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The Bratsk-Ilimsk Territorial Production Complex: A Field Study Report

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THE BRATSK-ILIMSK TERRITORIAL PRODUCTION COMPLEX: A FIELD STUDY REPORT

H. Knop and A. Straszak, Editors

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Preface

The Management and Technology Area of IIASA has carried out case studies of large-scale development programs since 1975. The purpose of these studies is to examine successful programs of regional development from an international perspective, with a multidisciplinary team of scientists skilled in the use of systems analysis.

The study of the Bratsk-Ilimsk Territorial Production Complex (BITPC) represents an interim effort in our research activities. The first study was of the Tennessee Valley Authority in the United States*, forthcoming is the study of the Shinkansen development program in Japan.

The present Report covers six major aspects of the BITPC program: goals, variants, and strategies; planning and organization; model calculations and computer applications; integration of environmental factors; energy supply systems; and water resources. It is hoped that the experience of the Soviet scientists and practitioners and the observations and suggestions of the study team will provide the IIASA National Member Organizations with insights into problem solving in the management, planning, and organization of large-scale development programs.

The study was accomplished with the support and assistance of the USSR State Committee for Science and Technology, and the Institute of Economics and Industrial Engineering of the Siberian Branch of the USSR Academy of Sciences. Special thanks are given to G. Aleksenko, Academician A. Aganbegyan, V. Smirnov, G. Filshin, V. Gukov, and K. Kosmachov for their assistance in preparing and implementing the field study.

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*Hans Knop, ed. *The Tennessee Valley Authority Experience*, 2 vols., CP 76-2, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1976.

Contents

Introduction

Planning, managing and organizing large-scale development programs are complex activities carried out by many governments, local authorities and corporations. Technological, political, economic, social and environmental factors must be taken into account when seeking solutions to problems in this area. Systems Analysis has proved increasingly helpful for these purposes.

Because of international interest in this subject the IIASA Management and Technology Area launched a series of studies of large-scale development programs worldwide. The first study was the Tennessee Valley Authority (TVA) in the United States. The Bratsk-Ilimsk Territorial Production Department (BITPC) in the Soviet Union is the second in this series; the third will be the Shinkansen super express railway program in Japan.

These studies cover program preparation and implementation including goal setting, elaboration of alternatives, decision processes and selection, organizational structure and functioning, model calculations, and computer application, as well as integration of environmental factors in planning and decisionmaking. The objectives of these studies are as follows:

- To learn about problems and solutions in large-scale development programs;
- To obtain a better understanding of the respective socio-economic environments;
- To extract and generalize methodological experiences;
- To ascertain principles and methods applicable to the development of other large-scale production complexes.

Each study has been preceded by an international conference at IIASA [1,2], followed by a field study and report by an IIASA team of scientists.

The results of the field study at Bratsk-Ilimsk are presented in this Report. During the field study, IIASA scientists worked as a team as well as in separate working groups. These working groups are responsible for the various papers in this Report. The composition of these groups and their subject areas are as follows:

- Goals, Variants, and Strategies of the BITPC: Hans Knop, Rolf Pieplow, John Tomb, and Detlof von Winterfeldt.

- Planning and Organization of the BITPC: Cyril Davies, Ada Demb, Raul Espejo, and Roman Ostrowski.
- Models for Regional Development Planning: Jan Owskinski, Kurt Schaffir, and Andrzej Straszak.
- Automated Management Systems in the BITPC: Bohumil Mazel, and Kurt Schaffir.
- Integration of Environmental Factors in the BITPC Development: David Fischer, Saburo Ikeda, Robert Tuch, William Matthews, and Weseley Foell.
- Energy Supply Systems: Plamen Tsvetanov.
- Water Resource Development in the BITPC: Ilya Gouevsky.

For the purpose of a unified report, there have been cross-contributions of working groups to other papers.

The study of the BITPC was sponsored by the USSR State Committee for Science and Technology. A group of Soviet scientists led by Academician A. Aganbegyan took part in the international conference, in the preparations for the field study, and in the internal organization of the study in the USSR, and played the important role of consultants to the IIASA team. This group had the following composition: Viacheslav Smirnov, Gennady Filshin, Vladimir Gukov, Kirill Kosmachov, and Leonid Kozlov.

The IIASA scientists had credible access to the organizations scheduled for interviews. All scientists involved recognized the helpfulness of those interviewed. The IIASA scientists developed a good rapport with their Soviet counterparts and accompanying translators. Close communication over the three week study period contributed to a broad understanding of the concepts and the context of the Soviet planning and management system.

In addition, the Soviet scientists accompanying the group in Siberia returned to IIASA to study and discuss the group's findings. This review further added to the verification process.

The schedule of the field trip was prepared in advance and the organizations to be studied were selected by the head of the study group in conjunction with the Soviet scientists. At the institutions visited, several hundred Soviet scientists and government officials attended the meetings, and gave presentations and/or interviews. These institutions are as follows:

Moscow

GOSPLAN (State Planning Committee of the Soviet Council of Ministers)

SOPS (Council for the Study of Production Forces under GOSPLAN of the USSR)

KEPS (Committee of Production Forces and Natural Resources of the Presidium of the USSR Academy of Sciences)

CEMI (Central Economic Mathematics Institute of of the USSR)

CERI (Central Economic Research Institute the Russian Federation)

Moscow State University - Department of Geography

SCST (State Committee for Science and Technology of the USSR)

HMS (Hydrometeorological Service)

Ministry of Energy

ENERGOSETPROJECT - design institute for energy systems

Institute of Geography, USSR Academy of Sciences

Novosibirsk (Academgorodok)

IEOIP (Institute of Economics and Industrial Engineering, Siberian Branch of USSR Academy of Sciences)

Institute of Mathematics, Siberian Branch of the USSR Academy of Sciences

Computing Center of the Siberian Branch of the USSR Academy of Sciences

Irkutsk

Siberian Institute of Energetics, Siberian Branch of USSR Academy of Sciences

Institute of Geography of Siberian and the Far East, Siberian Branch of USSR Academy of Sciences

Irkutsk Branch of IEOIP

OBPLAN - Planning Commission of the Oblast Soviet

Irkutsk Hydrometeorological Branch

Lake Baikal - Institute of Limnology of the Siberian Branch of the USSR Academy of Sciences

Bratsk

Executive Committee of Bratsk

Bratskgesstroi

Bratsk Hydroelectricpower Station

Aluminium Plant

Timber Processing Complex

Bratsk Hydrometeorology Branch

Bratsk Cultural Center

Ust-Ilimsk

Bratskgesstroi Ust-Ilimsk Branch

Ust-Ilimsk Hydropower Station

Cellulose plant construction site

STUDY PERSPECTIVE AND APPROACH

The BITPC is one of the major TPCs in the USSR. The method used for the IIASA study was a retrospective case analysis. Such hindsight reviews can be valuable tools for utilizing information about past projects in future planning of similar development projects. By monitoring development, it is possible to show how successful the project was in attaining prescribed goals, how unforeseen impacts--political, economical, technological, environmental and otherwise--were taken into account, and how the development process was adapted to changing sets of circumstances over time. Such reviews, however, are not common. The potential for criticism, the problems of impartiality, and the difficulty of confirming past perceptions may explain the general reluctance to undertake retrospective reviews. Thus, it was of immense interest that the BITPC invited a team of international researchers to study their performance.

The interview format was used to conduct the study. Generally each unit opened with a statement summarizing its tasks, organization, and role. Following this presentation, questions of clarification, follow-up and even opposing points were raised. The sessions were often characterized by in-depth discussions of both specific points and general principles. All sessions were recorded. Translators were needed at almost all meetings.

These interview sessions, conducted over a three week period and the material from the IIASA Conference on the BITPC constitute the data base of this Report. Written source materials have been used where available, readable, and applicable. The Report contains observations and recommendations compiled on the basis of interviews, direct observations, and the experiences of the participating scientists.

STRENGTHS AND LIMITATIONS

Any study has its strength and limitations and this one has its share as well. As *strengths* we include the following:

- Multidisciplinary nature of the team;
- International character of the IIASA scientists;
- Universality of the problems of planning, management and organization;
- Support of the USSR State Committee for Science and Technology;
- Integration of the scientific views of the major part of the team in advance;
- Rapport of team members with the Soviet scientists;
- Recording of sessions and the Soviet review of the Report.

Certainly, the major strength is the multidisciplinary nature of the study team which sets the stage for the wide range of questions and conclusions drawn from both the interviews and the direct observations made during the course of the study. With the exception of the environmental group the working groups were able to integrate their scientific views in advance so as to conduct the field trip with a common view. Eleven nations were represented in the group, thus giving it an international dimension.

The study *limitations* include procedural handicaps (e.g. time constraints, dependence on translation, limited program flexibility), a lack of knowledge of the Soviet planning and management system on the part of some team members, and limited experience with international studies in this field.

REFERENCES

[1] Knop, H., ed., *The Tennessee Valley Authority Experience*, 2 vols., CP-77-76-2, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1976.

[2] Knop, H. ed., *The Bratsk-Ilimsk Territorial Production Complex*, CP-77-3, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1977.

Concept, Goals, and Strategies of the BITPC

THE BITPC WITHIN THE NATIONAL FRAMEWORK

As one of the first territorial production complexes (TPCs) to be implemented in the Soviet Union, the Bratsk-Ilimsk Territorial Production Complex (BITPC) plays a wider role than can be observed from its impressive production statistics. The development of the BITPC has been an integral part of the development of the national economy. The concepts, goals, and strategies of the BITPC should be viewed within the framework of the national economy and within the regional framework of Siberia.

The BITPC is considered a forerunner of the TPC concept, and its success in accomplishing its goals has influenced the development of TPCs in Siberia and other regions of the Soviet Union. The importance of the TPC concept on the national and regional bases developed with the experience obtained by Soviet scientists, planners, and practitioners in conquering and settling the harsh environment along the Angara River.

The BITPC as a National Task

The major task of the national economy of the USSR is to improve the living standards and cultural level of the population on the basis of a dynamic and balanced development of social production, the enhancement of its efficiency, the acceleration of scientific and technological progress, the growth of labor productivity, and the utmost improvement of the quality of work in all sectors of the national economy [18]. This was especially evident during the period after the Second World War with the restoration of the national economy when the rate of growth of the economy was very high and the need for cheap energy and raw materials grew very quickly.

Given the assumption that energy sources and raw materials in the European Part of the USSR would become scarce if the economic growth rates continued at the post-war level, it was necessary to determine how to ensure further economic progress. It was already known that in Siberia, in parts of Middle Asia, and in the Far North regions of the USSR, very abundant sources of cheap energy and raw materials existed. Taken together, these areas comprise more than one half the total land area of the Soviet Union, while accounting for only about 10 percent of the total population. Figure 1 presents a map of the Soviet Union with the division of areas according to economic planning regions. Of special importance to this study are the Siberian economic

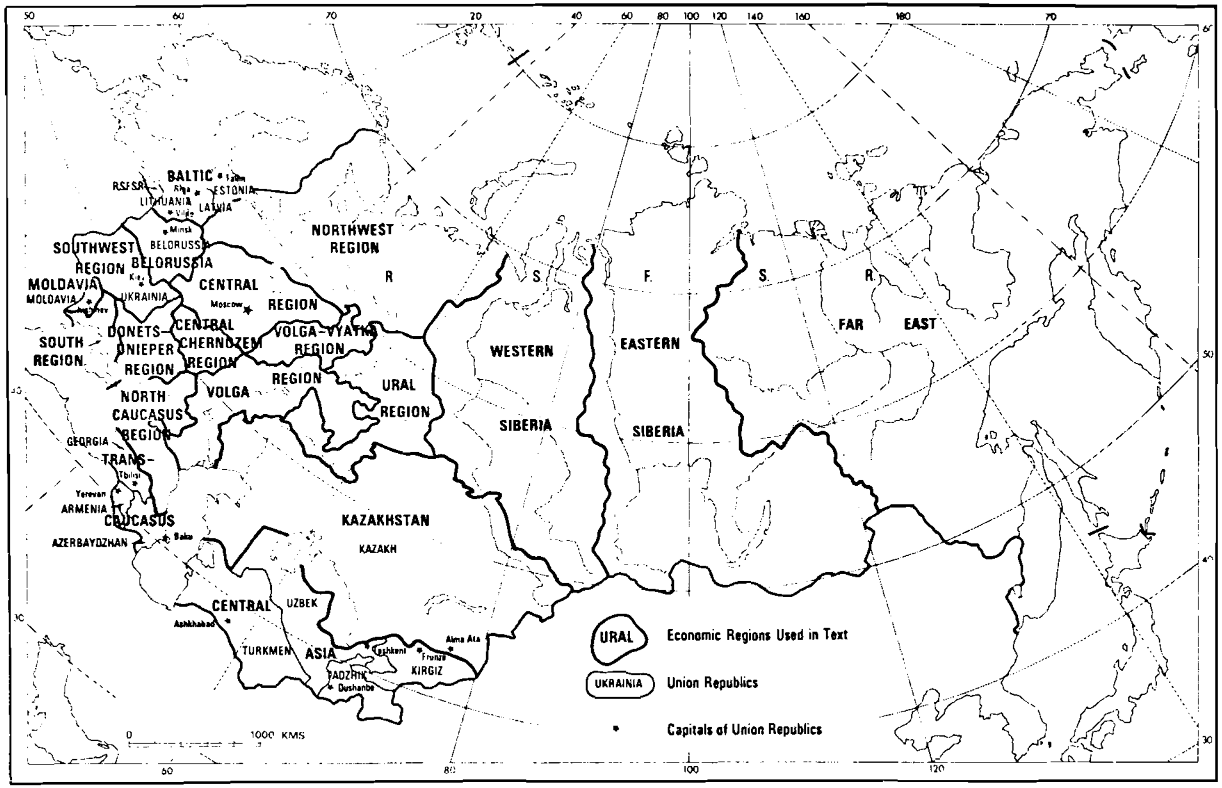

Figure 1. Division of the USSR according to economic planning regions.

Source: [20]

planning regions: West Siberia, East Siberia, and the Far East. Table 1 gives an overview of the economic planning regions and population data.

There is little doubt that Siberian regions contain extensive amounts of energy resources and raw materials: oil, natural gas, coal, timber, hydroelectric power potential, gold, iron ore, uranium, etc. The exact quantities that are available and extractable are still being determined.

In the early 1950s, a strategic decision was made to proceed with large-scale development in the Siberian and the Far North regions. It was decided to utilize the cheap energy available and to establish power-intensive industries. The products of these industries would be transported to the manufacturing industries of the European section of the USSR. Where possible, secondary manufacturing industries would be established in the Siberian and Middle Asian Regions as an alternative to transporting unfinished products. In line with this decision, Western Siberia is currently undergoing the most intensive development and exploration, and certain regions in Eastern Siberia are also being intensively developed. The BITPC is located in Eastern Siberia and has done much to lead the development and expansion of the use of natural resources in this Region.

Figure 2 presents a generalized map of the Region in which the BITPC is located and the major industries attached to the production complex. These industries are power intensive--that is, it was necessary to have a power source available which would meet the development demands for both industrial and private use. The solution was to utilize the vast potential of the Angara River by constructing the Bratsk hydroelectric power station (HEPS) which, at the time of its commissioning, was the largest capacity dam in the world. The importance of the Bratsk HEPS cannot be emphasized enough. Together with the completion of the Ust-Ilimsk and the Bogouchany HEPSs, the BITPC will have one of the world's largest power bases. Production from the HEPSs is not restricted to the BITPC; power is fed directly into the Siberian integrated power system. The development of the Angara-Yenisei power system is discussed later in this paper, but it is appropriate here to present a short overview of the power facilities that are operating in the Region and those that are approaching completion.

Table 2 gives a generalized breakdown of the Angara-Yenisei Cascade according to its basic characteristics. Table 3 presents the role of the Bratsk HEPS in the Siberian Joint Electric Power System (JEPS).

The start of construction of the Bratsk HEPS signaled the beginning of a remarkable transition from a basically rural region, sparsely settled with small communities and villages, to a region characterized by rapid growth of urban centers connected by a transportation system of railways and roads. Special construction

Table 1. Economic planning regions of the USSR according to area and population (as of 1 January, 1976).

