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STRUCTURAL MODELING AS A TOOL FOR STRATEGIC REGIONAL POLICY

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FOREWORD

There is a great need to develop tools for the treatment of information used by experts attempting to solve strategic policy problems. This paper describes special techniques based on interactive computer usage which enables one to analyze interrelations between objectives, problems, conflicts, functions, decisions and organization. Such a technique is called the STRUctural Modeling system (STRUM). The application of STRUM to formulate a strategic policy for the long-term development of a territorial production complex is considered. This paper also suggests some methodological procedures on how to use STRUM for the solution of other strategic regional policy problems.

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1. STRATEGIC REGIONAL POLICY: ORGANIZATIONAL APPROACH

From an organizational point of view, the ultimate goal of Strategic Regional Policy (SRP) is to substantially improve the ability of managerial bodies and individual policymakers to effectively manage global, national, sectorial, regional, and local developments in the changing environment of the real world.

In accordance with methodological requirement, a regional system is considered as a multiproduct line company or set of companies whose strategic behavior depends on interactions of internal (economic structure) and external (competition environment) factors. SRP is concerned with problems which have, as a rule, cross-cutting sectorial and spatial dimensions. On the one hand, it can be the traditional marketing and investment strategies relating to business units of both production and service sectors; on the other, there are non-traditional strategies, concerned with the technological (R&D), social, and ecological long-term development of strategic business units.

Thus, from an organizational standpoint, the SRP is viewed as a multidimensional system consisting of seven main components: products marketing, and investments, technological, social, ecological, and organizational strategies in their integrated sectorial spatial dimensions. The list of these dimensions includes the sectorial spatial activity orientation (internal or external), the possible use of territorial cooperation (isolated or synergistic sectorial development), the regional diversity of business activity, and some other aspects.

The 1970s and 1980s have been characterized by complex problems of choice in long-range regional development. This situation developed against a background, first, of growing structural changes in technological, socioeconomic, and other factors; moreover, these factors often have different dynamics, which makes it difficult to perceive their interrelationships. Secondly, the changes at the regional and city levels are interrelated and are influenced by (and, in their turn, influence) national and sometimes international conditions. Therefore, concepts and methods of regional policy must explicitly recognize and take into account this interdependence of strategic decision levels. Third, because of their long-term nature, strategic regional decisions involve considerable uncertainty and risk. Fourth, the diverse structure of various regional systems, including different elements of production and settlement and the numerous decision making and implementation points involved, complicate the process of regional policymaking still further.

In summary, large-scale regional problems, especially those caused by external influences, cannot be solved effectively with conventional methods of planning and management. What is needed is an integrated system of concepts and tools of strategic regional policy (Kochetkov, 1978).

However, strategic regional decision making as currently practiced shows too little awareness of the points listed above or of their interdependence. Available information on the future directions for the development of regional and urban systems is often inconsistent or inadequate.

This frequently results in the underestimation of future problems or critical factors and undue concentration on current issues. The predominantly narrow monodisciplinary approach frequently encountered cannot take into account the real diversity and interdependence of regional goals and decisions. Methods and organizational forms for long-term regional and urban policy questions cannot adapt quickly enough to changing needs or to developing circumstances, and the mutual effects of strategic decisions made at different levels are underestimated.

As a result, the concepts, methods, models, and organizational forms of regional policy are relatively loosely related and uncoordinated. Hence they are frequently ineffective. The basis for developing the organizational approach to SRP is to obtain an in-depth understanding of the close organizational interrelationships between:

(1) Strategic decisions taken at international, national, regional, and urban levels.

(2) Strategic solutions of technological, production, economic, social, and ecological problems of long-term regional and urban development.

(3) Strategic (long-term) and tactical-operational (short-term) decisions.

(4) Strategic decisions made at the sectorial and regional management levels.

(5) Principles and methods of strategic decision making and implementation.

(6) Strategies and structures.

The research, based on deep understanding of these relationships, will aim to develop an integrated system on two levels:

(1) Conceptual, involving methodological principles and approaches for the integrated strategic management of long-term regional development.

(2) Operational, consisting of techniques, models, procedures, and organizational forms for effective strategic decision making and implementation.

SRP, being oriented toward problems some way into the future, calls for specific types of analytical techniques and approaches; the possibilities for applying formalized models in strategic decision making and procedures for combining the models with analytical techniques should be extended.

Many suggested computerized models are so complicated as to give only a few results from the managers' point of view. Most of these models are designed to solve internal problems of regional development or deal with only interregional problems. The approach to the modeling of interrelations between regional systems and the environment is, in many cases, oversimplified and is realized through the introduction of a number of external arbitrary variables. It follows that it is necessary to meet two key methodological requirements:

(1) To develop communication models (between environment and regional systems) as an instrument of SRP

(2) To create such models as an organic part of relatively simple computer-based decision support systems.

