and "in interaction with other elements", forming together some mathematical model may vary substantially, reflecting not only various behaviour of the elements, but also various types of analyses and mathematical formalisms which led to establishment of given equations, then the same may happen on an aggregate level, with no detriment to the model's validity. In fact, diverse models, which form the system of models based on different kinds of analyses and mathematical formulations, can be regarded as elements of this system, inasmuch as they reflect certain real entities. And if these entities, along with their interrelations, are well modelled then the entire ıeal system is also well modelled.

The first task with which we are faced is to elaborate the structure of the system which can, in terms of the systems analysis stages evoked at the beginning, be treated as definition of system boundaries and elements. The boundary of a regional system can be defined on the basis of physical (geography, geology, land-use), economic (industrial, service and agricultural activities and their connections), social (types of settlements, daily migrations, stratification, cultures) and organizational classifications. The final deliminatation made for systems analysis purposes should also account for availability of adequate data for a given region. It may also be of interest sometimes not to define explicitly the region's boundaries, but rather to look for "regional" solutions as some specific features of other, well-defined national subsystems (e.g. territorial aspects of sectors). The same holds for enumeration of system's elements. They can be defined in different ways, depending on the person defining and the goal of analysis. It is most frequent to combine (or to imply combination of) ultimate users — planners or managers — and model makers points of view. The definition of elements is decisive for systems structure. We must try, therefore, to integrate in this stage of research as many aspects and views of regional system as possible. In order to reconciliate different classifications, one may use Zadeh's fuzzy set theoretical approach (Blin [1974], Kacprzyk [1975]), yielding a sort of non-frustrating compromise solution for, e.g. expert scoring. Speaking about general issues of the creation of systems structure we shall not go further on, because more detailedness may constrain the use of any individual model and determine a priori its place and role in the system which we want to avoid. The system's structure should be the general framework for allocating the models and to the least extent possible, reflection of a certain "general theory", which could be inconsistent with some models ("partial theories") included. We shall present now a somewhat simplistic example of models (elements) and relations classification that could serve as a basis for models system structure elaboration. Though this classification may seem banal, it has already been used for analytic purposes with satisfying results. The object of analysis, however, was not the regional system itself, but the modelling activities, hence appropriate sets or systems of models in two regional development cases — Tennessee Valley Authority and Bratsk-Ust-Ilim Territorial Production complex. These modelling activities were analysed in the manner similar to the one proposed in this paper. Appropriate detailed results are to be found in the TVA Case Study Report [In prep.] After presenting an example of possible model classification which can be used for creating model system's structure we shall give a very short overview of the results of our analytic studies in TVA and BI TPC.

Classification of Structure Elements and Relations: As example for the case of a region following classifications to be applied to incorporated models may be used:

I. Place in the "physical scale" hierarchy:
 1) international
 2) national
 3) regional
 4) sub-regional (one level below regional level)
 5) sub-sub-regional (two levels below regional level)

The final, lowest level relevant to a regional system should be established individually for other given aspects indices (as it depends on the object considered, etc.).

II. Object or sector (with further breakdown exemplified for some cases)

1.	Social demographic	(e.g. sex/age, labour force, occupation, education, mobility, income, consumption, model of life, demand)	
2.	Natural resources	— land (and landscape)	
3.	,, ,,	— water	
4.	,, ,,	— energetc	
5.	,, ,,	— forests	
6.	,, ,,	— mineral ε other	
7.	Environment	— pollution	
8.	,,	— waste and refuse economy	
9.	,,	— land-use (including landscape preservation)	
10.	Industry	— mining	
11.	,,	— energetic	
12.	,,	— construction	
13.	,,	— wood/timber	
14.	,,	— processing of agricultural products	
15.	,,	— production goods	with appropriate further breakdown accounting for all main sectors
16.	,,	— consumption goods	
17.	Transportation	— (cargo/human, and by means of transport)	
18.	Agriculture	— (crops, fruits ε vegetables, animal husbandry, honey, etc.)	
19.	Services	— trade ε related	
20.	,,	— health care	

21. Services — primary ε secondary education
22. ,, — infrastructural (water, gas, etc.)
23. ,, — emergency
24. Higher education and *R ε D*
25. Settlements and housing (including facilities location).

This sketchy classification is by no means exhaustive (see example below) or consistent (e.g. location or environmental problems are pertinent to any sector). It is a proposition drawn for specific purposes of regional analysis which partly explains the place of location and environmental problems. Examples of further breakdown include:

11. Industry — energy
111. Overall sector development
112. Demand for energy (by types of energy and by type of users)
113. Fuels ε sources
114. Transportation and transmission
115. Electric systems: development and management.