Economic Planning Region	Area (thousand km^2)	Population (thousands)	Population (per km^2)	Urban (%)
I. Siberia				
Western Siberia	2427.2	12,503	5.2	67.6
Eastern Siberia	4122.8	7,904	1.9	67.9
Far East	6215.9	6,579	1.1	75.4
Total Siberia	12,765.9	26,986	2.1	69.6
II. Ural	680.4	15,385	22.6	74.2
Central (includes Moscow)	485.1	28,376	58.5	76.9
NW (includes Leningrad)	1622.8	12,905	7.8	78.2
Volga-Vyatka	263.3	8,275	31.4	60.6
Central Chernozem	167.7	7,761	46.3	49.8
Volga	711.6	17,960	25.2	63.0
South West	269.4	21,313	79.1	44.6
Donets-Dnieper	220.9	20,829	94.3	74.5
North Caucasus	355.1	15,099	42.5	54.2
South	113.4	7,223	63.7	63.6
Moldavia	33.7	3,850	114.3	37.0
White Russia	207.6	9,371	45.1	52.0
Baltic	189.1	8,035	42.5	64.0
Trans Caucasus	186.1	13,477	72.4	53.8
III. Total West of the Urals	4865.8	174,474	35.9	62.3
IV. Central Asia				
Central Asia	1277.1	23,514	18.4	39.8
Kazakhastan	2717.3	14,337	5.3	54.0
V. Total Central Asia	3994.4	37,851	9.5	45.1
TOTAL USSR	22,402.0	255,524	11.5	61.0

After: [22]

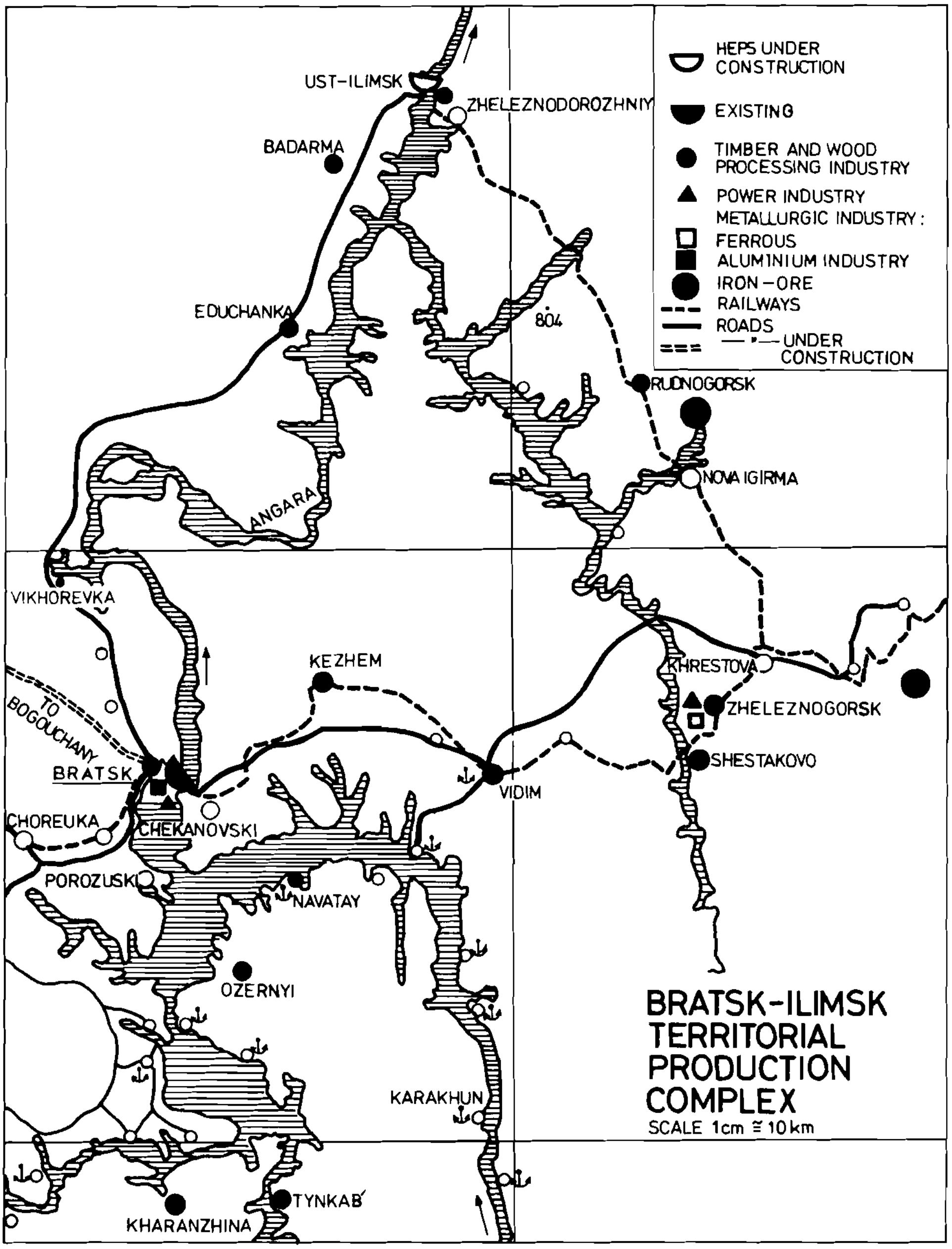

Figure 2.

Source: [17, p. 364]

Table 2. Characteristics of planned and existing hydroelectric stations of the Angara-Yenisei Cascade.

Source: [32, p. 72]

HES Hydroelect. Stations	River	Commis-sioning year	Design head (in meters)	Average annual runoff (in km^3)	Reservoir capacity (km^3)	Reservoir capacity run-off, (%)	Installed capacity, MW (in million of W)	Average long-term output (in 10^9 kWh)	Regulation
Irkutsk	Angara	1956	26	60	46.0	77	660	4.1	long term
Bratsk	Angara	1961	106	92	48.2	52.5	4,500	22.6	long term
Ust-Ilimsk	Angara	1974	86	101	2.8	3	4,320	21.9	seasonal
Bogouchany	Angara	1985-1990	65	107	2.3	2	4,000	17.0	seasonal
Sayansk	Yenisei	1978	194	47	14.0	30	6,400	23.7	seasonal
Krasnoyarsk	Yenisei	1967	93	88	30.4	36	6,000	20.4	annual

Table 3. Role of the Bratsk HEPS in the Siberian Joint Electric Power System (JEPS).

Source: [19, p. 190]

	1970	1971	1972	1973	1974
Total output of HEPSs in the Angara-Yenisei Cascade (10^9 kWh)	42.2	44.3	46.1	48.9	48.5
Total output of the Bratsk HEPS (10^9 kWh)	20.3	22.8	23.3	23.0	28.0
Percentage of Bratsk HEPS in Siberian JEPS	48	51	50	47	58
WINTER PEAK LOADS	1970	1971	1972	1973	1974
All HEPS stations in Siberian JEPS (1000 kW)	5990	6470	6590	7160	7700
Bratsk HEPS contribution (1000 kW)	2760	3660	3420	3040	4090
Bratsk HEPS contribution (%)	46	57	52	42	53

techniques had to be developed owing to extreme climatic conditions: over 30 °C in summer and sometimes less than -30 °C in winter. The adaptation of the workers and settlers to these climatic conditions also required special solutions.

The area of the BITPC covers approximately 90,000 km^2 and includes three administrative regions of the Irkutsk Oblast: the Bratsk district with an area of 33,000 km^2, the Ust-Ilimsk district with an area of 27,000 km^2, and the Nizhnei-Ilimsk district with an area of 29,500 km^2.

During the period 1959-1974, the population of the BITPC has increased 1.3 times, the urban population has grown 3.5 times, and the rural population has declined 6 percent. The network of urban type settlements in the BITPC now includes four towns: Bratsk, Ust-Ilimsk, Zheleznogorsk-Ilimsk, and Vikhorevka; there are also eight settlements approaching the urban classification. Two-thirds of the total population of the BITPC is concentrated in these four towns (see Tables 4 and 5).

Table 4. Population characteristics of the BITPC, 1974.

Settlements	Population	% of Total	Trend
Bratsk	182,620	46	Increasing
Ust-Ilimsk	31,760	8	Increasing
Zheleznogorsk	27,790	7	Increasing
Vikhorevka	19,850	5	Increasing
8 Urban-type	59,950	15	Increasing
Rural	75,430	19	Stable-declining
TOTAL	397,000	100	Increasing

After: [31]

Table 5. Urban and rural population characteristics, 1959-1974.

Year	Total Population	Urban	Rural
1959	170,000	90,100 (53%)	79,900 (47%)
1974	397,000	321,570 (81%)	75,430 (19%)
Increase	227,000 (130%)	231,470 (350%)	4,470 (Decrease) (6.%)

Table 5 gives the general population increase from 1959 to 1974, broken down into urban and rural classifications.

Migration, of course, plays a large role in the overall increase of population in this area. Of the total population increase of 227,000 in the period 1959-1974, migration accounted for 149,000 or 66%, and natural increase for 78,000 or 34%. Migration influx to Bratsk was 75% of the increase, 87% for Ust-Ilimsk, 78% for Zheleznogorsk, and 50% in Vikhorevka.

Special programs have been introduced to attract settlers and workers to the BITPC area. Wages are from 1.3 to 1.6 times the normal for the USSR, and a 10% increase in the monthly wage is allowed for each year of service, up to a maximum of 50%.

Those working for more than two years receive an additional 12 days leave and free vacation travel. Full wages are paid to those who are temporarily disabled. Early retirement is also possible for those working for at least 20 years in the BITPC. Men can retire at 55 years--five years earlier than the norm, and women at 50, also five years earlier than the norm.

The wage and benefit structure has done much to influence the growth of the BITPC, but these benefits are in addition to the social and cultural opportunities offered by the BITPC. Special training programs are available to upgrade and update a worker's skills, quality educational facilities are being expanded, and new housing is being built to keep up with increasing demand.

Figure 3 presents the main industrial production centers in the BITPC and their relative industrial output in 1974. The forest products industry permeates the entire BITPC complex; this is understandable when one observes the amount of forest lands in the Angara Region. Almost 90 percent of the total area is forested (approximately 7.8 million ha). Timber reserves are estimated at 1.4 billion m^3. The reserves of mature and over-mature stands of the coniferous species reach 257.5 m^3/ha, 242.1 m^3/ha for cedar, and 236.8 m^3/ha for larch.

Current logging in the area is 9 million m^3/a, of this number, 7.4 million m^3/a is logged in the BITPC. The Bratsk timber complex is one of the largest of its type in the Soviet Union, as indicated by the data in Table 6. Construction has also begun on the Ust-Ilimsk timber complex, which will greatly increase the timber processing capacity in the BITPC. Planned cellulose production for this complex is expected to be 624,000 t/a.

In addition to the forest products industry, the Bratsk aluminium plant has attained almost full operational capacity; upon completion it will be the largest of its type in the Soviet Union.

Table 6. Production data for Bratsk timber complex, 1975.

Source: [15]

Cord cellulose	200,000 t/a
Cardboard	245,000 t/a
Bleached cellulose	250,000 t/a
Viscose cellulose	200,000 t/a
Fiber board	100,000 t/a
Sawn timber	375,000 m^3/a
Nutrient yeast	200,000 m^3/a

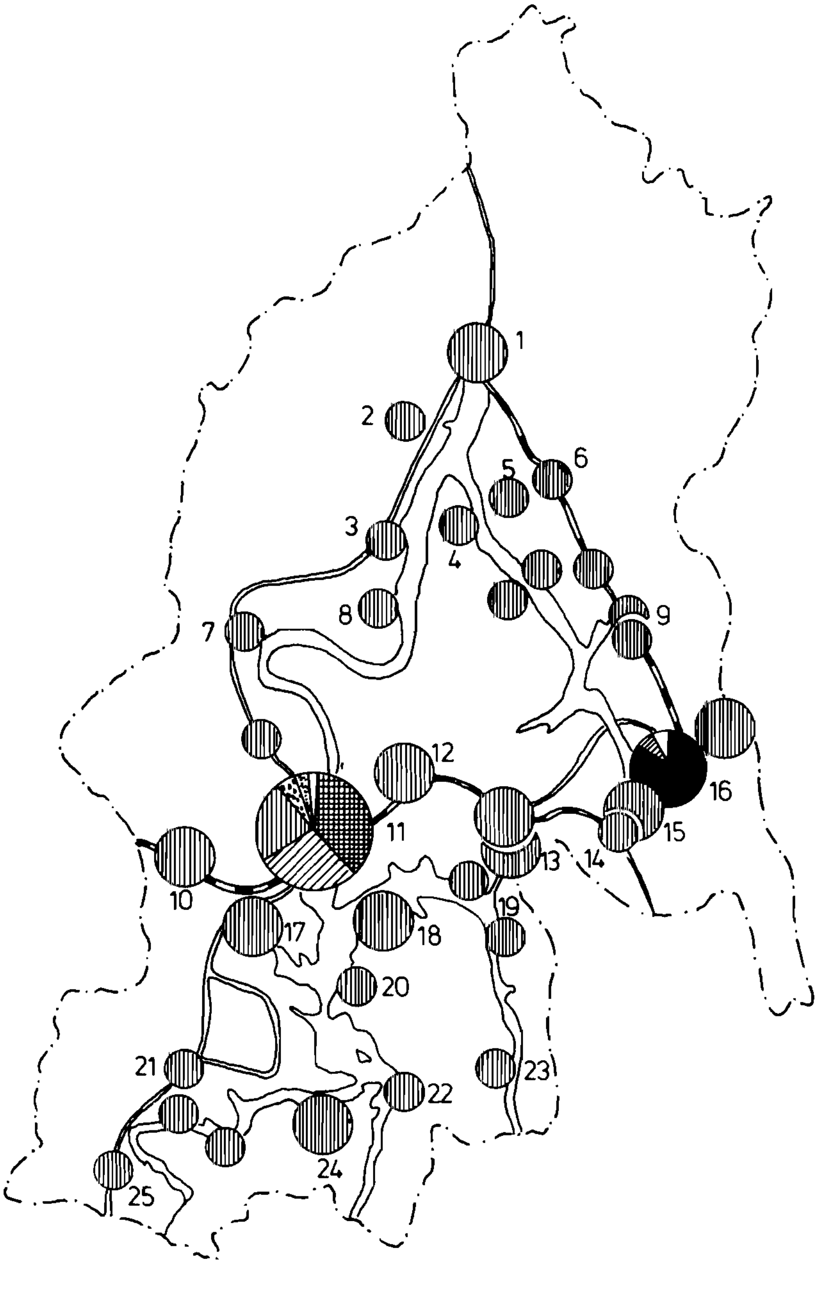

Figure 3. Location of industrial production in BITPC as of January 1, 1975. (See next page for key.)

Source: [12, pp. 57-58]

1. Ust-Ilimsk;
2. Badarma;
3. Educhanka;
4. Dalinij;
5. Kedrovij;
6. Tuba;
7. Sedanovo;
8. Ershovo;
9. Rudnogorsk;
10. Turma;
11. Bratsk;
12. Kezhem;
13. Vidim;
14. Zatoplyaemaya;
15. Shestakovo;
16. Zheleznogorsk;
17. Tarma;
18. Narataj;
19. Chistaya Polyana;
20. Ozernij;
21. Pokosnij;
22. Tynkobi;
23. Karakhun;
24. Kharanzhino;
25. Ilir;

power industry;

ferrous metallurgy;

nonferrous metallurgy;

timber, woodworking and cellulose and paper industry;

building materials industry;

food industry;

other industries;

railways;

motor roads;

boundaries of territorial-production complex;

Industrial Production in 1974

over 1×10^9 Roubles;

from 50-100 million Roubles;

from 5-15 million Roubles;

less than 5 million Roubles.

Mineral resources are abundant in the region. The Korshunovsky iron works produces 6.5 million t/a of iron ore concentrate. Additional iron ore deposits have been discovered near Rudnorsk, and plans are being developed to utilize this deposit. The Region also contains coal fields, extensive salt deposits, and quartz sands. The BITPC also serves as a base for further mineral exploration.

All of the industrial enterprises and the settlements for the workers were constructed by one organization, Bratskgesstroi. The current volume of construction capacity is 400 to 450 million Roubles per year.

It can be seen from this introductory material that the BITPC is clearly considered a national task of the USSR in providing bases for the development of Siberia. The remaining sections of this paper deal with the TPC approach in general, and the decision process involved in the development of the BITPC.

The TPC Approach

Bratsk-Ilimsk provides a good illustration of the evolution of a relatively new element in the USSR economy--the TPC. At the outset, Bratsk-Ilimsk was simply a massive project for the construction of a hydroelectric power system and industrial complexes. Normally, the development of each major segment of Bratsk-Ilimsk would have been carried out by the respective Ministry for that industrial sector. Very early in the Bratsk-Ilimsk's history, however, the decision was taken to assign responsibility for all construction to a single agency: Bratskgesstroi. This may be viewed as the start of the concept of integrating the full range of activities that must be undertaken for the planning and development of a new complex.

According to Aganbegyan [1], a TPC is a typical territorial production formation of the USSR national economy at its present stage. It is an expression of present perspectives for the goal oriented and concentrated development of special territorial units. A TPC can be defined as a separate object for goal oriented programming and planning in the development of a territorial unit as a whole. It is also a separate object for coordinating the activities of different management bodies and organizations. The TPC is not an administrative territorial system of the USSR. It holds a middle position in the hierarchy of territorial and national economic objects of planning and management. The TPC can be considered a basic means for providing structural-organizational solutions to coordination problems involving the national economy, industry, and regions at the medium level of the planning and management system.