SRP could also held to overcome the existing man-machine barriers.

2. STRUCTURAL MODELING - NOTION AND BRIEF DESCRIPTION

One of the promising approaches to be used as a modeling technique for SRP is structural modeling (SM). We have already gained experience of using SM in the detailed systematic analysis of interrelationships between objectives, problems, conflicts, functions, decisions, and organizations, i.e., elements of complex organizational systems.

Structural modeling is widely used in various tasks of socioeconomic management and policy analysis. As examples of PERT networks, flow charts, objective trees (e.g., PATTERN), and organizational diagrams should be mentioned. Being directed mainly at the analysis of the system structure (which is supposed to be known), these modeling methods do not deal with the synthesis of it. The development of computerized structural modeling techniques has been influenced by the the work of J.N. Warfield (1976; see also Lendaris, 1980).

One such technique based on interactive computer usage, is called STRUM (STRUctural Modeling system). This system is currently available at IIASA; it is described in more detail in a forthcoming paper. At present, we briefly consider the possibilities of using STRUM.

Generally, the process of structural modeling includes four steps:

(1) Main elements of the system being modeled are identified.

(2) The relationships with which it is desirable to organize elements are chosen.

(3) The structural models (SM) are constructed on the basis of the elements and identified relationships chosen.

(4) The SM are analyzed, corrected, and their adequacy verified.

If $\underline{V}$ is the element identified and the relation $\underline{R}$ is supposed binary we may introduce $\underline{G}$ ($\underline{V}$, $\underline{R}$) as a directed graph (or simply a graph) describing the SM. So we restrict our consideration to the class of binary relations that allow only pairwise relationships among the elements. There are several reasons for this:

(1) Binary relations in many cases are basic and the most simple components of higher order relations.

(2) Binary relations are widely used in various areas by experts of various disciplines and such SMs are easily understood.

(3) The process of binary relation reconstruction may be computerized and optimized.

There are many tools for generating ideas and problem solving (brainstorming, brain writing, DELPHI, and others), but there is a distinct lack of structuring tools aimed at organizing the generated elements into a structure.

A structuring tool, such as the well-known decomposition procedure used, for example, in PATTERN objective trees contain many restrictions. Besides, it is not always simple to structure an unstructured list of elements. A good example is the problem of enterprise development of analysis in which an analysis of the content of various publications and reports is used to generate a list of problems with the intention of structuring the general problem situation, i.e., to construct an SM on the set of these problems.

2.1 Usage of STRUM

Two main principles were used to produce the basis of the STRUM structuring algorithms:

(1) Experts are asked via the computer to answer a question about the links between elements, but only two at a time; this method of pairwise comparison concentrates the attention of the experts and is the most reliable way of structuring expert information.

(2) The number of questions put to the expert group must be as small as possible; the requirement of this parameter minimization is frequently and naturally placed upon interactive systems.

When the list of elements has been composed and the relation R chosen, their verbal representations are entered into the computer; SM construction is then an interactive systematic procedure as follows. STRUM, via the display, puts questions to the expert group in quasi-natural English: "Show the direction of the relation R between elements A and B" (here R, A and B are verbal representations). On obtaining the answer, STRUM automatically puts transitive inferences to SM (if the relation R is transitive) - it decreases the total number of questions, usually substantially. Then, according to special optimizing rules, STRUM chooses the next pair of elements, the next question is put, and the process is continued until the construction of SM is complete. It must be noted that this systematic procedure is based upon effective algorithms specially designed for the STRUM system (Ganin and Solomatin, 1981).

When the SM is completed it must be analyzed and corrected. The visual analysis is facilitated by the SM depiction utility, which provides an easily readable SM graph on the screen, a line printer, or a graph plotter. The automatic analysis includes the identification of levels, cycles, subgraphs on the element subsets, paths, reachability subsets, etc. For the correction of SM, any elements and links of their groups may be added or deleted.

These means of SM analysis and correction are available through interactive display usage. Simple command language enables a rapid activation of various STRUM procedures. It is possible to break an interactive session and resume it after an interval without any loss of information.

This STRUM user-friendliness enables the decision maker to participate directly in the structural modeling process.

3. SRP FOR TERRITORIAL PRODUCTION COMPLEXES (TPCs) AND THE STRUCTURAL MODELING ROLE

The main problems of regional development arise from the complexity of combining sectorial and territorial planning in situations where there is some divergence between economic interests of the various business units and where these units are subject to different jurisdictions or managements.

The fundamental objectives of regional policy in most countries are as follows:

(1) To improve the distribution of industries and jobs by the rational deployment of industrial development throughout the country.

(2) To attain an effective economic development of new territories and redevelopment of old ones.

(3) To create territorial production complexes (TPCs).