A model may describe either one of the sectors listed above, its part, or several of the sectors. To account for some macroeconomic models, however, which do not have explicit breakdown into sectors, we shall add one more „object":

O. General socio-economic processes

On the other hand, each of the subsystems listed is characterized by a set of features which form the next axis of classification:

III. 1. Organization (with a separate "box" for governmental models)
2. Economic mechanisms
3. Legal mechanisms
4. Informatics (information flows, subsystems and data bases).

The next classification pertainds to diverse functions which can be helped by the use of specific models:

IV. Function
1. Projecting
2. Strategy generation and evaluation
3. Forecasting
4. Planning
5. Programming
6. Monitoring
7. Controlling.

V. Time-horizon (closely linked with previous asoects)
1. Long-range
2. Medium-range
3. Short-term.

No specific criterial magnitudes have been given, as they largely depend upon the kind of activity (sector), scope (level) and function performed. We may only repeat after Chen (Modelling... [1975]) that the short-term modelling should account for the "inertia period", the long-range for "control period" (structure also being controlled) and the medium range for time points in between.

All the classifications given up to now can be regarded as reflecting certain objective reality. The following classifications refer only to pure modelling aspects.

VI. Kind of model

VI.A. 1. Normative
2. Forecast/descriptive

VI.B. 1. Deterministic
2. Stochastic

VI.C. 1. Static
5. Dynamic

VI.D. 1. Econometric
2. Input-output
3. Simulation — "structural"
4. Simulation — dynamo
4. Simulation — dynamo
5. Programming — linear
6. ,, — nonlinear
7. ,, — dynamic
8. ,, — others (combined)
9. Gaming
10. Expertise/interaction
11. Others.

This classification is also far from being complete and consistent (any combination of the above features is feasible). For instance, if would be very interesting to classify the optimization models according to their objective functions (cost minimization, profit maximization, demand satisfaction, etc.) or type of economic mechanism included (demand-supply balance, plan-goals achievement, prices adjustment etc.).

All the models that can be listed according to the above classification can be appropriately indexed, $X^{I,\ II,\ III,\ IV,\ V}_{VIA.\ VIB.\ VIC.\ VID}$ where subscripts show the place in real-life systems, superscripts indicate models nature, and X is the name of model or models (in case there is more than one identical with regard to this classification).

RELATIONS

Provision of the above classification has given us the general framework within which to place appropriately the incorporated models. The next step will be to establish relations. If we represent all the "boxes" created by the classification as points on one axis and plot this axis against an analogous one, we obtain a relation/dependence matrix for the models. On a very general level this matrix can show relations between models by means of the following distinctions:

relation : *R* (possibility of using output information of one model for the input of the other, or for verification);

connection : C (potential or real **direct** information flow between models);
subordination : S (submodel of the other);
inclusion : M (model comprising the other);
identity : I

This representation of interlinkages between models allows for certain preliminary analyses, such a determination of actual and possible degree of integration, multipurpose utilization of models or connectivity indices (see the TVA Case Study Report [in prep.]). These general analyses can give us important information about the real reflection of the systemic value of the region and its environment in current modelling undertakings.

Other essential information on relations of model scan be given by data relation indices. For each case in which the above relation exists, a statement of data compatibility and adequacy can be made:

aggregation : A (simple aggregation of data of lower-level models);
disaggregation : D;
identity : I;
partial fit : P (combination of above).

In further stages of analysis and then in systems construction, such representation of interlinkages will be insufficient, necessitating a switch to enumeration of variables.

CASE STUDIES IN TENNESSEE VALLEY AUTHORITY AND IN THE BRATSK-ILIMSK TERRITORIAL PRODUCTION COMPLEX

The concept that we have roughly presented in preceding section was applied in an analytic way to studies of development and use of models in two cases of regional development: the Tennessee Valley Authority (TVA) in USA and the Bratsk Ilimsk Territorial Production Complex (BI TPC) in USSR.

According to our assumptions if a single model reflects a part or one aspect of the real object, then the group, or the system of models is reflecting the greater "part" of the object and ultimately the object as a whole. If, therefore, a number of models have been developed in an organization, they form a part of a comprehensive model of the object system. The systemic features of the system consisting of individual models are, then, the reflections of appropirate features in the object system and in organization where the models were developed.

Thus, we have analyzed the existing and projected models and their systems for the descriptive purposes. Elaboration and analysis of the systems of models allowed, however, to formulate certain normative statements concerning gaps in the systems and future directions of development.