Currently, about 100 TPCs are operating or are being developed in the USSR. Among the important TPCs in Siberia are Bratsk-Ilimsk, the Sayan, and the TPCs along the Baikal-Amur Railway (BAM). The experience in the formation of the BITPC showed that the formation of a TPC is based mainly on two factors:

- The *existence of* large, accessible and high quality *natural resources* in a given territory which are important for the development of the USSR and the countries belonging to the Council for Mutual Assistance (CMEA), for export, and for the development of a large economic region within the USSR. These include energy sources, minerals, forests, water resources, and fertile soil.

- A considerable *national economic potential* for the simultaneous and concentrated *use* of the *natural resources* of the given territory, for the provision of the necessary material and labor resources (including transportation), and for the formation of the social infrastructure in the territory.

The first factor is decisive for determining whether a given territory will become a TPC. It also determines the specialization of the TPC within the production specialization framework of the USSR. The second factor is the main prerequisite for a territory to be developed in the form of a TPC. The TPC is not the normal evolution of a territory but a goal oriented approach. It is a concentrated, coordinated complex development of a territorial unit involving the means and efforts of the entire country, other regions, and even foreign countries. The national economic potential and the national importance of the natural resources determine the development sequence of the TPC and the possible time horizons and activities of its formation.

Figure 4 shows the position of the BITPC in the regional structure of the national economy of the USSR. The USSR has three economic zones: the European Zone, Siberia and the Far East, and

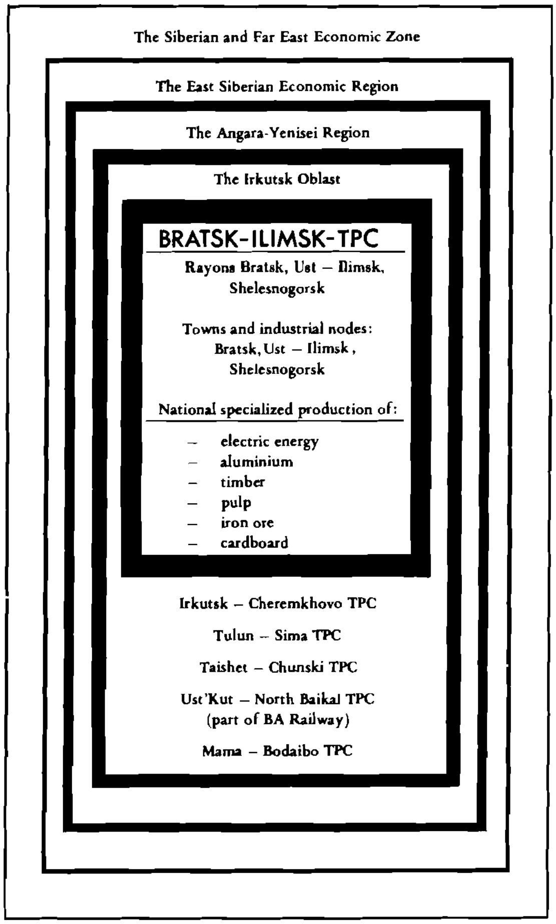

Figure 4. The BITPC in the regional structure of the national economy of the USSR.

Middle Asia. For planning purposes the USSR is divided into 19 economic regions. The BITPC belongs to the subunit Angara-Yenisei Region, which is sometimes referred to as a TPC. The Irkutsk Oblast has six TPCs, one of which is the BITPC. This, in turn, is subdivided into three industrial nodes, which are development centers of the TPCs, not only for industries but also for settlements, agriculture, and transportation. (Usually they are also transportation nodes.)

The links between the industries and the industrial nodes of the BITPC are mainly the power supply (HEPS--aluminium plant, iron ore dressing, timber and cellulose production, and others) and the railway and road system.

Figure 5 gives a simplified picture of the planning and management of the BITPC. Since a TPC has a special place in the development of the national economy of the USSR, planning and management start at the top; e.g. there was a special decision of the USSR Council of Ministers on the development of industries and towns of the BITPC. The BITPC is specifically stressed in the plans of the State Planning Committee of the Soviet Council of Ministers (GOSPLAN) and the Ministries. Programming and planning the BITPC takes place first on the level of GOSPLAN and the GOSPLAN of the Russian Federation (RSFSR) with the help of their institutes. (See, for example, the master scheme of the territorial development of productive forces of the USSR from the Council for the Study of Production Forces (SOPS) and the Central Economic Research Institute (CERI).

The territorial administrative unit, Irkutsk Oblast, is the main territorial organ for the BITPC. A special role in forecasting, programming, and planning is played by the organs and institutes of the USSR Academy of Sciences and in particular by the institutes of its Siberian Branch. Their activities are directed toward creating a scientific base for the development of the BITPC and the evaluation of feasible variants through expert opinions. Ministries, GOSSTROI, design institutes, and other management bodies take part directly in the development of the objects within the TPC in the planning and management process. Although the TPC is not an administrative unit as a whole, some executive bodies exist within it, mainly the Executive Committees of the rayon* and towns. In the special case of the BITPC, we find also the Bratskgesstroi and the Angarastroi construction organizations. The development of the BITPC is closely connected with the activities of Bratskgesstroi, because the organization is in charge of all construction activities in the BITPC, except for railways, for which Angarastroi is responsible. New forms of management of a TPC are being discussed in the USSR. The goal is to make management more complex and effective, possibly by creating a special body for planning and coordinating the activities related to the TPC.

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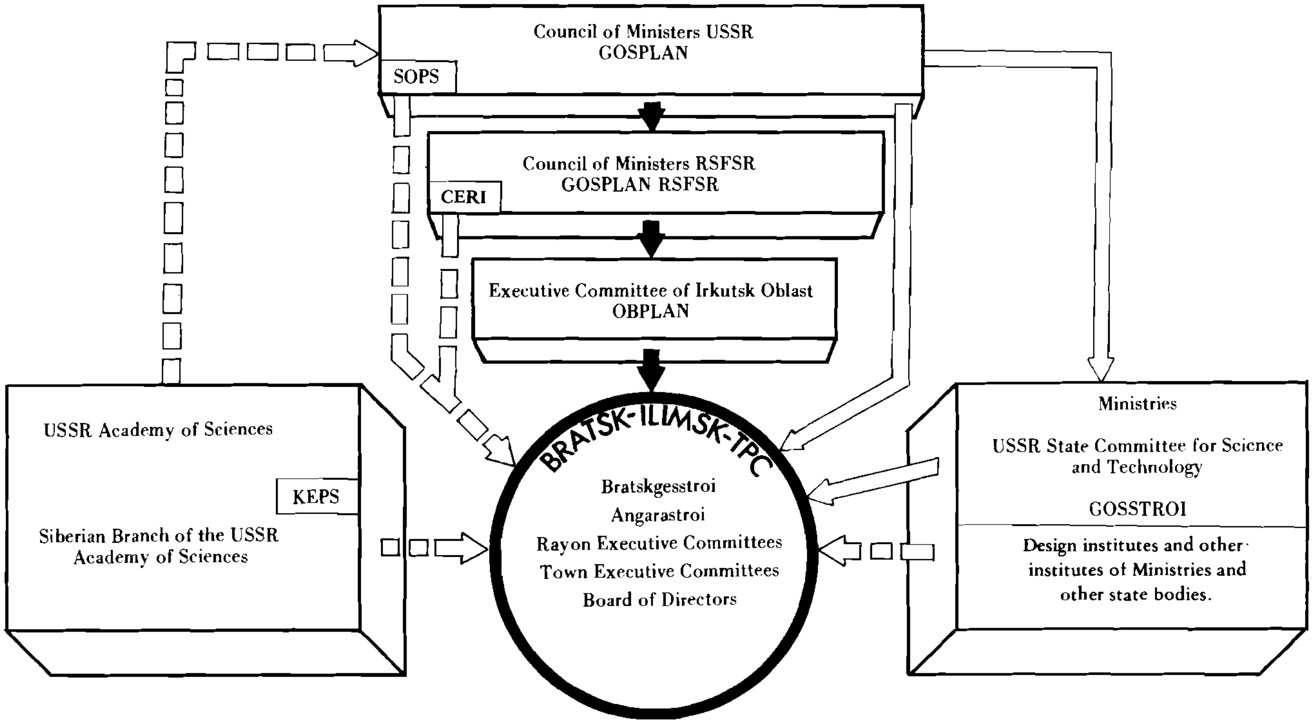
*Rayon may be defined as a small district.



SOPS - Council for Study of Production Forces

KEPS - Committee of Production Forces and Natural Resources

CERI - Central Economic Research Institute

planning and management

forecasting, programming, designing

administration direction

Figure 5. The main lines of planning and management of the BITPC.
(Simplified, many information feedbacks not shown.)

The BITPC, as a part of the Irkutsk Oblast, played a large part in the rapid development of this Oblast. Table 7 shows the growth rate of industrial development in the Irkutsk Oblast for the period 1960-1975. The growth rate of the industrial production in each region of the Oblast is shown in Table 8.

Table 7. Development in the Irkutsk Oblast, 1960-1975.

Source: [24]

INDUSTRY		Relative Ratio of Development			
		1960	1965	1970	1975
Electric power		1	3.24	4.79	6.52
Coal		1	1.15	1.30	1.50
Iron ore		-	1.0	4.3	8.1
Fodder yeast		-	1.0	58	130
Removal of wood		1	1.32	1.55	1.73
Sawn timber		1	1.29	1.32	1.48
Plywood		1	1.14	2.25	3.21
Cellulose		-	-	1.0	1.7
Cardboard		-	-	1.0	1.2
Cement		1.0	1.1	1.3	1.3
Population	Bratsk	43,000		155,000	195,000
	Irkutsk	366,000		451,000	519,000
	Angarask	135,000		203,000	231,000

As can be seen from Tables 7 and 8, rapid industrial development has taken place in the whole region, particularly since 1965. The relative growth of industrial production in the Oblast from 1965-1972 was approximately twice that for the year 1965. In addition, many of the industries in the Mid-Angara Region are becoming more dependent on energy and resource industries such as electric power generation, timber and wood processing, and iron and nonferrous metals (Table 9).

Table 8. Growth rate of production in each region of the Irkutsk Oblast, 1940-1972.

Source: [21]

Region	Rate of Production Amount (%)			Increase of Total Products (%)
	1940	1965	1972	1965-1972
Mid-Angara	0.8	14.1	26.1	400
Irkutsk-Chemkhovs	63.2	65.4	55.2	184
Rest of Oblast	36.0	20.5	18.7	198
TOTAL	100.0	100.0	100.0	216

Table 9. Structure of industry in the Mid-Angara Region, 1972.

Source: [21, p. 91]

Department of Industry	Amount of Production (%)	Investment (%)
Electric power	25.6	36.8
Timber and wood processing	28.8	29.6
Iron and nonferrous metals	30.7	27.9
Construction	7.2	3.4
Machinery	3.9	1.4
Food and light industries	3.8	0.9
TOTAL	100.0	100.0

The typical structure of industry in the Mid-Angara Region has been connected with the regional specialization of the specific natural resources in Siberia from the point of view of the national economy. In 1975, 5% of the electric power, 8% of timber, 12% of cellulose, 4% of coal, and 7% of paper and cardboard were produced in Irkutsk Oblast area from the total production of these goods produced in the USSR.

Decisions on the BITPC Development, Their Alternatives, and Selection Criteria

Methodological Remarks

A method for analyzing the concepts and the development of the BITPC is to study the decision processes that led to the formulation of basic strategies, to the formation of the complex, and to the various activities that characterize its development. Such a study should not be limited to the actual decisions and activities that occurred in the BITPC development. The nature and complex character of these decisions and activities can be understood only if seen in the perspective of their alternatives, objectives, and underlying concepts.

More specifically, an analysis of the BITPC decision processes should serve several related purposes:

- *To describe the actual decisions and the resulting activities*, focussed on the main aspects of the development (energy supply system (ESS), production sectors, and infrastructure). This should provide background information on how the BITPC was actually formed.

- *To increase an understanding of the nature of the BITPC decision processes* by analyzing possible development and decision alternatives. This should aid in an understanding of what could have been done in the BITPC development.

- *To assess decisionmaking in the BITPC* in terms of its objectives and concepts. This should aid in an understanding of why decisions on the BITPC development were chosen.

The analysis began by mapping the actual activities in the BITPC formation, e.g., construction of roads, dams, and industrial plants. The next stage involves the identification of the decision points that initiated these activities, such as a decree by the Council of Ministers. These are the easy steps of the analysis. The next step was to identify alternatives, by which is meant either of the following:

- *Variants:* different structural, technological, siting, timing, opportunities for the solution of the task of economic and social development; selection of goals for the same system or subsystem.

- *Strategies:* feasible combinations of structural, technological, siting, timing, goal selections, and other variants for the development of a complex socioeconomic system.

- *Scenarios:* detailed descriptions of strategies, taking necessary time sequences into consideration and projecting possible consequences of strategies.

Retrospectively, determining alternatives is more difficult, since only a limited number of alternatives may have been considered at the time and even those are usually clouded by the long time period since then. The approach used in the analysis was to tie the questions for alternatives closely to the decision points and to search for actual and discussed variants and strategies as well as for documented and logical alternatives.

The interviews were facilitated by the fact that we were able to inquire about specific decision points and also that we could generate ideas about possible past alternatives. Those interviewed usually generated some real alternatives, which were discussed, examined, and evaluated before the decision was made, or they expressed their own view about possible alternatives. In addition, we used several written sources to identify alternatives such as Party Congress materials, papers and speeches from [17], Soviet publications about the BITPC (only a very limited number were available in English), and working materials, graphs, and figures collected during the field trip.

In general, we have classified the alternatives into the following three categories:

- *Actual cases:* such alternatives were discussed, examined and evaluated before the decision was made (e.g., the alternatives for the siting Bratsk city);

- *Documented alternatives:* alternatives that were mentioned in the literature or were discussed in the interviews as possible or conceivable (e.g., different concepts of the Angara-Yenisei Cascade);

- *Assumed alternatives:* such alternatives existed logically, and presumably were considered, but we do not have any specific information about them (e.g., the energy export strategy).

The final step of the analysis was the identification of goals, objectives, and criteria, against which variants, strategies, and scenarios were evaluated. Goals, objectives, and criteria stand in a hierarchical relationship that is implied in the following definitions:

- *Goals:* general, qualitative formulation of the desirable states of a socioeconomic system (e.g., to increase the standard of living of the population);

- *Objectives:* intermediate specifications of goals, either in terms of ways how to achieve them or in terms of a logical explication (e.g., improved housing conditions);

- *Criteria:* ("attributes") operational and well defined measures against which actual decisions can be evaluated with respect to goals and objectives (e.g., operation costs).

Sometimes "task" is used to specify goals in terms of activities that are intended to achieve higher level objectives. Identifying goals and objectives retrospectively proves exceedingly difficult, mainly because of a lack of information and because of changes in goals and objectives after decisions were taken. The approach concentrated therefore on the more immediate criteria that were discussed in the actual decisions, or that were implied by the decisions taken.

Criteria and objectives thus identified are usually much more concrete and immediate, but the relationship to the general supergoals may be missing. Objectives and criteria that will be discussed fall into the following three categories:

- Those *objectives* and *criteria* that were clearly *identified*, discussed and explicitly traded off in the decisionmaking process (e.g., transportation time, cost of construction, and reduction of pollution in the decision to site Bratsk city).

- Those *criteria* and *objectives* that are *implied* by the selection of the final decision (e.g., efficiency criteria that led to the elimination of the two small dams in the originally six-dam strategy for the Angara-Yenisei Cascade).

- Those *objectives* that could be *inferred* from the Soviet documents (e.g., raising the standard of living, protecting the environment), and which were linked to the decisions under consideration indirectly as implicit supergoals, disaggregated objects, and their interactions.

We applied this analysis of decisions, their alternatives and criteria to four aspects of the BITPC decisionmaking process: strategy evolution, development of the power system, production sector development, and infrastructure development. These four aspects reflect the logical sequence of decisionmaking in the BITPC. First basic strategic decisions had to be made, then decisions about the power system were made; on the basis of the designed capacities and sites of the dams in the power system, decisions about energy intensive and other industries followed. Finally, the necessary decisions on transportation links and settlements had to be taken to provide the industries with the social and technical infrastructure.

Our analysis was not meant to evaluate past decision processes in the BITPC. The limited study time, the limited availability of written material, and other limitations of retrospective case studies (see the Introduction to this Report) made such an evaluation virtually impossible. Consequently, statements on decisions, underlying alternatives and objectives can be taken only as examples for a much deeper structured real decision process during the BITPC formation.