(4) To improve (at the regional level) socioeconomic development, with due regard to environmental regulations and ecological conditions.

(5) To remove regional disparities in living standards and to promote equal development of all territories.

These objectives are established and implemented through the joint efforts of national, sectorial, company, regional, and local planning and management bodies. Hence, regional policy is reflected in the policy system at all levels along both vertical (sectorial) and horizontal (territorial) lines. They are reflected in the territorial section of national economic plans, as well as in sections of sectorial and enterprise plans in the comprehensive socioeconomic development plans of each administrative/territorial unit.

Maybe one of the most interesting cases for international experience and regional science is the TPC approach which has been developed in the USSR. The theoretical basis of TPC development involved the optimal deployment of resources through effective sharing of individual (enterprise) and common infrastructures (e.g., construction, energy supply, transport, housing, cultural and community centers, etc.) in the area.

It is important to emphasize the basic concepts of TPC, such as supplementing specialized activities with support industries and infrastructure, strict development priorities, the rational distribution of jobs, proportional development of production and nonproduction activities, efficient utilization of resources, and the establishment of rational (from a national economic point of view) intra- and inter-regional relationships.

An especially significant contribution to TPC theory was made by Kolosovsky (1958), who first formulated the basic principles of the concept in a systematic form:

(1) Interrelationships between TPC construction and rational spatial organization of productive forces (resources).

(2) Integration of multidimensional TPC objectives.

(3) Organization of internal TPC structure with regard to scale, sectorial composition, and other characteristics.

(4) Wide topological range of TPCs.

(5) Mechanisms of TPC performance as integral systems.

Soviet experience in TPC development was reviewed at IIASA in 1976 through the Bratsk Ilimsk case study. The principles of the allocation of economic, social, and environmental projects formulated on the basis of this experience considerably affected the validation and implementation techniques for subsequent schemes. In fact, each such project is now treated as a TPC with a particular specialization, in order that the negative consequences of development can be reduced, and otherwise irreversible mistakes avoided.

It is important to emphasize the complexity of TPCs, the methodology of which embraces problems of long-term territorial sectorial interaction, interregional analysis, socioeconomic interrelations, contradictions between economic and natural protection requirements, and other aspects which are simultaneously the subject of SRP methodology.

It can also be argued that TPC methodology, owing to its integrated nature, has a systematic background. Therefore, advanced SRP methodology, which is based on systems analysis philosophy, in its turn can be the common framework for improving the methodology of TPCs.

Since the majority of TPCs are energy-oriented (West-Siberia, Kansk Achinsk, Pavlodar Ekibastuz, etc.), the experience gained in the planning and management of large-scale energy projects (LSEPs) could be used to show the role of structural modeling techniques in the process of decision making. The TPC approach to the development of LSEPs has also helped to ensure optimal energy exploitation. All such projects supply some power to energy-consuming regions, while the remainder is consumed _in situ_ by large energy-intensive industries. In addition, the energy-producing TPCs contribute to the creation of a centralized infrastructure, stimulate attention to social and environmental problems, and provide a structural basis for the development of settlements. The results of analyzing the application of the TPC concept to LSEPs are shown in Figures 1 and 2.

Figure 1. Strategic regional policy: external relationships of large-scale energy projects.