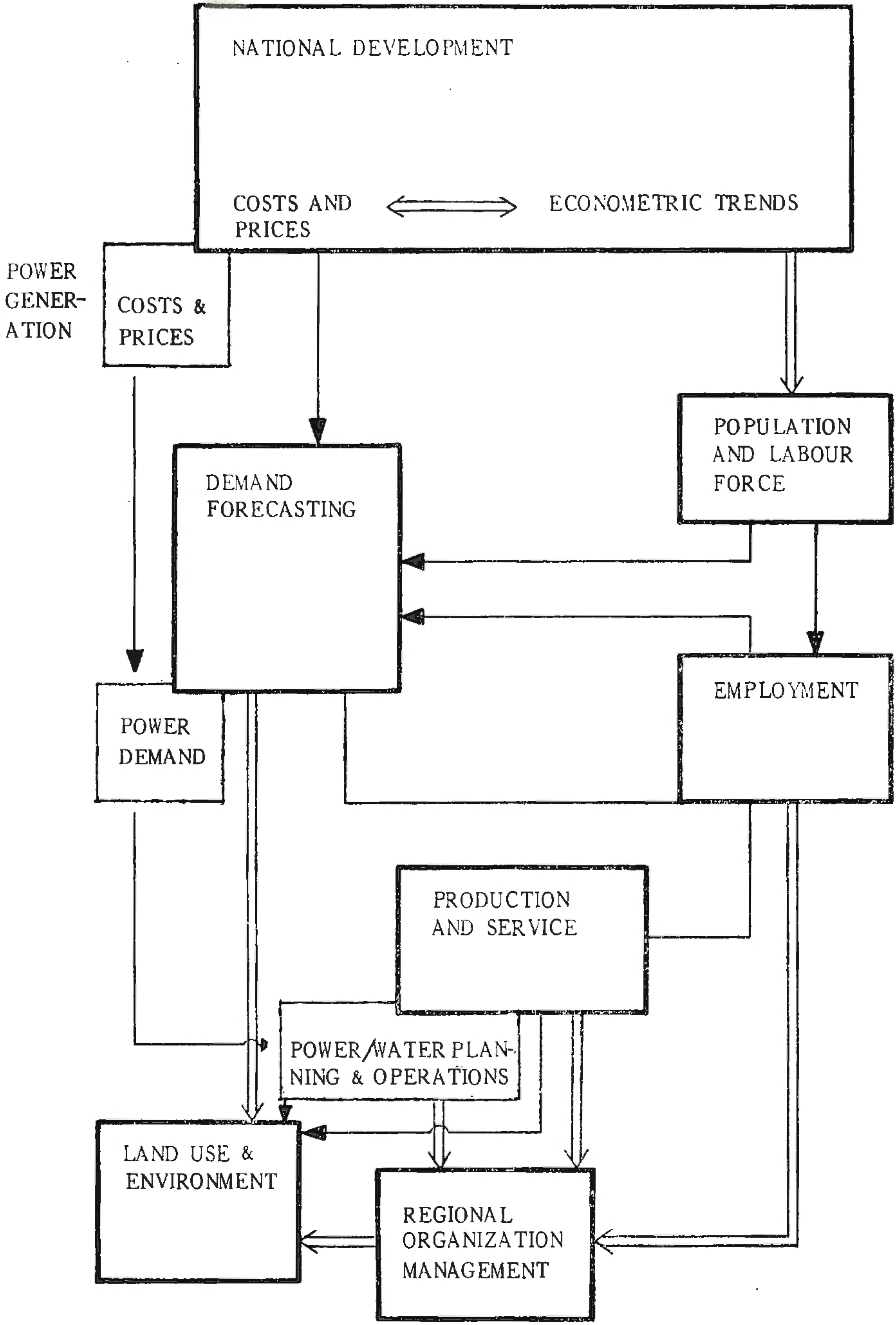
Of course, utilization and role of models in decision making is not only a matter of model availability and model-building capacity, but also of the general policy towards model development and use. Therefore, we tried to analyze the **general attitude towards the creation** of models assisting decision makers and the **general characteristics of the ways in which the models were utilized**, rathed than going deeply into **analysis of individual models**. Our approach consisted of three stages which can also be regarded as levels of analysis. The analysis starts at the level of elements, i.e. individual models and their homogeneous groupings, then the model system as a whole is considered, and finally this system is mapped into the decision process.