The following five sections are organized along our framework for studying the BITPC decision process and the four-step logic of the BITPC decisionmaking. First, an introduction to the development of the BITPC is presented which outlines the basic steps in the formation and development of the BITPC. The second section analyzes the strategy evolution of the BITPC, and discusses in greater detail information presented in the first section. The decision processes involved in the power system development, in the development of the production sector, and in infrastructure development are analyzed in the following sections. For each of these aspects the basic decisions, their alternatives, and their evaluative criteria will be discussed.

Overview of the BITPC Development

The basic strategy for the BITPC was laid down in the 1920s by the Siberia Bureau of GOSPLAN. It consisted of a scheme for the development of hydroelectric power resources of the upper and middle reaches of the Angara River. The scheme also proposed the construction of two industrial complexes [12].

Subsequent work by the multidisciplinary Angara Bureau in Moscow led to a more detailed strategy that was completed in 1934. The number of HEPSs was expanded from three to six, and these six were divided into four groups [12]. Of the six stations the Bratsk HEPS was considered the most promising from the point of view of its efficiency in the entire scheme [12]. However, it was deemed unfeasible and inexpedient to begin with the construction of gigantic HEPSs. Thus, it was proposed that a "pioneer" industry be developed first in the more accessible region of Irkutsk. This would make it possible to provide subsequent construction activities in the Bratsk area with the necessary building materials, fuel, and electric power; it would also "accumulate experience and know-how in the severe climatic conditions" and provide training for the necessary personnel. This multistage approach gave priority to the more accessible Baikal Region (now the Irkutsk-Cheremkhovo TPC) within 70 km of Irkutsk. The scheme was approved in 1936 by a team of experts of GOSPLAN.

The strategy developed by the Angara Bureau for the Bratsk area [12] envisaged the establishment of power intensive industries i.e., ferrous and nonferrous metallurgy, production of synthetic material and liquid fuel from coal, nitro-hydrogenous compounds, chloride, and silicate and alumino-silicate electthermics. Grain growing and livestock raising in places of population concentration were planned. Development of the timber industry in the Region was expected to provide construction projects with lumber; it would also include production of finished goods on the spot.

The Second World War interrupted the implementation of the strategy for the development of the Angara River. At the end of the war, priority appears to have been given to all earlier recommendations of the Angara Bureau for the construction of "super long railway lines" that would "bring the Soviet Far East closer to the economic center of Siberia" [12]. In 1949, the Angara River bank in the Bratsk area was connected by rail with Taishet to the west; this link would be important in the latter construction of the BAM during the 1970s.

Directives of the 19th Congress of the Communist Party of the Soviet Union (CPSU) for the national economic development in 1951-1955 envisaged beginning the work by making use of "the hydropower resources of the Angara River in order to develop aluminium, chemical, mining and other industries on the basis of cheap electric power and local raw materials" [23].

In 1953, the Gidroprojekt evolved a new scheme for developing hydropower engineering along the Angara which took into account the discoveries of new deposits of raw materials, mainly iron ore. It also reflected changes in the economic potential, the ability to apply new engineering solutions, and changes in requirements for several types of products as well as their manufacturing efficiency [12].

The scheme envisaged the construction of six HEPSs with a total capacity of more than 10 million kW. The Bratsk HEPS was to be the most powerful. The scheme "defined the scope of the consumption of energy by major industries, their location, and the direction of transport arteries" [5].

Guidelines for this scheme were grouped into four categories [8]:

- Meeting the growing requirements of the national economy for cheap electric power, power-intensive products of the chemical industry and the ferrous and nonferrous metallurgical industries, as well as the products of the timber processing and mining industries;

- Increasing the social productivity of the resource development in the Mid-Angara Region on the basis of modern technologies;

- Providing the most favorable conditions for attracting and settling manpower;

- Converting the Mid-Angara TPC into a potential support base for developing new territories located within the zone of influence of the BAM and North-Siberian Railway.

Thus, the ultimate aims of the draft regional scheme virtually merged with the major national goals for improving the living standard of the Soviet people by raising the social productivity of labor on the basis of the accelerated technological progress and the most efficient location of the production forces [8].

Construction of the Bratsk HEPS was authorized by the USSR Council of Ministers in 1954. Two years later the Council decreed the "organization of a single base in Bratsk for the construction of all projects in the region" [12]. The Bratsk HEPS was viewed as a key link in the Siberian energy supply system (ESS) from Novosibirsk to Irkutsk.

The further national economic tasks for the development of the BITPC were given by the 20th Congress of the CPSU. In 1956, the 20th Congress of the CPSU resolved to put into operation the Irkutsk HEPS on the Angara River within the Five-Year Plan 1956-1960. The Irkutsk HEPS had a capacity of 660,000 kW and was the first stage of the Bratsk HEPS. Also, the development of the Central Siberian ESS from Novosibirsk to Irkutsk was considered. During this period it was decided to put into operation the Korschunovo iron ore mine in East Siberia, and to construct three aluminium plants in Siberia and five cellulose paper plants in the Eastern regions [26].

The 23rd Congress of the CPSU in 1966 chose to accelerate the construction and put into operation the capacities of the Bratsk aluminium plant, to finish the first line of the Bratsk timber complex, and to start the construction of the second line. The industrial development of these regions was to be guaranteed by the construction of the Chrebtovaya-Ust-Ilimsk and the Reschoty-Bogouchany railways [30].

The 24th Congress of the CPSU in 1971 decided to ensure the further development of the BITPC, to finish the construction of the Bratsk aluminium plant and the Bratsk timber complex in the Five-Year Plan 1971-1975. It was also decided to put into operation the first aggregates of the Ust-Ilimsk HEPS, and to begin construction of the Ust-Ilimsk timber complex [29].

The "Guidelines for the Development of the National Economy of the USSR for 1976-1980", drawn up at the 25th Congress of the CPSU in 1976, resolved to finish in principle the formation of the Bratsk-Ust-Ilimsk TPC, to put into full operation the Ust-Ilimsk HEPS, and to construct the cellulose plant with the participation of the CMEA countries [27].

Those resolutions set the main national tasks for developing the BITPC from the very beginning in 1952 to 1980. These tasks had been fulfilled in general terms, and followed in principle the main direction which had been outlined in the beginning of the 1950s. All these tasks were, and still are, connected with tasks for the formation of the social infrastructure. During this time, new towns such as Bratsk, Ust-Ilimsk, and Shelesrogorsk grew with the TPC infrastructure; some hundreds of thousands of people were settled here and opened a large area within the Taiga for civilization.

The first two industrial complexes in the Bratsk-Ilimsk area were timber and iron ore, both started in 1958. Each of these reflect the way in which the development of Bratsk-Ilimsk was an integral part of national economic policy.

The timber complex was not energy intensive, and thus would not normally have received top priority in the evolution of the program to develop the resources of the Bratsk-Ilimsk area. However, a lack of production capacity in the USSR for viscose tire cord and the sudden unavailability of imports led to the decision to upgrade the priority assigned to the timber complex.

The iron ore complex was initiated as part of the efforts aimed at developing another metallurgical base of the country, in addition to those at Donbass, Urals, Karaganda and Kuzbass.

The decree to establish the Bratsk aluminium complex was issued in 1968. The complex is expected to have the world's largest output. Although all of its principle raw material--bauxite converted into alumina--must be imported from one of the 15 alumina plants in the USSR or from foreign sources such as Hungary, Greece, and New Guinea, the unusually low cost of electricity more than offsets the transportation cost disadvantage.

The BITPC owes its significance to the fact that it lies at the intersection of the BAM and the Angara River. The continuation of the BAM (construction is currently under way) parallels the Trans-Siberian Railroad roughly 500 miles to the north. It opens up a vast area rich in a variety of mineral, energy, and forest resources. The Angara River flows from Lake Baikal northwest to its confluence with the Yenisei and from there to the Arctic Ocean. It represents a huge hydropower source. The Bratsk dam, almost 5 km long, is the centerpiece in the series of hydroelectric plants built to harness this power; it provides the Angara River crossing for the first part of the BAM, built during the period 1946-1955.

The eastern regions of the USSR will continue to develop at priority rates. Energy-intensive industries, the fuel industry, and agriculture, and simultaneously the entire social infrastructure (including housing, public utilities, cultural and community institutions, and urban transportation) will be expanded at especially high rates in Siberia and the Soviet Far East.

Strategy Evolution of the BITPC

The strategies for the BITPC development have been an integral part of the national economic policy of the USSR. The main lines of strategy development, decisions, and activities are shown in Figure 6. At the bottom row are the main stages in planning and decisionmaking for the BITPC development between 1925 and 1982. The top three rows show the activities that were derived from the formulation of strategies and basic decisions divided into power systems development, development production sectors, and infrastructure development.

The main strategic evolution took place before the decision to construct the Bratsk HEPS in 1952. It consisted mainly of specifications of the Angara Cascade and of a determination of industries of specialization and settlement patterns.

Energy supply is one of the most important prerequisites for colonizing the virgin East Siberian territories, for making them hospitable for human beings, and for exploiting the rich natural resources. In this respect, the Angara-Yenisei water power project is part of the larger strategy for the regional development of East Siberia. The enormous investment costs of constructing huge HEPS in Bratsk, Ust-Ilimsk, and Bogouchany can be counted as part of the costs for colonizing and opening up the rich mineral and forest resources of this Region.

Water power resource development was the starting point of all strategic decisions in the BITPC. Figure 6 shows the typical decisions and activities for dam construction as laid down by the documents of the Congress of the CPSU. These were accompanied by directives to explore possibilities for the further development of the production sectors, in accordance with the development of the energy resources. Later, either by decree of the USSR Council of Ministers or through the Five-Year Plan, plans for the construction of industrial facilities were approved.

The plans and decisions for infrastructure development were mainly generated from the need to provide roads and other transportation means for the already planned industrial facilities or dams, and to provide housing and other accommodations for the construction workers and other personnel.

Priorities for the development of industries and infrastructure are decided on the level of the USSR Council of Ministers. The evolution of the basic decision and priorities was a stepwise learning process, in which initial strategies underwent several modifications. We are lacking information, however,

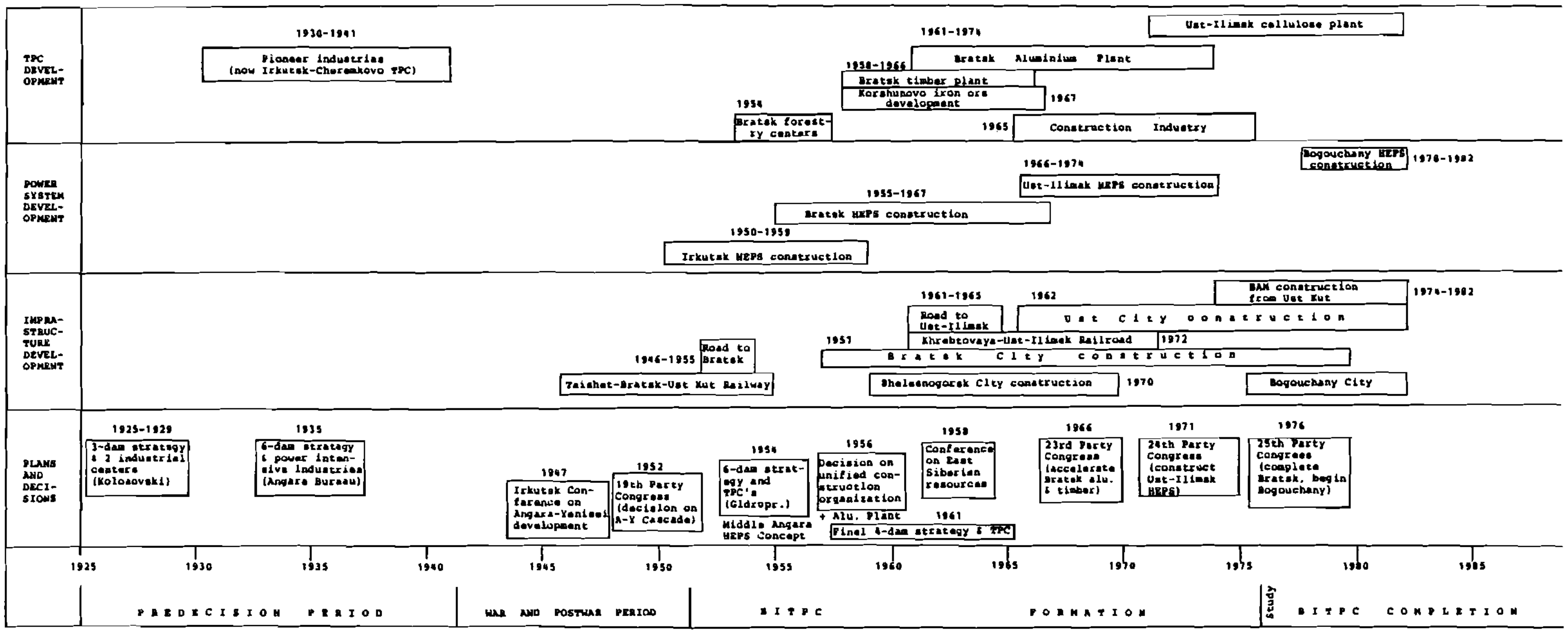


Figure 6. BITPC Development: plans, decisions, and activities.

about whether the basic strategy, namely to develop the hydropower resources of the Angara and to develop energy-intensive industries in connection with the dam construction, had any serious alternatives, such as to give priorities to other regions, or to limit settlements to the basic needs for dam construction and operation.

Our information about the basic objectives of the Angara-Yenisei development becomes clearer when we go into specific variants of the BITPC development. With regard to the global strategy of hydropower resources development and the development of energy-intensive industries, three main objectives seem to dominate:

- To provide the national economy with cheap electricity;
- To directly develop the regional economy;
- To provide a manpower and construction base for the further development of adjacent territories.

Power System Development

The exploitation of the rich water power resources of East Siberia must be understood as a result of several cross-cutting and overlapping development aspects of the USSR. These aspects are:

- The regional systems development aspect;
- The national energy demand and supply aspect;
- The aspect of embedding locally bound HEP plants in the regional and national ESS.

The exploitation of water resources plays an important role in the development of ESSs in USSR. Over a five-year period, the average annual growth of power generation capacity and power production between 1950 and 1975 was in the range of 7 to 12 percent. In 1960, one-fifth of this capacity was generated by HEPSs (see Table 10). Since then the share of hydroelectric power capacities and hydroelectric power generation has slowly declined. Considering the construction opportunities for HEPSs in the Angara-Yenisei River system within the framework of the USSR ESS, it is necessary to consider several positive and negative socioeconomic effects of hydroelectric power construction in East Siberia, which are important decisionmaking criteria.

The *positive effects* are:

- Low power generation costs (two to three times less than Volga HEPSs);

Table 10. USSR power generation system.

		1950*	1960*	Ø ANNUAL* %	1970*	Ø ANNUAL* %	1975*	Ø ANNUAL* %	PLAN** 1980	Ø ANNUAL** %
Capacity total	GW	19.6	66.7	13.0	166.2	9.6	218.0	5.6	285-288	~ 5.6
Capacity hydroelectric power stations	GW	3.2	14.8	16.5	31.3	7.8	41.0	5.6	~ 55	~ 6.1
Share hydroelectric power stations	%	16.3	22.2		18.8		18.8		~ 19	
Production total	TWh	91.2	292.3	12.3	740.4	9.7	103x8.6	7.0	1340-1380	~ 5.2
Production hydroelectric power stations	TWh	12.7	50.9	14.8	124.4	9.4	126.0	0.3	-	-
Share hydroelectric power stations	%	13.9	17.4		16.8		12.1			

*Data of the national economy of the USSR compiled from the 1970 *Statistical Yearbook*, Statistika, Moscow, 1971.

**Directives of the 25th Congress of the CPSU, Gospolitizdat, Moscow.

- High reliability of power generation;
- High concentration of power capacity (about 4000 MW each);
- Steady level of power generation over the year;
- Improvement of environmental conditions.

The *negative effects* of Angara-Yenisei HEPSs compared with new coal or gas-fired thermal power stations in the Western or Ural Regions of the USSR are:

- Higher investment costs;
- Longer construction time (1.5 to 2 times);
- Disadvantages of large construction sites in virgin territories combined with severe climatical conditions;
- Long distances from the traditional power consumption centers of the USSR, which lead to the need for either high voltage/high capacity long distance transmission lines and/or the local development of energy-intensive industries.

Basic Decisions

The BITPC includes three of four HEPSs that are either built, under construction, or planned for the Mid-Angara ESS as a part of the Angara-Yenisei Cascade. (See Table 11.)

Table 11. The Mid-Angara ESS*.

Hydroelectric Power Station	Construction Time	Capacity (GW)	Maximum Output (TWh)
Irkutsk	1950 - 1959	.66	4.5
Bratsk**	1955 - 1964	4.50	22.6
Ust-Ilimsk**	1966 - 1978	4.32	21.9
Bogouchany**	1978 - 1982	4.00	19.8

*Data for the installed capacity and the output of HEPSs on the Angara-Yenisei Cascade are in [23].
**These stations belong to the BITPC.