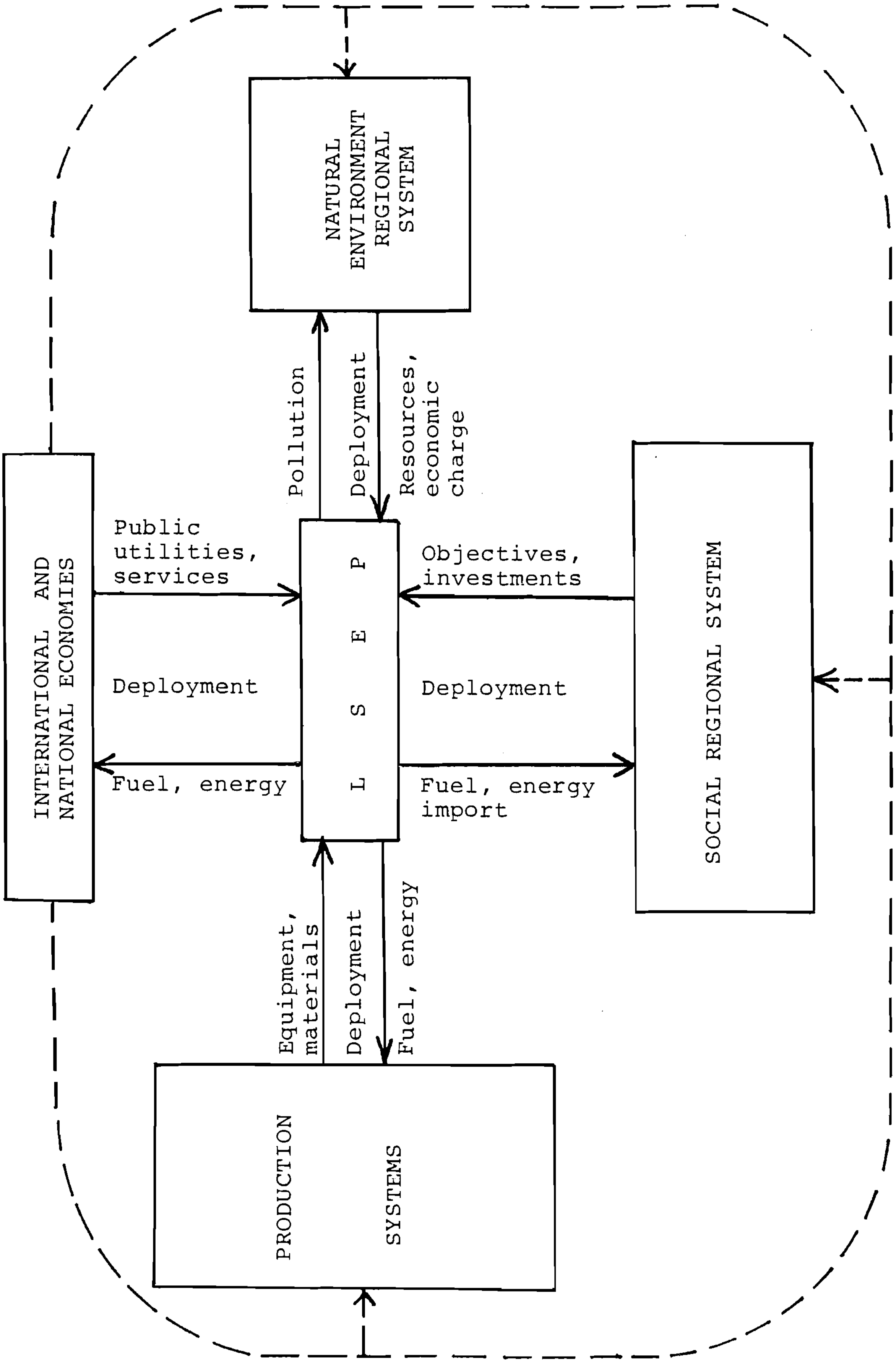
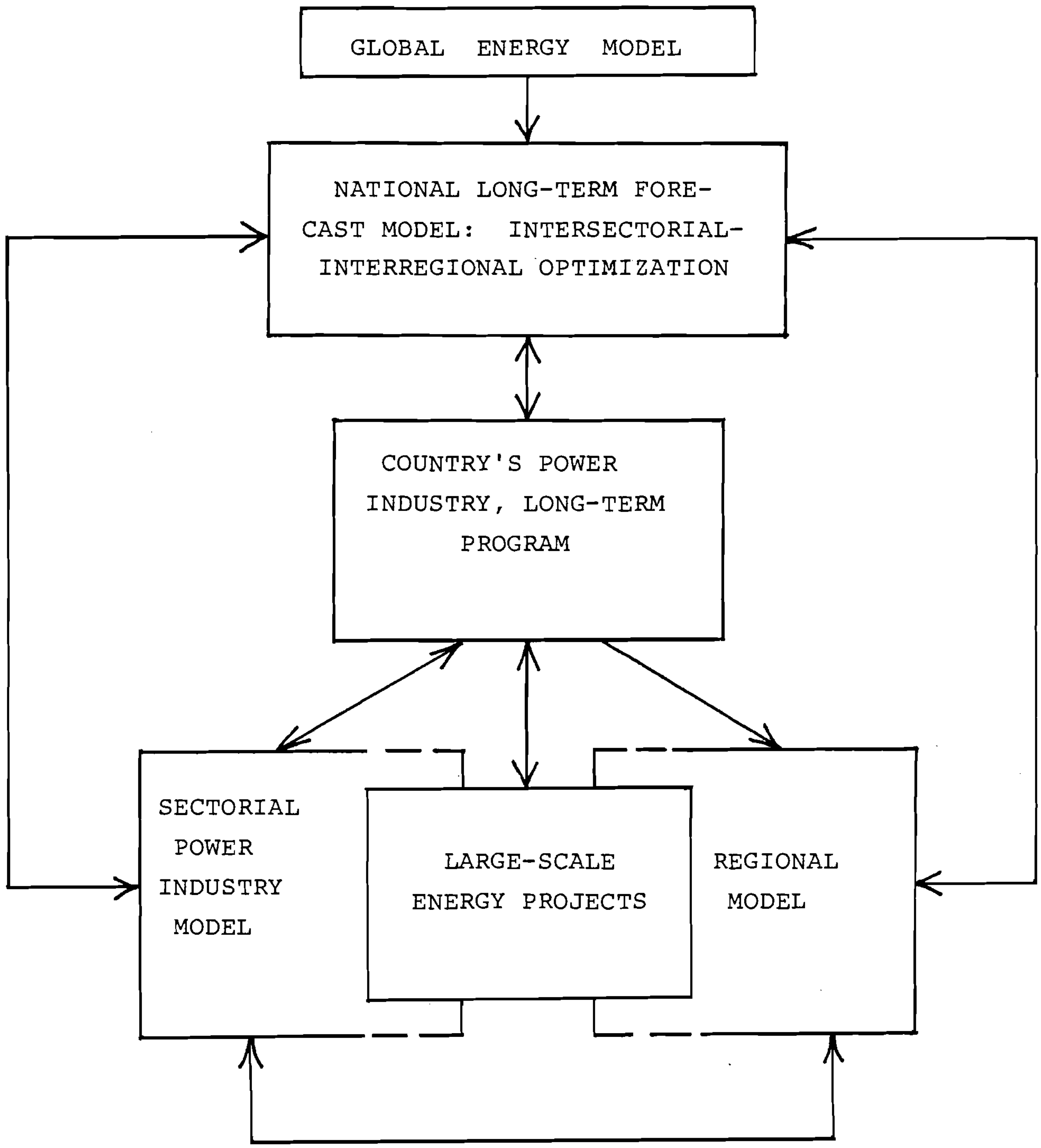