Elaboration of the Table of Models - The table contains very rough characteristics of individual models. For each model we identify its purpose, methods used, dimensions of tasks solved, ways of utilization such at "analytic", "forecasting", "planning", "operational" or "engineering", stage of development, and connections with other models. It can generally be stated that the classifications of models in each particular case may be based on subsets of a certain hypothetical comprehensive classification. On the lower level the same may apply to variables. The sample of models taken into consideration consists of those models that are significant in planning and management of the regional program. In the TVA case the sample comprised 65 models out of several hundred existing in the organization, and the preliminary table for BITPC contained descriptions of 37 models, a number which is very likely to grow in further studies.

Analysis of the System of Models — On the second level of analysis, the set of models characterized in the table along with their interconnections is considered as a system itself. The structure of this system and its dynamics are analysed. Our aim is to assess the directions of development of the system of models and its systemic properties such as connectivity or organization. This gives us an important insight into the philosophy of the treatment of models in a given setting on an aggregate level.

In TVA we were dealing with a number of relatively isolated subsystems, or even separate applications. The connectivity ratio was low, and the direction of development was from isolated models and computer applications to subsystems; we were at the time witnessing the efforts to interconnect several subsystems. The main subsystems of interest here were the regional socio-economic and the power/water subsystems. During the Bratsk-Ilimsk Conference, in the other hand, we were presented with an idea, already to large extent implemented, of creating a consistent model system in the domain of general socio-economic regional planning. Other models relevant to the regional program, though not yet interconnected, were all related the problem of power production and river control, just as in TVA.

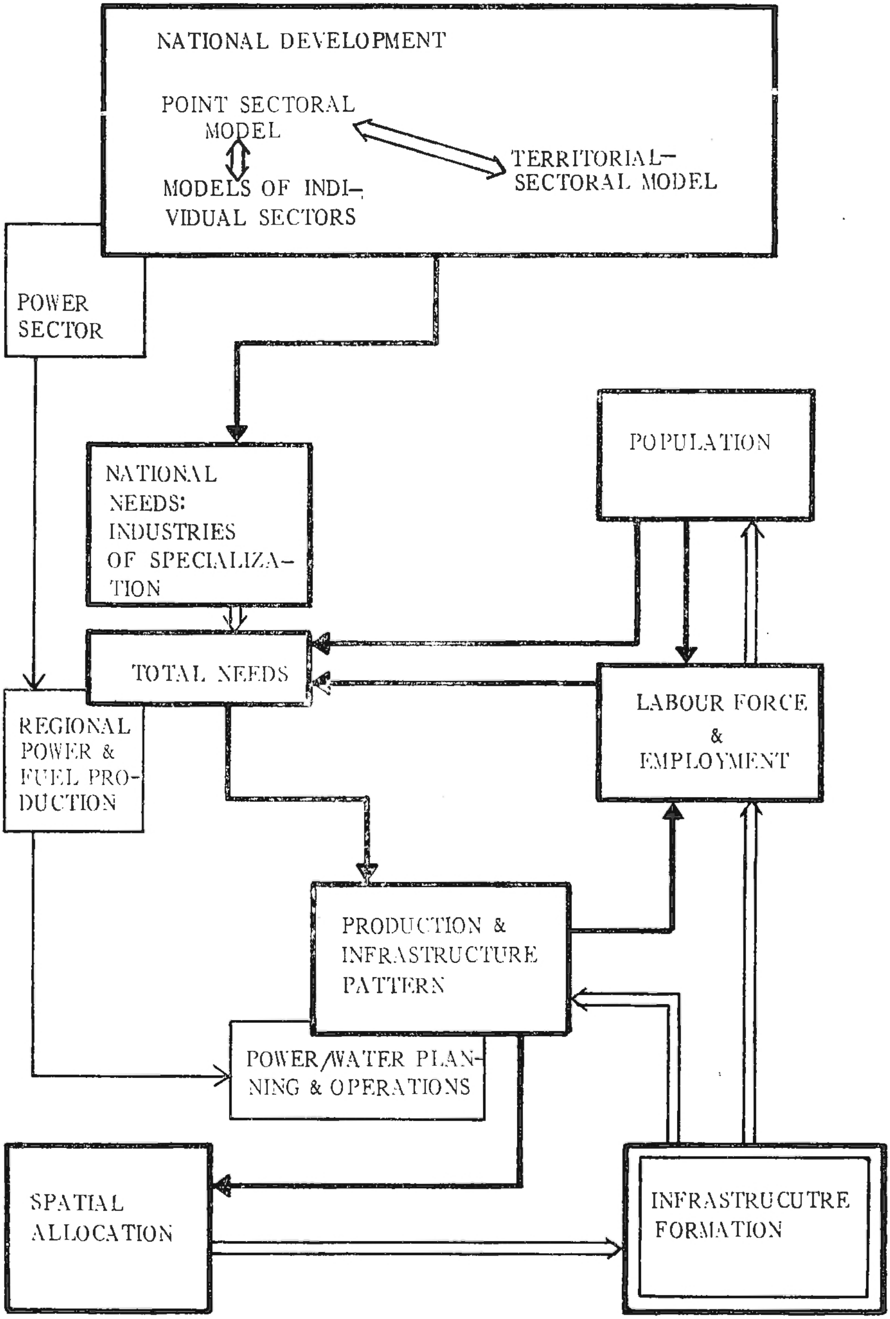
Embedding in the Decision Process — We begin this stage o analysis by mapping the general structure of the model system against the real structure of the planning procedure and the reality of the decision object. It is at this stage that we obtain the simple diagrams, which reflect to some extent the planning rationale behind the system's creation (see Exhibit 2 and 3). In these diagrams we can see the main modules of the system of models, connected with national-scale considerations and most important regional problems and subsystems. These modules are more or less coherent groups of models. Interconnections between modules show main existing or potential informa-