The basic decisions related to the power system development are shown in Figure 6. When the 19th Congress of the CPSU made the decision in 1952 to construct the Angara-Yenisei Cascade, the Irkutsk HEPS was already under construction [23]. This station completed the industrial base of the Irkutsk-Cheremkovo TPC, which later played an important role as a point of departure and support basis for the BITPC. The first preparations for the Angara-Yenisei project and related industrial nodes began 50 years ago, but at that time the USSR economy lacked the enormous means for its realization. After the Second World War, the project was taken up again during the 1947 Conference on the Angara-Yenisei development and then prepared for the basic decision of the 19th Congress of the CPSU [23].

Alternatives

The multistage decision process in the creation of the Angara-Yenisei power system had to deal with three basic types of alternatives (Figure 7). They are:

- Whether to build a dam at a certain place (layouts of the power station system included number, capacity and location of stations);

- Alternatives in siting, design, and operation of the HEPS;

- Different layouts of the energy grid.

The layout of the Mid-Angara HEPS system was elaborated in 1954 by Gidroprojekt, Moscow; it included six dams and industrial nodes. In 1961, this number was reduced to the present four-dam strategy, in accordance with the general policy of the Seven-Year Plan 1959-1965 to concentrate on new thermal power stations based on natural gas, heavy fuel, oil, and cheap coal, in order to save time and to use investments most efficiently. This decision was substantiated at the 21st Congress of the CPSU [28] as follows:

> If the relation between investments for thermal power plants and hydropower plants is maintained, as it was established in the past, one would either have to reduce the planned commissioning of capacities, or one would have to increase the investments for the development of the energy sector by more than 20 billion Roubles*.

The four dams of the Mid-Angara system have subsequently been constructed since 1950 or are under construction, and will be completed by 1982 (Table 11).

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*20 billion Roubles (1959) is equal to 2 billion Roubles (1976).

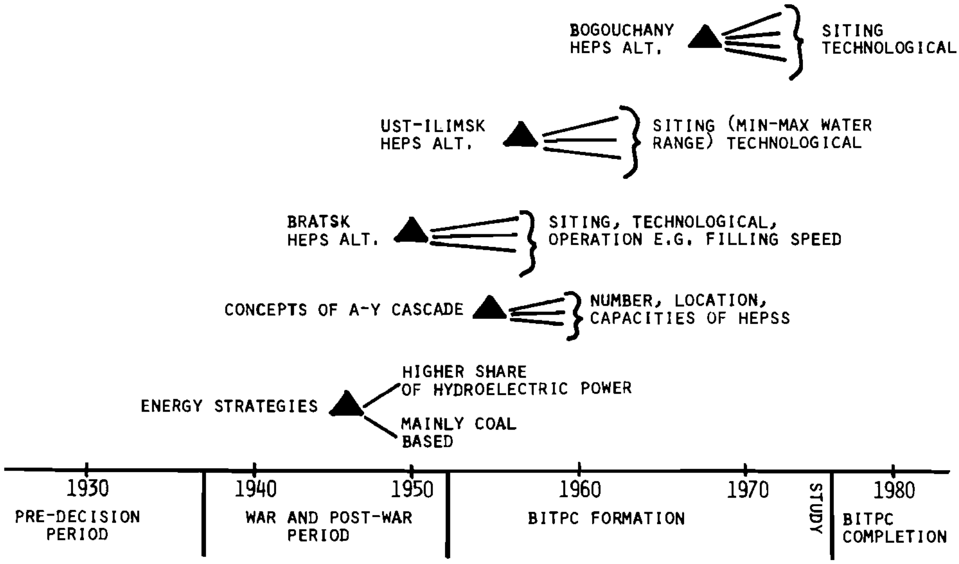

Figure 7. Power system alternatives.

Alternatives to siting, technological design and operation existed for each of the HEPSs of the system. For example, the location of the Ust-Ilimsk HEPS was changed by a few kilometers in order to improve construction conditions. The present construction site of the Bogouchany HEPS, which is 70 km upstream from the site, was considered first; the reason for the change was to keep an economically valuable area unflooded [14]. Both examples show that there was some freedom of choice which led to different siting variants.

In the predecision stage, other alternatives for the technological design and operation of the HEPSs existed. For example, in order to maximize the filling speed of the Bratsk reservoir, it would have been necessary to accept a temporary lowering of the Baikal level by up to five m, with severe consequences for Baikal flora and fauna. To profit Lake Baikal and to procure the timber in the Bratsk reservoir, this variant was not accepted and the filling speed was actually slowed down. The Bratsk HEPS reached its full capacity several months later [12,16].

The design of the Ust-Ilimsk reservoir originally allowed to run the power station with a reservoir regime of 10 m difference between maximum and minimum levels. After having coordinated the reservoir regime with the interests of fisheries, the maximum-minimum difference was reduced to 5 to 6 m [13].

Energy grid alternatives concern mainly the extension and the layout of the grid and the specific technology of transmission. The choice among these alternatives is determined by the potential use of energy from the HEPS ranging from concepts of long-range transmission to full local use of energy. Until 1960, long-range transmission by high voltage lines to the western parts of the USSR was considered a possible alternative to local use. Although long-range transmission was feasible, its efficiency was found to be substantially smaller when compared to local use, particularly for aluminium production with imported bauxites. The current technology would allow more efficient transmission of electricity; but efficiency calculations still favor local use, although the question is still being debated for the Bogouchany case. Perhaps future technologies of high voltage direct current transmission will provide alternatives to the present grid concept.

In the decisionmaking about grids, consideration had to be given to the fact that for some time after the completion of the HEPSs there would be no full use of the energy by local industries. For this reason, and to increase the flexibility, reliability, and exchange capacities of the Siberian ESS, integration of the HEPSs in the Siberian ESS was required.

Objectives and Criteria

All decisions mentioned above were taken in the light of criteria and objectives for the selection of one variant of development. These criteria are economic as well as technological, social, military, and environmental. For example, to choose the system, design, and site of power plants to be built, the following criteria were used to substantiate and to formalize the decisions [28]:

- Availability of natural energy resources in the respective region;
- Special natural, production and transportation conditions of the region;
- Available technologies;
- Required concentration of power capacity;
- Volume of investment;
- Period of construction;
- Efficiency of investment per unit of capacity;

- Efficiency of operation of the station;
- Environmental impacts;
- Allocation and function of the station in the energy grid.

Other factors such as construction conditions, available construction and engineering capacity, and national defence considerations may also be included.

Decisions on the Development of Production Sectors

This section will present our analysis of the decision processes in the development of various production sectors in the BITPC, including timber processing, iron ore, and aluminium production. In accordance with our three step logic of decision-making and planning of the BITPC (power, other production sectors, infrastructure) the decisions on the development of production sectors are considered on the basis of the previous decisions on power systems development.

Main Decision Points

Plans to develop energy-intensive production in the Angara Region date back to the 1920s (Figure 6). In the early plans of the Angarastroi project, two industrial complexes were envisaged in accordance with the Angara Cascade: one at Irkutsk-Cheremkovo Region, the other in the Mid-Angara Region.

The Angara Bureau of 1934 considered the use of timber and mineral resources of the Mid-Angara Region and the following industries: ferrous and nonferrous metallurgy, production of synthetic materials, production of liquid fuel from coal, chemicals, and aluminium [12].

As a result of these plans, the first real decision was to develop a "pioneer" industry in the northeast of Irkutsk, based mainly on the thermal energy produced with Cheremkhovo coal. Its main development took place in the pre-war period (see Figure 7); this is now called the Irkutsk-Cheremkhovo TPC.

The preparatory work for the industrial development of the Mid-Angara Region was carried out by Gidroprojekt in the early 1950s. Besides specifying capacities, location, and other aspects of the Angara Cascade, Gidroprojekt worked out schemes for exploiting the timber and iron ore resources, and planned the construction of energy-intensive industries such as aluminium production. After the decision to construct Bratsk in 1954, the first industrial activities began with the setting up of a large number of forestry centers for the woodfelling operations in the future reservoir of the Bratsk dam.

On the basis of the Gidroprojekt plans, the 21st Congress of the CPSU in 1956 decided to construct the Korshunovo iron ore plant in Shelesnogorsk and the Bratsk timber plant during the seven year period 1958-1965. Also, the construction of the Bratsk aluminium plant was considered.

The construction of the Bratsk timber plant began in 1958 and was essentially completed in 1966. The timber complex produces 1 million t/a of wood products, including cellulose pulp, liner board pulp, bleached pulp and viscose cellulose. It draws on an area of 30,000 km^2 of woods, enough for 100 years supply corresponding roughly to the Siberian growing cycle.

Construction of the Korshunovo iron ore plant also began in 1958 and was completed between 1965-1967. At present, its capacity is over 6 million t/a of iron ore concentrate (in 1974 this was 5 million t) [1]. These iron ore concentrates are shipped to West Siberian metallurgical works.

By decree of the USSR Council of Ministers in 1956, it was decided to set up a unified construction organization, Bratskgesstroi, responsible for the construction of all industrial plants, dams, and settlements of the BITPC. Bratskgesstroi set up a large construction industry with local production of building materials such as ferro concrete, fittings, keramzit sands, and crushed stone [1]. Bratskgesstroi currently employs about 80,000 workers, and its annual program in 1977 amounted to 400 million Roubles of construction work. The building material enterprises produced 100 million Roubles worth of products.

In the early 1960s, a meat packing and a dairy plant were constructed. Construction of the Bratsk aluminium plant began in 1961, and the first units began operating in 1966. The plant is one of the largest in the world in terms of annual production capacity and is still expanding. It produces aluminium ingots, alloy ingots, rolled elements, pipes, etc.

The decision to build the Ust-Ilimsk cellulose plant was adopted by the 24th Congress of the CPSU. Construction began in 1974 and is to be completed by 1982. The production pattern and capacities are to be similar to those of the Bratsk cellulose plant.

Alternatives

The most fundamental alternatives regarding the development of the production sectors in the BITPC are the type of production specialization and the character of the complex development (Figure 8). One alternative for the Bratsk industrial node was to transport energy to the Western part of the country, where industrial facilities existed or could be built under more favorable climatic and population conditions. Between this alternative and the alternative to fully use the local energy resources for

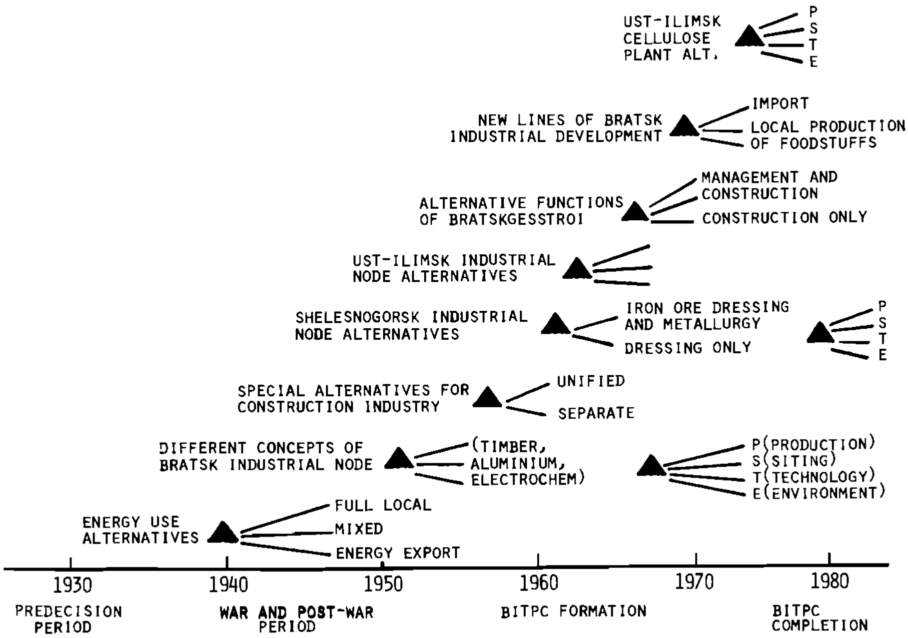

Figure 8. Production sector development alternatives.

locally settled energy-intensive industries, there exists a whole span of mixed alternatives. Other alternatives concern the selection of the type of industries that are to be settled. In the early schemes some industrial production was considered that has not yet been realized. Among them are the construction of a chemical industry (nitrohydrogenous compounds, chloride production) which was considered in the work of the Angara Bureau [12].

Finally, alternatives in the production sector concern the capacities and the degree of further processing of the timber, aluminium, and iron ore plants. It was considered conceivable, for example, to enlarge the capacities of the Bratsk aluminium plant even further [13], or to further process aluminium products from the plant. Similarly, there exist alternatives for further processing timber products (higher quality viscose cellulose, paper products), or to process iron ore concentrates in possible local metallurgical works. In fact, construction of metallurgical works on the BITPC territory was considered an alternative to the Taishet variant [12].

For the Bratsk industrial node, further alternatives arose in the mid-1960s (see Figure 6) when decisions had to be made about the local production of auxiliary products and foodstuff for the settlements. The main alternative to local production was to import heating elements, textiles, foodstuff, etc.

The decision to build up a unified construction industry had several alternatives. On one hand, the question was whether to leave the construction activities as a separate responsibility of the various Ministries. On the other hand, alternatives existed about various schemes for developing a unified construction agency (local production of construction materials versus import). In the early 1960s, several alternatives existed for the functions of Bratskgesstroi (Figure 8). For example, it was conceivable that Bratskgesstroi, already responsible for various management functions in the BITPC (housing, shop management) would expand or reduce these activities [13].

On the next level, we can consider various alternatives for the development of the main industrial plants (Bratsk timber, Bratsk aluminium, Korshunovo iron ore, Ust-Ilimsk timber). These alternatives vary mainly for production structure, technology, sites, and environmental protection.

With regard to *production structure* (capacity, type of products, degree of further processing), some alternatives were already considered. As far as *technological alternatives* are concerned, our knowledge is rather limited. There are several examples of siting alternatives. For example, the Bratsk aluminium plant originally was to be located closer to the settlements (in Energetik). The present site had been reserved for future possible industrial plants, but was chosen as a location for the aluminium plant in 1960 [13]. Alternatives in the environmental protection aspects are discussed elsewhere in this Report.

Objectives and Criteria

National and regional level objectives for evaluating alternative strategies and variants in the production sector have already been mentioned. At several places in [17] and in Party Congress materials, high level goals such as raising the standard of living, raising the efficiency of production, minimizing investment costs are laid out. There are several intermediate layers of objectives, some formulated as tasks for the BITPC in the Bratsk-Ilimsk papers, among them: providing the national economy with cheap electricity and energy-intensive products, improving the regional standard of living, and creating favorable conditions for a further expansion of the East Siberian industrial development.

If one looks at the practical criteria against which the types of decisions and alternatives identified were evaluated, we get removed from these general objectives. The overwhelming criterion, coming up in many choices, is, of course, efficiency of production. But this objective includes several factors, if one considers, for example, the inclusion of investments for environmental protection, investments for settlements and infrastructure, or transportation costs. We were told that the energy transport alternative mentioned earlier was at the borderline of efficiency. We were also told that transporting aluminium raw materials (mainly bauxites) to the energy source is more efficient than transmitting electricity to removed aluminium plants that had easy access to bauxites.

The importance of settlement and transportation costs is demonstrated by Bandman [3] who claims that if no sufficient regional bauxite deposits are discovered, it may be inefficient to locate another aluminium plant at the Bogouchany dam. In this case a transport strategy for the Bogouchany electricity may have to be considered, since local energy consumption is already sufficiently supplied.

Manpower shortage is an important criterion in the selection of the degree of further processing materials from the timber, iron ore, and aluminium plants. Further aluminium processing, paper production, etc., seems inefficient because of its labor-intensive character. The balance of male and female workers is an important consideration for building light industries in the BITPC (textile, etc.). One major reason for developing light industries is that they provide employment for female labor [10].

The role of environmental criteria can be seen in various decisions as, for example, the location of the aluminium plant or the installation of various purification devices in the Bratsk timber and aluminium plants. Another criterion for the relatively high degree of purification of the processed water from the timber plant was to maintain high quality water downstream the Angara for further use by the Ust-Ilimsk timber plant.

Consideration of future developments of East Siberia is another important aspect often mentioned as a criterion for decisionmaking. The decision to build a unified construction industry and organization was clearly motivated by such long-term considerations as further development of the Angara Cascade, further industrial development in the whole BITPC area, and BAM construction.

Development of the BITPC Infrastructure

In the previously described planning and decisionmaking logic, the BITPC infrastructure development is the last step following power development and development of the production sectors. The plans and decisions for infrastructure development were mainly generated by the need to provide roads and other transportation means for the already planned dams and industrial plants, and to provide housing and other accommodation for workers.