Figure 2. Strategic regional policy in the USSR: energy territorial sectorial model systems.



Policy improvements arising from the integration of both regional and strategic management sciences, as well as experience, are:

(1) Building a methodology of LSEPs as an interactive mechanism between the main levels of policy making (to counterbalance the simple reflection of the influence of external conditions). This requires a careful analysis of external relationships of LSEPs (see Figure 1), taking into account the changing environment. From the modeling point of view, it is worthwhile to build multilevel hierarchical model systems with mutual coordination interlevel relationships.

(2) Modeling LSPEs as a structural part of the fuel energy intersectorial complex (FEIC) of the national economy, and, at the same time, as a structural part of the regional economy (see Figure 2). The external relationships of LSEPs are endogenous to the models of FEIC and exogenous to the LSEP models.

(3) Taking into consideration the strong influence of LSEPs on the development of industrial sectors cooperating with the energy branch (due to the high resource capacity of LSEPs, high fuel energy prices, and high growth rates of energy demand). Energy saving policies can only reduce this influence. The spheres in which energy has most influence are the following: metallurgy, chemistry, construction materials, mechanical engineering, transport. It is important to reflect intersectorial relationships in the modeling of LSEPs.

It should be noted that the boundaries of large energy complexes (or TPCs) do not always coincide with those of administrative areas; for example, the West Siberian complex is located within the Tjumen and Tomsk areas, and the Kansk Achinsk complex is within the Krasnoyarsky province and Kemerovo area, etc. At the same time, each complex contains several industries: West Siberia - oil, gas, power generation, petrochemicals, timber, etc.; and Kansk Achinsk and Pavlodar Ekibastuz - coal, power engineering, etc. This supports the theory that large-scale energy projects require specific planning, and management using a combination of sectorial and territorial planning as well as a program-oriented approach.

3.1 SRP for TPC: Main Objectives

Strategic regional policy oriented to development and management problems of TPC is supposed to meet the following objectives (Bandman, 1980):

(1) Identify the national economy's strategic demands which determine the TCP production profile.

(2) Identify the high priority regional demands which have to be considered.

(3) Systematically analyze internal and external problems connected with the construction of TPC.

(4) Identify and structure the system of the TPC strategic objectives with basic requirements.

(5) Designing of an organizational system for TPC strategic management.

This paper does not attempt to give a full description of the SRP for TPC. The intention here is to identify SRP features that determine the possibility and usefulness of structural modeling applications to SRP tasks.

3.2 SRP for TPC: Complexity Features

Experience shows that in the context of long-term development of TPCs there is a strong interdependence between political, economical, social, and ecological factors. This results in interconnections between decisions made at the national and regional levels. Thus, the SRP aim is to solve internal (regional) and external (national) problems of long-term TPC development, which strongly influence each other.

Consequently there is an inevitably high complexity of problem analysis for TPC development as well as the high internal complexity of the objectives and organizational structure of the strategic management system.

The general form of the objectives system for the TPC that is oriented to fuel and energy production is displayed in Figure 3. It includes four main objectives, three promoting objectives, and is intentionally hierarchical (diagonal links are not included) to distinctly show the consequent blocks. (The Appendix contains the structure of the main objectives synthesized with the STRUM system.)