TVA – REGIONAL MODEL SYSTEM

═══ elements not existing in BI TPC

Exhibit 2



BI TPC – REGIONAL MODEL SYSTEM

═══ elements not existing in TVA

Exhibit 3

tion flows, and at the same time the points where the major decisions are to be taken.

Though the set of modules and the outlook of the systems structures in both cases are fairly similar, reflecting the objective reality of any regional socio-economic system, the role and functions of models in TVA and BITPC are different.

In the TVA case the region-oriented model subsystem had predictive purposes for **processes on which the model sponsors had little or no governing power;** in BITPC, the analogous system (much bigger in scope), was meant to **provide optimal planning** alternatives **to be implemented** through use of adequate measures. On the other hand the TVA model system stretched down to the operational level as the result of the operationality o TVA activities; this was not the case with BITPC, which was exclusively the object of planning.

Differences between the contents of seemingly similar structures of model systems can be illustrated by the example of a "Needs-Demands" module. In the TVA case, the demand for various commodities is projected on the basis of costs and prices forecast by national econometric models and on the basis of social-regional forecasts. In the BITPC system, the module is broken down into two pieces. In one, the pattern of so-called "industries or regional specialization" is determined, i.e. the quota of production in chosen branches, which are of national importance. In the second, the previousre quirements are summed up with those resulting from social infrastructure formation needs and from other industries in the region. The information flow in the BITPC case has, then, a fully normative character.

This regional planning system is in fact the part of a greater concept of a national model system for planning on all levels and for all time horizons (see Exhibit 3). Presently, the regional system is operated in relative separation from the national-level modules. It is used for pre-plan studies in long-range planning of territorial entitites of the territorial production complex type. The model runs are requested by planning bodies of various levels and serve mainly for elaboration of socalled "general schemes of allocation of productive forces", the main quideline for planning the spatial dimension of economic development. The system's operation is divided into stages on which the plans are elaborated with increasing detailedness. The stages correspond to iterations of procedure that are formed by closed loops of modules in model system structure (Exhibit 3).

This system is not regarded, of course, as a main tool of long-range planning, but it is capable of giving clear-cut recommendations for siting and volume of different production and infrastructure activities. It has been run for data on various territorial units within and in the vicinity of the BITPC, and in several cases the proposed planning alternatives differ from those obtained by using traditional methods.

While in BITPC the regional planning system has been implemented and thoroughly tested, in TVA the need for an analogous system has appeared fairly recently and the system, having purely forecasting and not planning purposes, is now being created.