Basic Decisions

Long before the actual decisions on the Angara Cascade were made or implemented, the construction of a railway from Taishet via Bratsk to Ust-Kut was decided (Figure 9). Construction began in 1946, and the connection to Bratsk was established in 1949. After the 19th Congress of the CPSU had decided to build the Bratsk HEPS, one of the first follow-up decisions was the construction of a road to the Bratsk dam. This road was built between 1954 and 1956.

Early settlements of construction workers began in 1954 in Bratsk. Construction of Bratsk city proper began in 1957, and the main plans are now realized (the population in 1975 was 250,000). The town of Shelesnogorsk was constructed in a similar time period (the population in 1975 was about 30,000).

The decision to build the Ust-Ilimsk HEPS required the construction of transportation facilities to the dam site. Beginning in 1961, the waterway to Ust-Ilimsk was cleared, and a railway line from Krevtubaya to Ust-Ilimsk was constructed. In addition, a road from Bratsk to Ust-Ilimsk was built.

Early settlements in Ust-Ilimsk began in 1962, but actual construction of Ust-Ilimsk proper did not begin before 1970. Today the left bank city development of Ust-Ilimsk is in progress, and the site for the larger right bank development has been cleared. (The population in 1975 was more than 30,000.)

The most recent infrastructure developments were the beginning of the construction of the road to Bogouchany (which branches off the Bratsk-Ust-Ilimsk road), and, of course, the continuation of the BAM beyond Ust-Kut, which began in 1974. All these developments, including the main structures for Bogouchany city, will be completed in the early 1980s (see Figure 9).

Alternatives

Infrastructure development was considered at the same time as the series of decisions on power and industrial development, with somewhat more limited freedom of choice. For example, the decision to build a dam in Ust-Ilimsk made the construction of the road from Bratsk to Ust-Ilimsk necessary, and there were probably only few alternatives about, say, the trace or the construction technology.

In general, with respect to transportation modes, the alternatives are clearly water, rail, road and air. Usually, all four alternatives were realized (Bratsk, Ust-Ilimsk, Bogouchany, Shelesnogorsk). There is no railway yet to Bogouchany, but it may be necessary to build rail transport if there will be industrial settlements near the Bogouchany dam.

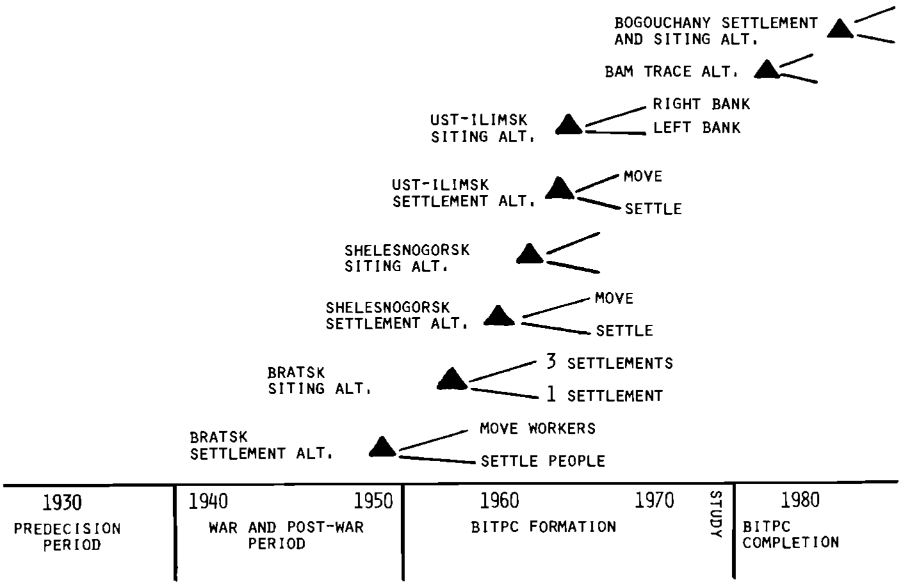

Figure 9. Infrastructure development alternative.

Within each transportation mode there exist several mode specific alternatives (e.g. siting of airports, size of airports, trace of roads, and construction technology). We know little about such alternatives, and assume that their selection was mainly dictated by necessity.

Time schedules of infrastructure development are, of course, very crucial alternatives. Several documents refer to the importance of selecting an optimal time schedule in the construction of roads and settlements. Roads must be ready for timber transport, settlements must be ready for arriving workers, etc.

With respect to settlement alternatives, there was one basic decision to be made: whether to settle or not. It was a conceivable alternative to move construction workers to the building sites and withdraw them again after construction. (This strategy was followed in the mid-Ob development.) Such an alternative suggests itself in cases of sparse population and severe climatic conditions as in Bratsk. The decision for Bratsk and Ust-Ilimsk was to settle workers. In fact, only about 50 percent of the construction workers moved on to Ust-Ilimsk, the remaining ones stayed in Bratsk.

The next alternatives in settlement decisions concern siting. Here we know of more concrete alternatives. In Bratsk, for example, the question was whether to build one unified city or to build three cities. The three cities concept that has been realized enabled shorter commutes to the industrial plants, but also meant increases in capital costs, and less unity and comfort. Bratskgesstroi had originally argued for a unified city near today's Energetik. This plan was not realized because of transportation problems. Today, the transportation problem could be solved more efficiently, and one would prefer a unified city.

Similar arguments have led to the plan to build a unified city on the right river bank in Ust-Ilimsk. However, there were some constraints imposed by the left bank settlements of early construction workers. The current plan is to build a large city on the right side of the Angara, but the left side development is also growing.

Final alternatives, after the siting decisions have been made, concern the size, design, and construction technology. We know little about such alternatives, but there were some considerations about the quality of building materials, recreation sites, etc.

Objectives and Criteria

Much of what has been said before about the objectives and criteria in the evaluation of power and industrial development alternatives also holds for the evaluation of infrastructure alternatives. Over-riding consideration is given to efficiency criteria. But as some of the settlement decisions show, these efficiency considerations include several often conflicting criteria. Most of these criteria were discussed in the previous section and will not be repeated here. In more general terms, objectives and efficiency criteria will also be discussed later in this paper.

As siting decisions show, there are some conflicting objectives between environmental goals (e.g. clean air in settlements), design goals (e.g. proximity to water resources), and cost considerations. Housing construction costs also had to be carefully weighed against quality considerations, a question that is particularly important if one considers the need for attracting workers through quality housing.

In road and other transportation construction, the main criteria were to meet the existing constraints of future sites for dams and industrial developments.

The Future Development of BITPC

The evolution of Bratsk-Ilimsk has been and will continue to be influenced by the development of East Siberia. At the end of the Second World War, as noted earlier, priority was given to constructing the link in the BAM that connected Bratsk with Taishet and the West. Now that work on BAM is progressing eastward, local planning bodies continue to study intensively the opportunities for Bratsk to become an industrial support center. One approach has been to try to demonstrate that additional investments in one industrial complex or node, such as Bratsk, help to reduce costs for developing others to be located in adjoining territories, as for example the Ust-Ilimsk complex 250 km to the north, or Bogouchany to the northwest, or Zelesnogorsk to the east. To the extent that Bratsk may serve, at least initially, as a base for construction operations or as a transportation hub for these new implementations, some economies can be demonstrated.

Paralleling this concept of using Bratsk-Ilimsk as a support center is the concept that the long-term viability of Siberian development requires a balance of growth. Development of the energy and raw material sectors alone cannot create the kinds of self-contained communities in which women as well as men, old people as well as young, can achieve a high level of social and economic satisfaction. Secondary manufacturing and service operations must be added to provide a balanced industrial and social environment.

This concept of balanced growth is at variance with the traditional approach in which investment decisions are based on minimization of direct costs and of labor utilization, based in turn on the principle of specialization of labor. On the other hand, more balanced Siberian development is held to be consistent with the broader--although operationally more difficult--concept of promotion of the common good. The argument here is that the welfare of the people of Siberia is a necessary element over the long run to the welfare of the people of the USSR as a whole. The question of how these concepts are to be reconciled is highly complex and occupies at the moment an important place in the policy evaluation programs of a variety of planning and research organizations.

The future development of Bratsk-Ilimsk has to be scheduled in three directions. The first is to *fill in the structure with elements complementary to the present ones* with a view to ensuring truly complex development. This may include complementing the existing raw material production by more advanced manufacturing technologies.

The second is the *creation and further development of such branches of industry that can be used for creating other centers of industrial activity in East Siberia,* in particular along the BAM or in the Upper Lena. This involves the development of branches for construction materials, foodstuffs, manufacturing of special equipment, etc.

The third relates to *the expansion of Bratsk-Ilimsk in connection with the construction of the Bogouchany HEPS*. The resources for the construction of this station are transported on a large scale from the BITPC under the planning and management of Bratskgesstroi. The power line and road will be built from Bratsk. Therefore, it is possible that the BITPC will expand more widely than was planned at the beginning of its development. The future of the BITPC as a TPC depends first of all on the answers to these questions.

PROBLEMS AND METHODS OF SELECTING EFFICIENT ALTERNATIVES

Methodological Problems

The decisions taken during the process of preparing and forming the BITPC development, which were analyzed above, include several steps of selection of efficient variants and strategies. These include strategies of the East Siberian development, variants of the BITPC formation as a whole, and design, construction, and settlement variants.

The choice opportunity and the need to select variants and strategies for socioeconomic systems such as the BITPC is generally caused by the following factors:

- Different sets of goals and social needs which reflect different priorities and preferences;
- Different paths for general economic growth, differing in speed, structure and direction of growth;
- Different ways of utilizing natural resources and the natural environment;
- Different ways of reacting to changing external economic conditions, as different variants of specializations and different regional input and output variants;
- Different technological solutions or technological options, reflections of national and regional technological policies;
- Different possibilities for the siting of facilities and of settlements;
- Different sequence and duration of activities, for example, as a result of different investment policies;

- Different ways to meet manpower needs;
- Different modes to adapt skills, branch structure, and manpower structure to a changing economic and technological structure.

Our analysis of the multistage, multilevel selection process of efficient variants and strategies for the BITPC formation showed many methodological problems, some of which have been solved. These problems, particularly in the decision preparation, are summarized below.

At the same time more than one decision criterion exists. The criteria reflect multiple objectives which are neither completely given at the time the planning process starts, nor are they fixed over time. The determination of objectives and their relative priorities is usually a result of the planning process rather than its starting point. It is only possible to determine objectives when the requirements and consequences of each variant and strategy are known. This means that the goal setting and selection process is an iterative process with a multiplicity of changing parameters.

Not all criteria appear in a quantified or quantifiable form.

Different decision-makers and decisionmaking bodies at different organizational levels take part in the decision process. They represent partially different interests and respective sets of goals.

Not all decisions can be taken simultaneously. The decision process through all participating levels is sequential over a certain time span. New aspects have to be taken into consideration as time passes, making the decision process a learning process.

Decisions have to be made in the light of uncertainty about future resources, future needs, and future developments of the national and international market.

Complex socioeconomic systems such as the BITPC do not possess only one clearly defined optimum. They permanently change themselves and their environment in reaction to changing internal and external conditions and in fulfillment of a set of hierarchically structured goals and objectives, which in turn also change over time. Socioeconomic systems have to be understood and managed as systems in the state of dynamic adaptability, as learning systems. They are composed of self-adapting and learning subsystems connected to each other by coordination relations and to systems of a higher or lower level by relations of subordination.

The multistage, multilevel selection process of efficient variants and strategies of the BITPC formation and development does not yet follow completely formalized rules. The predecision phase can merely be described as an interaction of formalized calculations of efficiency and subjective evaluation of effects.

Considering the complexity of the problem of selecting efficient variants, and considering the lack of fully formalized procedures to deal with this complexity, it is not surprising that a retrospective analysis of the selection process is exceedingly difficult.

The first problems arise in the stages of decisionmaking that precede the actual evaluation and selection, namely the stages of formulating alternatives and objectives. Ideally, one would like to describe alternatives in terms of decision trees that show the initial possible actions, follow-up actions, future conceivable events, and final consequences. Similarly, one would like to describe goals and objectives in a logical goal tree with general supergoals on top, medium-level objectives in the middle, and operational attributes or evaluation criteria at the bottom. We had previously made an attempt to retrospectively study the BITPC strategic decisionmaking in such a manner [17], but it proved unsatisfactory, because of a lack of information and biases in retrospective assessment of alternatives and goals.

When it comes to the selection process, the retrospective analysis is limited mainly by the elements of subjective evaluation that is part of the process. There is absolutely no hope to recover retrospectively the trade-offs, time preferences, etc., that are implicit in these subjective evaluations.

The retrospective analysis of the selection process is on firmest ground where formal techniques and models have been applied for evaluation and selection. It is therefore quite natural that we concentrate in the following on these formal aspects of the selection process. Naturally the more we go into the past, in the BITPC development, the fewer formal models, methods, and algorithms for evaluation we found. Our analysis will therefore concentrate on the more recent developments of formal selection of variants for the BITPC development, and it will discuss some new models and techniques for evaluation and selection.

The Logic of the Selection Process

The selection of efficient variants and strategies for all stages of the BITPC formation and construction is a part of a decisionmaking process, which has several dimensions. These are as follows:

- The logical interdependence of decisions on different levels and with different systems aspects;

- The time horizon and sequence of decisions;
- The interaction of decisionmaking organizational units on different levels of the hierarchy and with different specializations.

Logical Interdependence

The logical interdependence comprises decisions on sectorial and territorial input-output relations, siting and land use, transportation relations, proportions between production sectors and services, population and manpower structure, financial relations, and others. These are shown in Figure 10. The procedures and instruments for handling these interdependencies during the planning and decisionmaking process of the USSR are described in the methodological instruction for planning of the national economy [9].

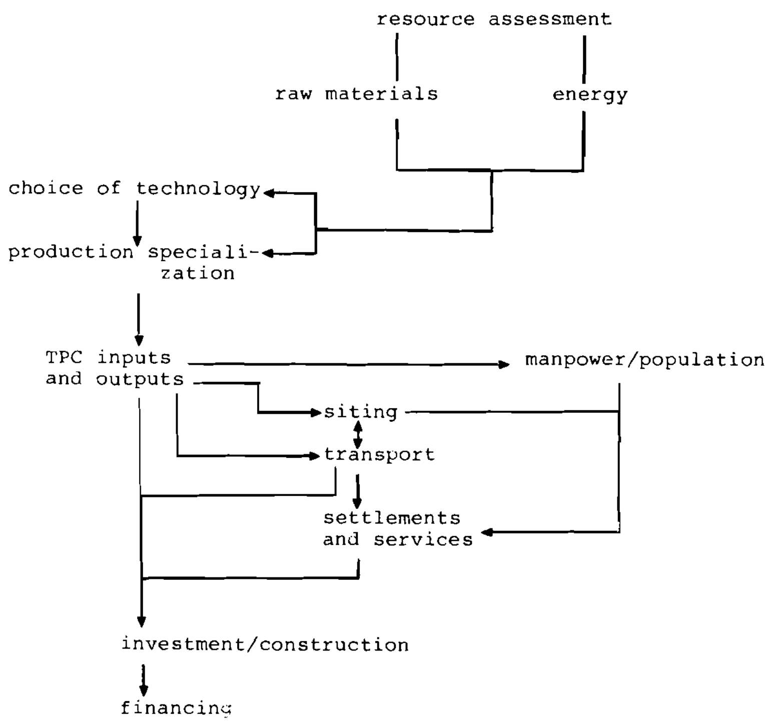

Figure 10. Logical interdependencies of decisions on BITPC formation.

These instructions are subdivided into the following sections:

- Planning of development of science and technology;
- Planning of increase of economic efficiency of social production;
- Planning of industrial production;
- Planning of agriculture and forestry;
- Planning of transport and telecommunications;
- Planning of capital investments, design, and construction;
- Planning of geological prospecting;
- Planning of manpower;
- Planning of costs, surplus, and rentability;
- Planning to raise the standard of living of the population;
- Planning of domestic trade;
- Planning of public utilities and social services;
- Planning of national education, cultural activities and public health services;
- Planning of the development of the economy of the union Republics;
- Planning of environmental protection and the efficient utilization of natural resources;
- Planning of international economic relations;
- Planning the balance of the national economy of the USSR and of the union Republics;
- Input-output table and distribution of products in the national economy;
- Material balances and plans of distribution;
- Elaboration and application of normatives of expenditure and of production stocks of material resources in industry and construction;

- Planning of improvement of management of the national economy;

- Classification of sectors of the national economy.

These instructions describe the key indicators, algorithms and models used for plan preparation in each sector and region, and include the tools for regional and TPC planning. (A detailed analysis of the model system for regional and TPC development planning is given elsewhere in this Report.) They are the framework for preplanning research and modeling for national embedding and formation of a TPC. Bandman [4] has described the logical steps of scientific preparation of a new TPC. Figure 11 shows the principle structure of a model system for optimizing production and spatial structure of a region and its TPCs [4].