Carrying out the SRP decisions for TPCs requires:

(1) That the scientific, planning, and designing organizations simultaneously provide technologically advanced and economically efficient methods for construction and production.

(2) That financial, material, natural, labor and land resources are used rationally.

(3) That effective environmental control measures are employed.

Furthermore, they must endeavor to use designs with circulating water supply systems; minimize the amount of solid and liquid wastes and air pollution produced; create up-to-date working conditions; check the reliability and operational safety of buildings and other structures, etc.

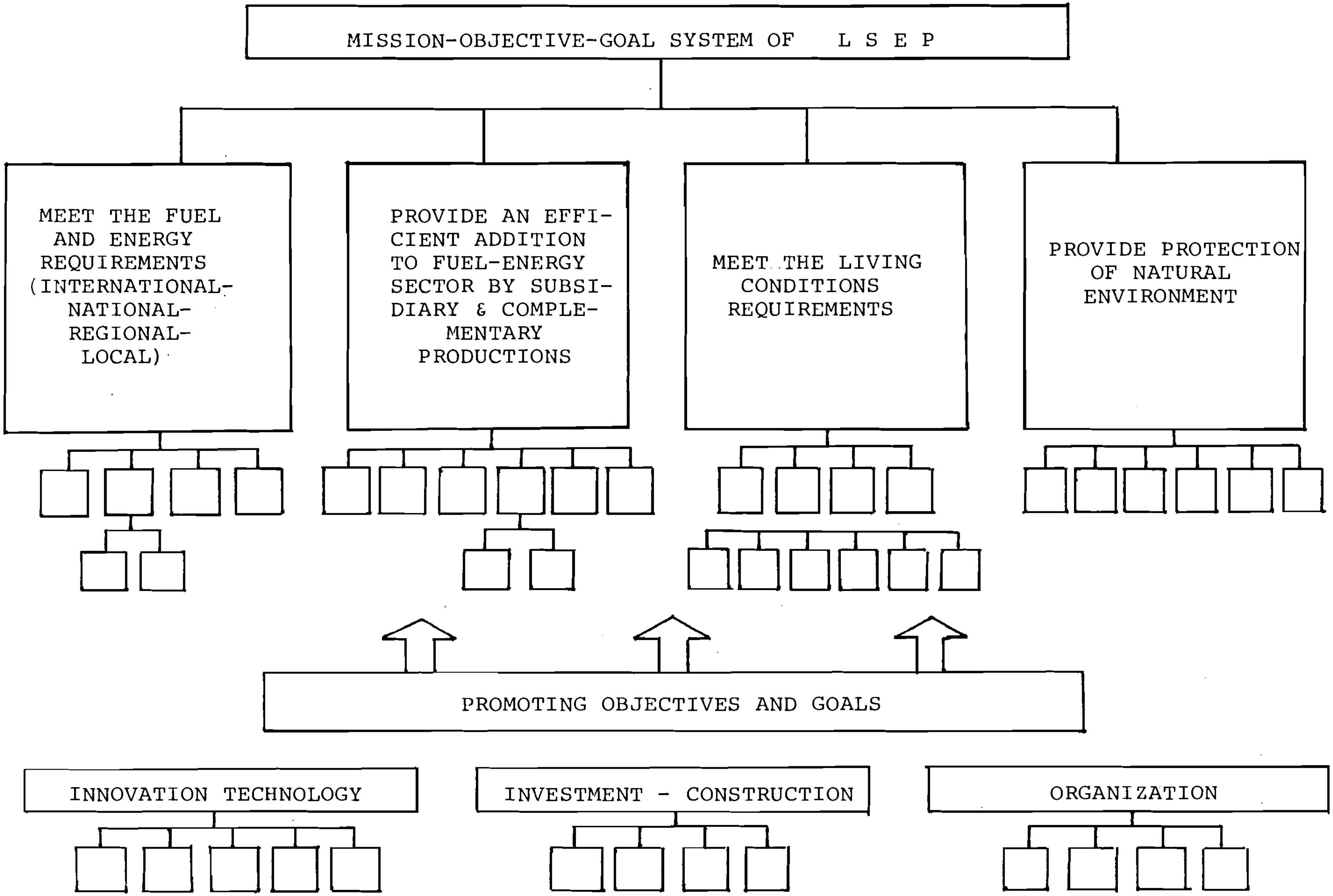


Figure 3. Strategic regional policy: TPC approach to LSEP goal-setting module.

All these requirements encourage designers to apply a complex systems approach to their work, and this tendency is strengthened by the need to coordinate TPC development with sectorial design schemes and to generate plans for national industrial nodes.