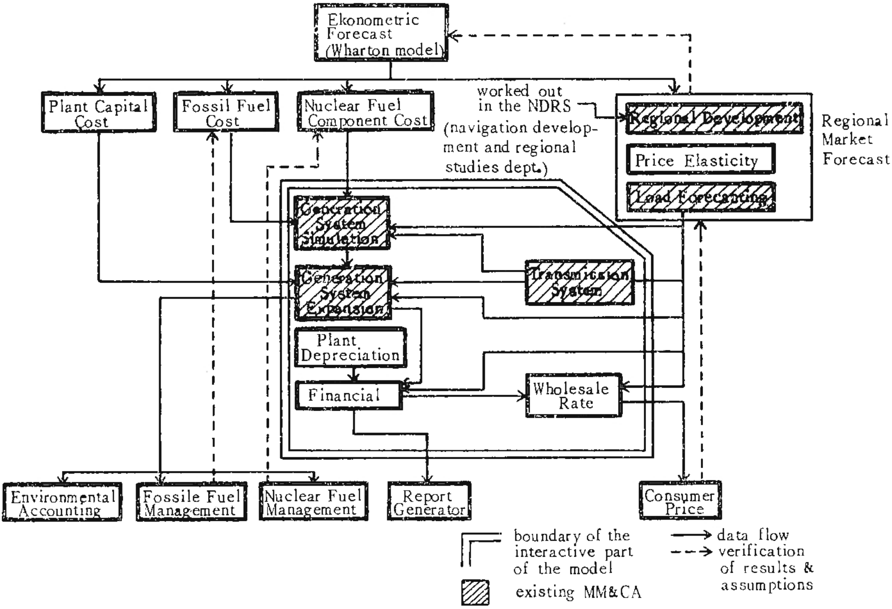


Exhibit 4

In both regional cases the leading sector of the regional economy is the power production. It is of paramount importance, then, to be able to chose properly the direction of development for this sector, and, in fact, in recent years TVA management was bound to make substantial decisions concerning the development of its power capacity.

In this particular process of power generation strategy choice, some individual models were used - for forecasting of power demand, for assessing future generating capacity, for siting, etc. — in order to assess the consequences of alternative courses of action. But it was only after the decision had been made that the need was felt to create the consistent, comprehensive system of models for power planning purposes. This system will be closely connected in its "upper-level" part with the regional forecasting system previously mentioned (Exhibit 4). On the other hand, "below" the planning system for power there is an operational system which has been in existence for several years, for power generation and water control scheduling and operations for time horizons ranging from one year to a half-hour or less. This system has never been designed as a whole and, moreover, its elements were operated by two different organizational units within TVA: the Office of Power, and the Division of Water Management. Well-defined imbedding of individual models constituting the system in the planning process allow, however, to view this system as a coherent whole. The question of the futuıe is, though, how this consistent operational system will be linked up with longer-term power planning systems.

The situation in power planning is typical for models development and use in TVA. The direction of system's evolution was from separate applications developed by line staff for operational, instrumental purposes, towards interconnected subsystems emerging where the overlappings or the need for interaction occurred. This kind of "natural evolution" with all its shortcomings of unplanned development may be opposed to the conscious system design in the case of Bratsk-Ilimsk.

HOW TO CONSTRUCT? HOW TO USE?

To begin with, we shall use once again the analogy of a simple model of a system-and-its-elements structure. When we have data about the elements' behaviour and we "understand" this behaviour in the light of some theories, then, on this basis, there is a whole universe of models that can be constructed. In general, the same applies to a system of models situation. There is a wide class of supra-models with which the models we dispose of are consistent. By supra-models we mean here models containing more than one elementary model.