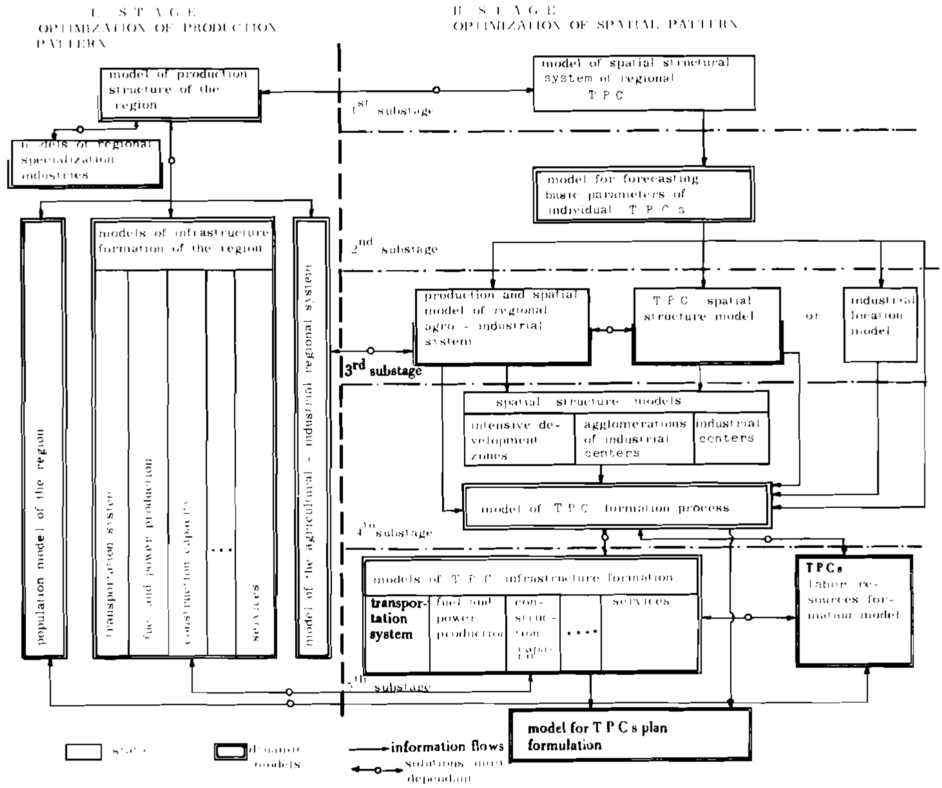

Figure 11. Model system for optimization or production and spatial structure

Source: [11, p. 282]

Time Interdependence

The time horizon and sequence of decisions is another aspect of the selection process of efficient variants and strategies of TPC formation and construction.

All previous decisions of the BITPC have been taken during the last 30 years. Obviously, the selection of variants of technological design details for new plants can be taken only if the specialization of the respective region or TPC is decided upon, i.e. each discussion dealing with the selection of efficient variants and strategies has to be put into a sequence of decisions with different time horizons (see Figure 12). During the long-range construction process of a TPC, new international, national, and regional economic, political, and technological conditions arise which lead to changes, adjustments, and corrections of variants and strategies of development.

The first aspect of the time horizon and sequence of decisions is taken care of by organizations of the planning process and the interaction between long-, medium- and short-range planning; this subject is treated in detail elsewhere in this Report. The second aspect is reflected in the actual conflicts and sequence of decisions on the BITPC formation and construction over the past 30 years.

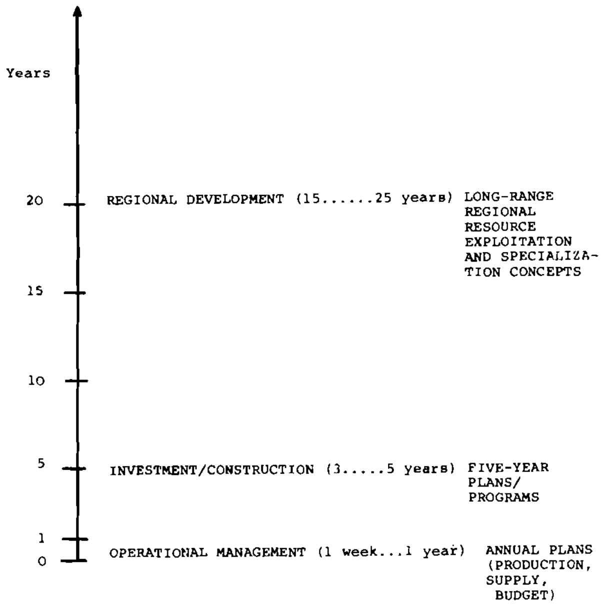

Figure 12. Time horizons of decisions on TPC formation.

Interdependencies of Decisionmaking Units

The third logical dimension of the TPC variant/strategy selection process is the organizational structure and interaction of decisionmaking bodies.

The BITPC is located in a part of the Irkutsk Oblast, and is subdivided into the districts of Bratsk, Ust-Ilimsk, and Shelesnogorsk. Looking at the managerial structure in relation to the territorial production complex, we can arrive at some important observations (Figure 13). One of these is that there is no special managerial unit dealing with the operational management of the complex. The TPC approach was mainly used for planning purposes. The operational management in the case of Bratsk-Ilimsk lies in the hands of the Irkutsk soviet and its department and in the hands of the region and city soviets responsible for parts of the TPC area. Also, Bratskgesstroi, a construction enterprise with 80,000 employees, played an important role during the construction period by coordinating all activities for the development of the TPC. This results in the need for strong regional coordination between several managerial units.

This need is emphasized when we consider that many activities within this TPC are influenced by managerial units located outside the region. This is caused by the fact that the major enterprises are centrally planned and supervised and in the case of the Ust-Ilimsk Cellulose Combinate there is some international influence as well.

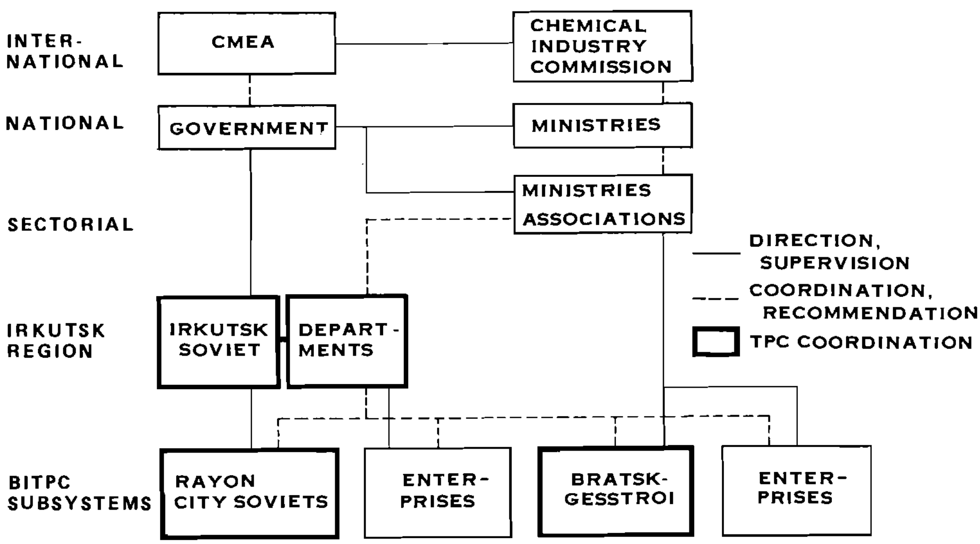

Figure 13. Management of the BITPC.

The construction of this enterprise is the joint activity of several socialist countries, and was initiated and organized by the CMEA and its Commission for the Chemical Industry.

Methods of Selection

This section deals with some formal aspects of the selection of efficient variants and strategies for the BITPC formation, which have been analyzed above [7]. Although we often refer to selection processes in the BITPC, the main stress is on general methods for selecting good efficient variants in development as applied in the USSR, many of which also found application in the decision processes for the BITPC.

We will first address the persistent problem in selection, namely that of formulating and operationalizing goals. Then we will discuss methods of efficiency calculations for program evaluation, and we will outline the ideas of several Soviet models to deal with the main interdependencies in evaluation: physical, spatial, and time dependencies. Finally, we will discuss some aspects of uncertainty handling in the planning process.

Goal Identification

Complex development programs have usually multiple and conflicting goals. Unidimensional criteria, such as minimization of expenditures, are used sometimes as the main criterion for evaluation, but they only hide in their implicit inclusion of several cost components (costs for environmental protection, costs for infrastructure development) the multidimensional nature of the problem and the real trade-offs that have to be made.

For an efficiency evaluation (be it in terms of aggregating several criteria into one through cost or other), it is important to spell out the main goals and objectives that are to be achieved. One method to identify such goals and objectives is the goal tree approach. Currently, two principal ways of goal tree construction are known: construction by logical explication of supergoals, and construction by taskwise specification of supergoals.

In *logical explications of supergoals* one specifies at increasing levels of detail what is meant by the general supergoal, its various subgoals, etc. For example, the general goal to improve the well-being of the people of a region could be explicated as improving the material and the cultural well-being. Further disaggregation could define material well-being, for example, by quality of housing, level of income, and number of doctors per capita. The lowest level of such explication should be operational (measurable) indicators such as square feet of housing area per capita, which can be transferred into quantified plan-tasks.

Specifying goals by taskwise disaggregation defines at increasing levels of detail those tasks that must be fulfilled in order to achieve intermediate objectives and supergoals. For example, if the supergoal is to improve the material and cultural well-being of the people in a region, one may consider the tasks of building new apartments, improving infrastructure, etc. Such disaggregation ends up--instead of indicators--with very specific subtasks such as building a road.

Several research institutes in the USSR are working on the problem of goal tree construction as part of the development of the method of "goal oriented program planning".

During our visit, we found three institutes that were particularly concerned with goal definition problems:

- Central Economic Mathematical Institute of the USSR Academy of Sciences (CEMI);

- Central Economic Research Institute of GOSPLAN RSFSR Planning Commission (CERI);

- Institute of Economics and Industrial Engineering, Siberian Branch of the USSR Academy of Sciences (IEOIP).

The CEMI approach attempts to realize goal tree construction along the lines of a logical specification outlined before [7,25]. In the first step, such a goal tree is constructed with operational indicators at the bottom. These indicators are then translated into "technical normatives" that define the final demand over time. Usual balance methods can then be used to evaluate the feasibility of variants, or to revise the normatives, if all variants are feasible. Also, a weighing function can be defined to further evaluate feasible variants. Here we will only describe the actual goal tree construction approach. The further evaluation steps envisaged by CEMI will be discussed later, when we talk about the handling of physical interdependencies in evaluation and selection.

Starting with the rejection of the idea that "viability" or "survival" should be the ultimate goal of a socioeconomic system, four main supergoals are defined in the CEMI approach (see Figure 14):

1. Raise the welfare of the members of the socialist society;

2. Strengthen and develop the system of social relations;

3. Guarantee a safe development;

4. Develop the potential for the future.

Examples for specifications of type 1 objectives are satisfaction of material needs, satisfaction of social needs, and

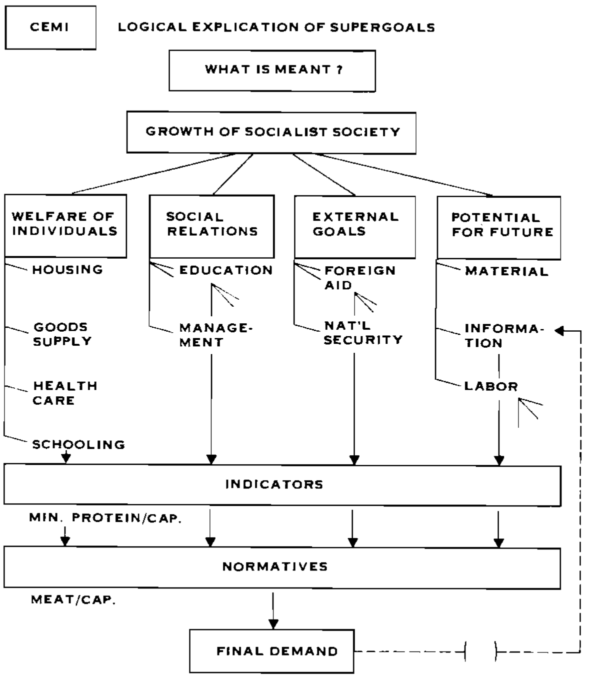

Figure 14.

guarantee of access to material and social welfare and services. These objectives are specified down to a level of, for example, satisfaction of needs for transportation and movement, and finally attributes such as quality of city transportation.

Examples of objectives falling into type 2 are improvement of the country's management system, development of the personality of the members of society, and improvement of social structure of society.

Examples for type 3 objectives are national security goals, foreign aid, etc. (also environmental objectives as far as they are external to the actual system). Examples of the last goal category are the development of the scientific and technological potential, development of the resources of production means, development of people as members of society and as labor resources, development of the state of the natural ecological environment and of natural resources, and development of resources of nonproduction nature.

On the lowest level of this goal tree are operational indicators such as the amount of spendable income and size of dwellings. These indicators are once more translated into production related technical normatives that define final demand, such as amount of meat per capita per week, and number of teachers per schoolchildren. Program variants are then evaluated against the degree to which they achieve these normatives. The actual procedure CEMI suggests for this evaluation will be discussed in the next section.

This approach by CEMI is still at a research stage. The goal trees are not fully constructed, but there are several attempts to logically structure the trees from the top, and to accumulate statistics, indicators, and measures that could be used to fill in the tree from the bottom. Critiques of the approach claim that it is unrealistic, because most goals cannot be operationalized. They prefer a taskwise specification of objectives as a more practical alternative.

Taskwise disaggregation of goals is represented in the work by Orlov (IEOIP) and in the work by Moshin/Kozlov (CERI). An example of Orlov's approach is documented in Dubnov and Orlov [6]. Their problem was to specify research tasks for the development of the Mid-Ob industrial complex from the goals for the complex development. The levels of their task-specific goal tree are as follows:

- National economic tasks;
- Regional goals;
- General contours of the directions of activities;
- Types of activities;
- Methods for realizing these activities;
- System demands and means for realization;
- Alternative ways of creating systems and means;
- Directions of research (alternatives).

Thus national economic objectives provide the framework and constraints from which regional development goals are derived. These are in turn translated through several layers of tasks and task elements that are needed to achieve them. Finally, the actual (research) alternatives are derived from the possibilities to realize the activities on the lowest level.

CERI's approach to task specification of goals is slightly different. Here alternatives that are to be evaluated are time consequences of activities in the development of a region or TPC. This approach starts with supergoals, which are really tasks (see Figure 15): optimal formation of the complex of material production, and optimal formation of the material and technical prerequisites for living conditions. These general tasks are then disaggregated into branch subtasks down to the enterprise level or the level of specific research or construction activities.

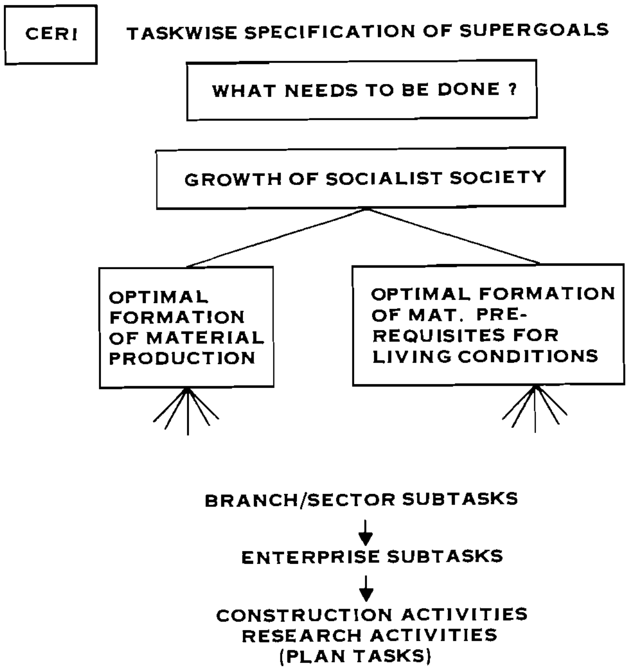

Figure 15.

Critiques of the taskwise specification argue that it implies a restriction of possible alternatives. What is left after a taskwise specification of general objectives is a selection of optimal timing of the derived activities with criteria that are external to the taskwise goal system (e.g. minimum expenditure).

The various attempts that are presently made in the USSR to construct goal trees reflect the need to substantiate the principle of goal oriented planning. Difficulties in goal identification through goal trees are widely recognized. Among them are the following:

- Different principles of goal tree construction (which supergoals to start with, which type of disaggregation to use, which logic of specification to follow);

- Difficulties in operationalizing goals;

- Difficulties in translating indicator oriented goal trees at the lowest level into production relevant normatives;

- Difficulties in avoiding restrictions of alternatives in taskwise specification of goals.