These requirements also result in the necessity to implement complex organizational decisions, including structures combining sectorial and territorial bodies. The complexity of combining sectorial and territorial management is manifested in the very significant problem of managing interdepartmental interactions during the decision-making and decision-implementing processes. The effective solution of this problem implies a coordination of the activities of hundreds of enterprises and organizations from different sectors, and the extent of their cooperation in the investment process can have a considerable effect on the timing, quality, and efficiency of the regional complex as a whole.

Accordingly, the setting up of a large-scale regional complex presupposes the introduction of new forms and techniques of management through the application of the program-oriented approach, including matrix structures and improved coordination and cooperation procedures.

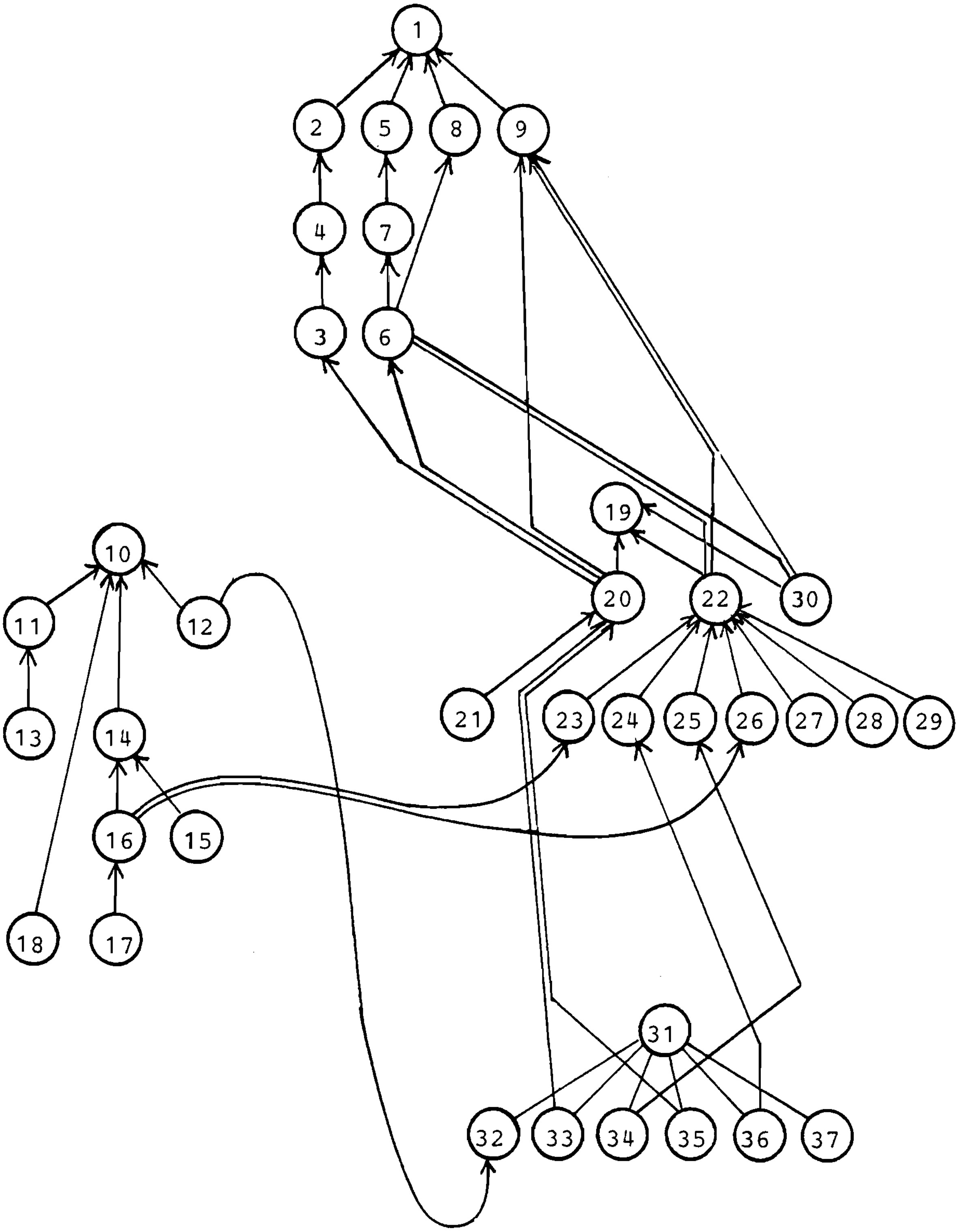
3.3 Structural Modeling Role

The features of the TPC complexity considered here result in the necessity to undertake a detailed multidisciplinary analysis of the TPC structure. Structural modeling techniques make such an analysis possible.