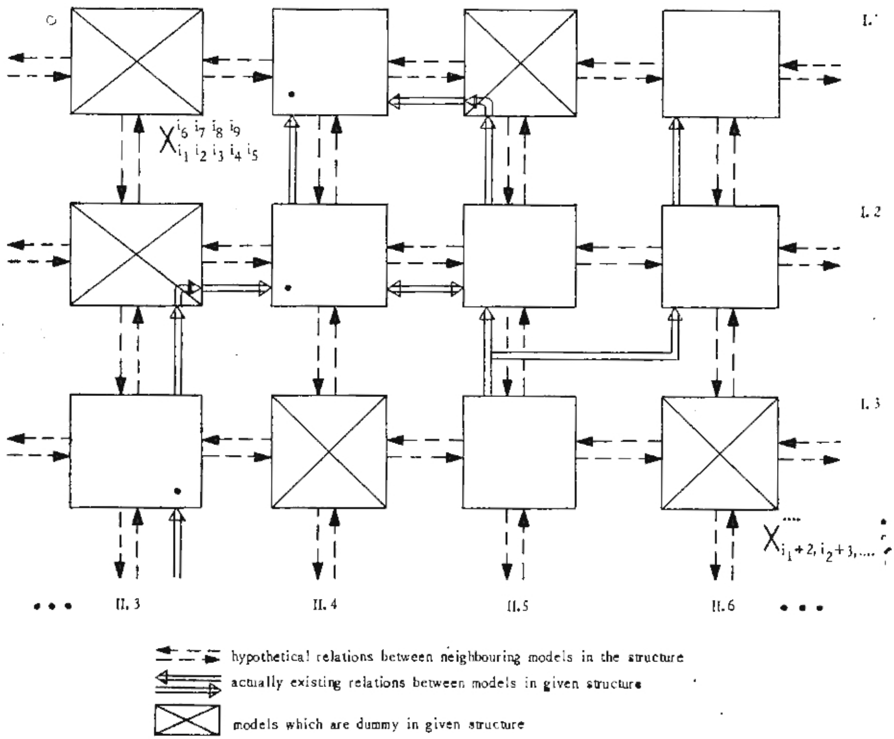


Exhibit 5

If in the above statement we understand by consistency the existence of one of the data flow relations mentioned before, the possibility of supra-model generation emerges (a simplistic illustration is given in Exhibit 5). This possibility, however tempting, poses several questions.

The questions, as well as opportunities, change according to the current stage of research and by means of the system of models. From what has been said previously, we can easily see that in the first stage of analysis we operate on the aggregate indices already shown. The indices of supra-models generated within the whole structure on the basis of given interconnections allow us, as was metioned, to assess certain general systemic features of the models' system (or rather each of the supra-models generated within it), for it is a dynamic system itself and can be analysed as such. On the other hand, the supra-models correctly reflect behaviour of the real system. If we analyze, then, the models' system for its general, "systemic" features (level of abstraction induced, e.g. by indices of connections), the results of such analysis can have important bearing on our understanding either of modelling activity or — hopefully — of the real system modelled. In further stages of research, when we go down to individual variables, then above perception becomes indentical with model/ /object perception on the level of individual models and their structure.

At the first stage of research it is very important to have the possibility of an **easy insight into the kind of structure created**. This amounts to using the **pictorial or iconographic approach** to analysis of obtained systems of models. If the system is very large then it must be stored in the computer memory and its appropriate supra-models displayed. The pictorial approach must therefore go together with the **interactive utilization** of the models system. Both relate to **language and communication** problems. By disposing of the models' system which reflects a variety of problems and perceptions on the aggregate, intuitively tractable level, and by working in the interactive mode with the use of iconographic presentation we can solve communication problems through the adequate process of learning in the creation and use of the models' system. The human need of variety is matched by manifold perceptions of the same system, providing necessary redundancy; of urthermore, his incapability to follow detailed computations is balanced by the method of presentation and the level of his insight (entire models). In the process of creation and use the **natural and machine languages** converge through, respectively, **formalization and naturalization**.

An example of a system to be created in the frame-work of general structure is given in Exhibit 6. The scientific language of the person proposing this system may be completely different form the language of the designing of general system. This should not, however, pose a utilization problem.

Problems of language and hence **generation mechanism** become, then, the most crucial ones for passing from the preliminary stage of research to more detailed analyses. The mechanism of supra-model generation should be based on the **modelling metalanguage** utilizing the vacabulary of relations among models. The studies of multi-hierarchical, multi-criteria systems may be considerably simplified through the use of these mechanisms. On the other

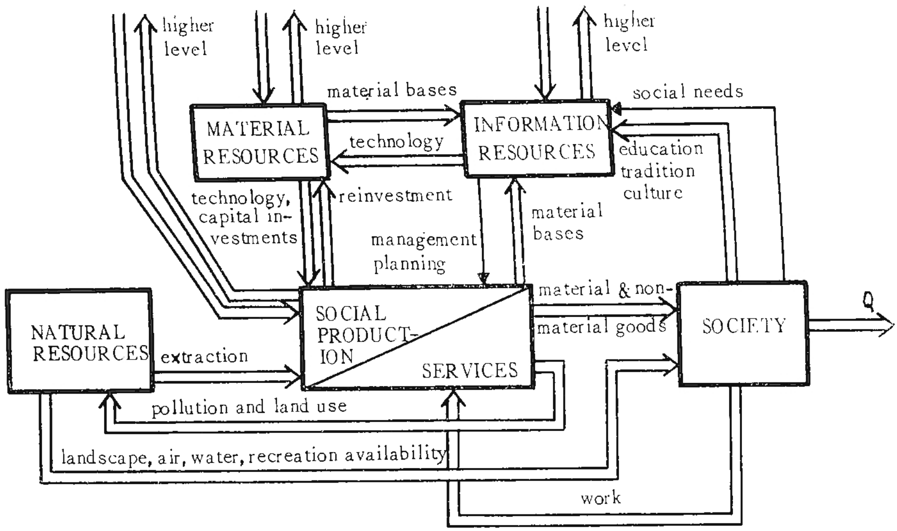


Exhibit 6

hand the theory of such systems may have an important impact on the creation of the generating mechanism. As we have already touched on the difficult question of criteria, let us now speak of them.