These techniques are of considerable assistance to decision makers in performing a comprehensive structural analysis of problem situations, forming objectives and conflict structures. A conventional way of forming problem and objective structures is the well-known method of decomposition in which, for example, the general objective is decomposed into several objectives (goals) supporting it; then, each of these goals is further decomposed, and so on. The result is a tree-like figure which reflects the hierarchy of objectives. The multisectorial and multiobjective character of TPCs leads to complex interactions between problems, and organizations, and hence the TPC system of objectives is seldom hierarchical.

We participated in the design of the organization of a management project for an inter-sectorial territorial production complex and encountered these restrictions during attempts to build an objective tree for this complex. The decomposition procedure could not reflect the characteristic features of program management - the horizontal and diagonal links in the objective tree (more precisely, the objective structure). The example of the objective structure formed with the help of the structural modeling system STRUM is given in the Appendix (see also Figure 4).

Figure 4. TPC objective structure (fragment).



The structural modeling technique described above is the tool which can provide an effective identification of links between problems, objectives, and goals corresponding to different sectors and organizations. This is especially important for strategic policy tasks, because these links very often influence long-term socioeconomic processes.

Structural modeling also plays an important role in the rational choice of the proper organizational structure of TPC. It gives the expert group dealing with the organizational design the possibility to conduct a rapid and detailed test of how the organizational structure version satisfies the given system of objectives.

We believe that using techniques of this kind is the optimum way to develop the structural modeling method as a whole and is extremely helpful in solving strategic regional policy problems.

APPENDIX

In the following, we give an example of structural modeling application to the objectives of a large-scale energy project.

There is already experience of using structural modeling for constructing the following SMs:

(1) Objective trees (more precisely, structures) in which the elements are objectives, goals, and tasks and the relation is "objective A supports objective B".

(2) problem trees (structures) with problems as elements and the relation "problem A aggravates problem B" or "without resolving problem A problem B cannot be resolved".

(3) Conflict structures showing links of a similar type between conflicts that organizations encounter during their activities.

As an example of the STRUM system application to strategic management, we show a fragment of the objective structure of a large-scale regional complex. This work was performed at IIASA with the help of the IIASA version of STRUM recently installed on the computer.

The list of objectives was composed with the help of a literature content analysis and objectives decomposition was partly used. The list is as follows:

1. (1) To satisfy the national economy demand for fuel, energy, and other types of given TPC final products according to the required volume of output and terms.

2. (1.1) To satisfy the national economy demand for the electric power sector of TPC.

3. (1.1.1) To produce the required output of electric power.

4. (1.1.2) To transfer electric power (produced by TPC) to consumers.

5. (1.2) To satisfy the national economy demand for coal products of TPC.

6. (1.2.1) To mine the required output of coal.

7. (1.2.2) To concentrate the planned amount of coal.

8. (1.3) To satisfy the national economy demand for TPC products of chemically processed coals.

9. (1.4) To satisfy the demand for external transportation, coal and other products of TPC.

10. (2) To provide an economically effective supplement to fuel energy production by subsidiary activities.

11. (2.1) To provide the central maintenance of equipment for main and subsidiary production activities.

12. (2.2) To provide complex and economically effective waste utilization.

13. (2.3) To provide the main and subsidiary sectors with complex infrastructure services (production type) and activities.

14. (2.4) To satisfy TPC demand for infrastructure services (nonproduction type).

15. (2.4.1) To satisfy TPC internal demand of production sectors for transportation services.

16. (2.4.2) To satisfy the demand of TPC production sectors' utilities (energy, water, heat supply).

17. (2.5) To provide for the creation of integrated construction enterprises.

18. (2.6) To provide the complex utilization of secondary heat and water and, on the basis of this, organize hot-house market-gardening and fish factories.

19. (3) To provide normal living conditions and social development for the population connected with the given TPC.

20. (3.1) To meet the population food demand.

21. (3.2) To provide employment for second family members.

22. (3.3) To provide normal living conditions.

23. (3.3.1) To provide proportionality in urban construction.

24. (3.3.2) To provide normal housing conditions.

25. (3.3.3) To provide normal social, cultural and recreational conditions.

26. (3.3.4) To satisfy population demand for basic utilities and services (energy, water, heat).

27. (3.3.5) To provide the diversity of choice and social correspondence of employment.

28. (3.3.6) To meet population demand for social security.

29. (3.3.7) To meet population demand for public health services.

30. (3.4) To provide a normal level of wages and incentives.

31. (4) To secure the protection, restoration and improvement of the natural environment under construction and operation activities of TPC.

32. (4.1) To secure the protection of nature in the course of mining and construction.

33. (4.2) To secure the protection, complex utilization, and rehabilitation of lands.

34. (4.3) To secure the protection of relics.

35. (4.4) To secure the protection and reproduction of fish stocks.

36. (4.5) To secure the protection of the natural environment for towns and other types of settlements.

37. (4.7) To economically secure the effective operation of infrastructure for protection of the natural environment.

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