The question of objective functions arises in the case where we want to perform optimization. The analysis that we intend to carry out for regional systems has its clear objectives which, in general, may be expressed in quantitative terms. In reality, many models are meant to perform some optimizing functions, and some even with regard to explicit criteria. The problem which arises, is that of verifying the reconciliability of these objective-oriented models for each quantitative objective we propose for a given supra-model.

If, however, optimization can be carried out by generation of a specific supra-model, then the optimal solution obtained may show us what the relations between models (hence subsystems of the real system) ("optimal state") should be (see Straszak [1976]). This, in turn may lead to creation of new supra-models, and so on. Such an iterative process, if converging, will tend toward the best supra-model structure.

Another problem is connected with observation of the specific hierarchic structure implied by the supra-model to be generated, not to mention the causal relationships thereof.

According to what was stated in the first section of this paper, the creation of a system of models for regional purposes will constitute a great success in itself. The availability of tools helping to answer 1) how to plan regional development, 2) how to organize regional develpoment, 3) how to coordinate it with sectoral policies, is very desirable. Perhaps it is a too ambitious goal for the time being. But some steps must be made in this direction. Too much has happend in regional planning, too many practical decisions have been taken and, on the other hand, the body of modelling experience in regional problems is too great to wait and watch what the next intuivite steps will be.

REFERENCES

AGANBEGYAN, A. G. et al., [1971] Modelling of Teritorial Production Complexes Formation (in Russian) Novosibirsk.

BLIN, J. M., WHINSTON, A. B., [1974] Fuzzy Sets and Social Choice. Journal of Cybernetics Vol. 4, No. 3.

BEER, S., [1972] Brain of the Firm. Allen Lane: Penguin, London.

CHARPENTIER, J. P., [1974] A Review of Energy Models: No. 1. IIASA RR-75-10.

CHARPENTIER, J. P., [1975] A Review of Energy Models: No. 2 IIASA RR-75-35.

FOELL, W. K., [1975] Integrated Energy Systems Modelling and Policy Analysis IIASA WP-75-38 (internal).

HINOTE, H., [1976] TVA Economic Simulation Model, in the TVA Experience, Conf. Proceedings, H. Knop (ed.) IIASA CP-76-2.

HOAG, M. W., [1956] An Introduction to Systems Analysis. Rand.

KACPRZYK, J., [1975] Application of fuzzy relations to determination of ordering of subcriteria in complex multicriterial problems. (in Russian)) Paper to fifth Polish-Bulgarian Symposium "Applications of Cybernetics in National Economy" Zakopane.

MESAROVIC, M. D., SANDERS, J. L., SPRAGUE, C. F., [1968] An Axiomatic Approach to Organizations from a General Systems Viewpoint, in: New Perspectives in Organizations Research. Wiley.

MESAROVIC, M. D., PESTEL, E. [1974]: Mankind at the Turning Point.

MODELLING LARGE SCALE SYSTEMS AT NATIONAL END REGIONAL LEVELS. [1975]. Raport of a workshop held at Brookings Iustitution, Washington, D.C.

ORCHARD-HAYES, W., [1976] Complexity in Modelling and Analytic Use of Computers. IIASA WP-76-9 (internal).

QUADE, E. S. [1963] Military Systems Analysis. Rand.

STRASZAK, A. [1976] Muiltmodelling Problems in Large Organizations,in: New Trends in Mathematical Modelling, Straszak, A. and Owsiński, J. (eds.) (in press).

TVA Case Study Report, H. Knop ed.: Instrumental and Informational Tools for Planning and Decision Making, Straszak, A. and Owsiński, J. (eds.) (in preparation).

SUMMARY

The paper presents an approach to study and design of the informational and instrumental bases in organization, planning and management of large undertakings. As the main object of consideration the development of new industrial region is taken.

The approach presented utilizes main principles of systems analysis as applied not only to the real object of condiserations, but also to mathematcal models and camputer applications thereof, in their capacity of information — providing and decision aiding tools.

Mathematical models and computer applications are viewed as forming appropriate system. This system is then subject to analysis for its various features. Examples of such analyses conducted for programs of regional development within the framework of the International Institute for Applied Systems Analysis are given.

The system of mathematical models and computer applications is, however, primarity regarded as a methodological proposition for synthesis. In situation of overabundance of diverse modelling efforts it is of major importance to ensure that they be utilized in management with maximum efficiency. Creation of appropriate systems of models, as opposed to individual applications or their unorganized sets may constitute one of the ways out.

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