Efficiency Evaluation

The planning and evaluation program and plan efficiency is an integral part of the USSR planning system. It is done by using specific indicators on each echelon of decisionmaking, related to the national economy as a whole, the Soviet Republics, the sectors of sectorial production, and the enterprises. These indicators are fixed in the methodological regulations for national economic planning [9]. The principle structure of this indicator system for planning efficiency is as follows:

- Growth rates of national income and production;
- Output per one unit of fixed assets, circulating funds, costs of material, and wages;
- Rentability (revenue per unit of capital and current costs);
- Costs per unit of production;
- Growth rates of labor productivity;
- Growth caused by increase of labor productivity;
- Savings of labor compared with the previous year;
- Capital rentability.

These indicators are also the main tools of program evaluation through accounting of expenditures and benefits and comparing variants on this basis.

Independent subgoals such as environmental protection are taken into account by an evaluation of additional expenditure necessary for their achievement. For example, costs for reforestation or land reclamation are included in the calculation of total expenditures.

Costs for settlements in virgin territory and regions with severe conditions are taken into account as well as possible increased costs of construction and operation of facilities according to coefficients set by the USSR Council of Ministers. These coefficients are different in the various economic zones of the USSR. (Economic zones are, for example, the zone of the Trans-Siberian railway, the zone of the north and the BAM, and the zone of the far north and the mountains of Sayan.) In Siberia, these coefficients are about 20 percent higher than in the western part of the country.

Comparison of variants is done on the basis of the calculated flows of expenditures. Various criteria are possible, such as payback period, internal rate of return, or net present value. Net present value calculations are based in the USSR on a discount rate of 12 percent, which reflects the efficiency of investment.

Handling Interdependencies

In the evaluation of alternatives, variants, and strategies for TPCs, several important interdependencies between activities have to be taken into account: physical, spatial, and time interdependencies.

Physical interdependencies result from interactions between production activities, and are usually represented by physical flows of products. In modeling and evaluation, they are usually handled by balance models, linear programming models, or dynamic programming models (Figure 16). Spatial interdependencies stem from the pattern of location of industrial plants and settlements and their transportation links. They are handled in models for optimal spatial allocation and models for site evaluation. Time dependencies are a result of the interactions between the various activities in construction and production over time. In modeling and evaluation, they are handled usually by network models such as critical path analysis. The model system of the IEOIP [2] for TPC planning is a rigorous approach to coping with such interdependencies in the evaluation of variants. This model system for spatial and physical interdependency handling is used in the preplanning stage for TPCs to elaborate and evaluate variants of the TPC development. (The system is discussed elsewhere in this Report, and is described in detail in [11, p. 277] and IEOIP papers.)

An interesting idea to handle physical interdependencies in connection with the goal tree approach has been presented by CEMI (see Figure 17). Once the goal tree indicators are translated into technical normatives that define final demand over time, production variants can be analyzed by usual input-output methods to assess the feasibility of the variants with respect to these normatives, or to re-assess the normatives themselves (if no variant proves feasible). For further evaluation of feasible variants CEMI suggests a weighting approach that constructs an evaluation function for variants on the basis of weighted normatives.

Time interdependencies are typically analyzed with network or critical path models. In CERI and the Irkutsk branch of the IEOIP, we have been presented with various models of this type for timing activities in TPC development.

In IEOIP, we were presented with a network model combined with a regional optimization model to optimize construction activities in the TPC development. This combined model has as its main decision parameters time, amount of supply, and volume of housing. The model has been applied in several experimental cases, and its retrospective application to construction activities in the Bratsk TPC showed that it could have achieved a 20 percent reduction of expenditures.

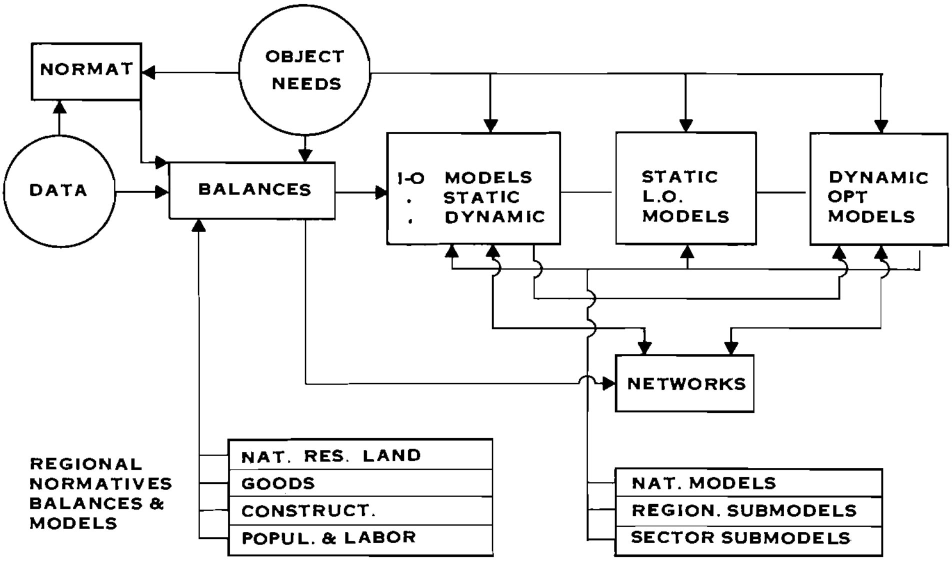

Figure 16.

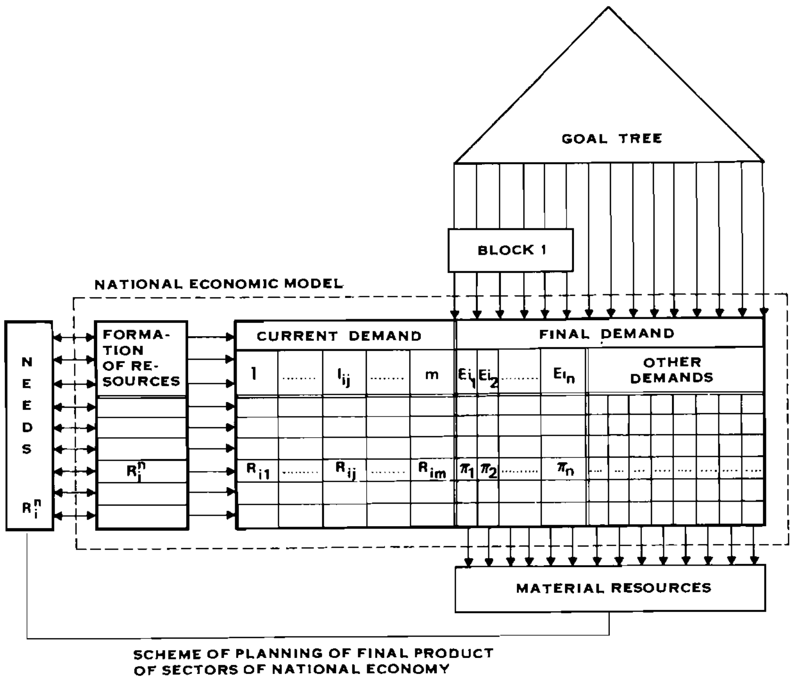

Figure 17. Connection of goal tree approach with input-output models (CEMI).

These network models as well as the previously mentioned models for optimizing spatial and production patterns are considered preplanning tools.

Summary of Findings and Conclusions

Our study of the BITPC decisionmaking and selection of efficient variants and strategies could extract several facts, problems, and methodologies which might be of interest when handling comparable large-scale development programs. These include:

- Findings about the special physical, economic, and social features of the BITPC;
- Findings about typical or specific problems that were encountered;
- Findings about solution approaches and methodologies that dealt with these problems.

These findings are summarized below.

Special Features

The development of the BITPC was based on a central decision and will be dependent on central decisions in the future. National needs and the embedding in the national economy were predominant factors in the initial stage of elaborating the BITPC concept. Specialization of hydroelectric power, timber, cellulose, and aluminium production was derived from national goals and was based on a concentration of national means and efforts. From this point of view, the BITPC was never regarded as "self-sufficient".

The development of virgin territories was started from adjacent but developed regions. In these regions, "pioneer" industries were especially developed to provide a construction and manpower base.

Severe climatic conditions and sparse population was a limiting factor on the basic strategy to develop industries in the BITPC. The rule seems to be not to engage in further processing or manufacturing because of their labor intensive character.

Strategies for the BITPC that were adopted in the early 1950s proved to be very stable. Adaptations to new requirements of the national economic development (e.g. new energy strategies) and of external market (CMEA, Ust-Ilimsk timber complex) could be managed within the framework of the long-range strategy with sufficient flexibility.

Interviewing scientists, local and central government officials, and managers of various enterprises, we found a broad variety of options about the future of the BITPC with respect to its future size, degree of completion of production structure, and management. This reflects also the fact that currently several variants exist within the general strategy of exploiting East Siberian resources.

The human factor has played and continues to play an important role in the BITPC strategy and variant elaboration and selection. It influences the settlement policy, the strategies and variants of specialization and future completion of the BITPC. It also influences the creation of favorable living conditions under the severe climatic conditions in East Siberia. Particularly young workers are attracted to virgin territories, partly for educational purposes, partly because of their superior endurance.

In the present stage of the BITPC development, the creation of new facilities for female employment became an important task. The solution of this task is not only handled from an economic point of view, but also from the point of view of favorable living conditions for the population.

Problems Encountered

One set of problems is connected with the specific nature of the Bratsk-Ilimsk Region: severe climate, sparse population, and inaccessibility of resources. These problems have been known before the Field Study began, but they turned out to be more significant for the selection of variants and strategies than expected. After the initial stages of coping with these problems, the main problems now seem to be out-migration, and sex imbalance of the labor force.

Another set of problems is connected with the difficulties to coordinate the numerous planning and decisionmaking organs involved in the BITPC development. The main difficulty seems to lie in the coordination between sectorial and territorial interests in planning.

Timing of activities proved to be a substantial problem. Several authors and interviewees mentioned that there sometimes were time lags in the development that may have led to economic losses.

Methodological problems relate to the difficulties in assessing the efficiency of variants and strategies (e.g. settlement strategy versus export of energy). These problems were partly due to the multistage, multilevel nature of the decisionmaking process, partly to the difficulties in assessing secondary or tertiary costs of say settlement strategies, and partly to the uncertainty factor in the development.

Soviet planners and decision-makers realized the new challenges posed by environmental problems. The importance of maintaining good environmental conditions had increased in recent years and new approaches and methods were introduced in the BITPC planning and decisionmaking.

Several problems relate to the management of the whole TPC. It was discussed several times whether a new management body may have to be found to solve the management problems more efficiently.

Solution Approaches and Methodologies

Preplanning plays an important role in the solution of some of these problems. In the BITPC, the preplanning phase was very long and intensive. Decisions were made in a stepwise process to maintain flexibility to adapt to new circumstances such as settlement problems or discovery of new resources.

Already in the early stages of preparation of the BITPC concept, all socioeconomic system elements of this complex (resources, energy, production, transportation, construction, housing, services, employment, incentives) have been taken into account and became the subject of comprehensive planning.

The elaboration and evaluation of the BITPC concept and possible variants and strategies is done under participation of many scientific institutes and councils in Moscow, Akademgordock, Irkutsk, and other places. The process tries to maintain an open view on different variants to provide planners and decision-makers with independent and scientifically based variants of development.

One of the main innovations for solving problems in the construction of the BITPC was the formation of a unified construction agency, the Bratskgesstroi, that can be used for all construction tasks in the Region. Thus further development of the BITPC can be achieved without creating new construction organizations.

There are some considerations to find new management solutions for the whole TPC, without changing the basic present management structure.

Several new models and model systems for a stepwise evaluation or optimization of development patterns have been developed for the TPC at the IEOIP. These models are intended to aid the preplanning process and long-term planning as a whole.

There are several new attempts to formalize the goal-oriented planning approach as applied to TPCs. To these belong goals and task hierarchy methods, network models, and methods to deal with uncertainty.

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Planning and Organization of the BITPC

PLANNING AND MANAGEMENT CHALLENGES OF TPC DEVELOPMENT

This paper presents an analytic study of the organizational and managerial dimensions of the Bratsk-Ilimsk Territorial Production Complex (BITPC). The BITPC is one example of the present trend in the Soviet economy to solve some of the problems of the sectorial-territorial interface.

Historically, and to the present time, the development of the Soviet economy has been managed mainly through a sectorially organized planning and management system. The development of a territorial production complex (TPC) hinges on the notion of intersectorial activity, complemented by social and technical infrastructure development whose timing in a frontier leaves little margin for slippage. A TPC-based development strategy thus places new demands on the Soviet planning and management system. These demands pose five planning and management challenges which are characteristic of TPC development, particularly in the formative period.

First, the definition of TPC specialization presents special challenges to the national planning system. The rather separate justification of investments, supported by national norms and standards, may be sufficient for the bulk of Soviet investment in developed settings. However, this procedure cannot capture the complex support of one investment by another that TPC formation involves.

Secondly, synchronization of industrial development controlled by different sectors increases the demands on the Ministries for an all-round coordination across activities related to the TPC. In addition to synchronization of industrial complexes themselves, synchronization of the technical infrastructure supporting industrial activity is of equal importance.

Thirdly, synchronization of industrial development (sectorially-managed activity) with the construction of social infrastructure (territorially planned activity) has a significance in frontier regions which is unparalleled in other regions. In the context of an undeveloped region where the TPC forms a sort of oasis in the countryside, coordination demands a very high level of exactness. Miscalculations in this context might affect the balanced development of the region.

Fourthly, planning for integrated systems of social infrastructure represents an area of activity as important as the management of the industrial activity. In this context the challenge is to design and construct attractive and self-contained settlement communities in the wilderness, not simply to construct adequate shelter. The provision of schools, medical facilities, shops, and public transportation fall within this category.

Finally, if the TPC is to be as self-contained and self-supporting as possible, there is the set of management considerations which revolve around the choice and operation of secondary and service industries, i.e. completing industries.* It is these industries, often the responsibility of Republic and Union-Republic Ministries, that provide food, clothing, and jobs for second and third family members.

These five dimensions of TPC development provide the basis for our analysis of the planning and management processes in the BITPC. Later in this section they will be consolidated into three primary challenges, (see Figure 1) where our interest will be to identify the organization strategy used in the BITPC to meet these challenges.

Elements		Management Challenges
Industry	→	Specialization
Infrastructure Secondary Industry	→	Community Formation
Inter-Sectorial Sectorial-Territorial	→	Synchronized Implementation

Figure 1. Elements of TPC as a development strategy.

Methodological Remarks

An examination of the organizational dimensions of the BITPC requires a sound understanding of the basic elements of the system of planning. Our understanding of that system, which is

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*In the terminology used throughout this section, all industry can be included in one of two categories. A *specialization* industry is located in the territory to satisfy national economic objectives. A *completing* industry is that which is not specialization industry but which is essential in the concept of a TPC. Republic industry covers a large part of this class, but other types may also be contained within it.

contained in the next section, covers preplanning, the process in which opportunities are recognized and activities substantiated, and planning the actual decision process in the Soviet context. The complexity of the planning system is huge, and we do not claim an understanding of its totality. Rather we have centered our attention on its particular implications for the TPC strategy.

Following this, we shall identify the major actors of the BITPC and discuss their embedding in the system of planning. In addition special attention will be given to the management mechanisms particular to the TPC.

This background information will support our systemic analysis of the organization and management of the BITPC. The thread of this argument is the management complexity of the national and territorial systems. In particular, we will analyze the implications of this situation in the transition from sectorial to sectorial-territorial management.

Finally, this analytical presentation of the alternative and viable distributions of control capacity among administrative groups, both national, sectorial and territorial, provides the springboard for comment on some of the management solutions for TPCs suggested by Soviet scientists and practitioners.

SYSTEM OF PLANNING IN THE SOVIET UNION

TPCs have been defined as comprehensive objects of planning. For the purpose of analyzing the implications of this definition, we will outline the system of planning in the Soviet Union, focusing our attention on its territorial-sectorial dimension. While the behavioral implications of the planning system are most interesting, our research does not focus on the planning system as a whole. Rather we will use it as a background for analyzing the processes supporting the BITPC.

Decision Time Frames in Soviet Planning

In the Soviet Union, the role of planning is to provide a comprehensive approach to the task of policymaking and decision-taking. Plan formulation is the decision process in itself. Once a plan has been formulated and approved, decisions affecting different horizons have been taken. This is the logic of a planned economy.

The Soviet system of planning considers mainly three time horizons; the decisions in each of them are of a very different nature, evolving from a broad definition of long-term strategies to the very detailed specification of tasks. These horizons are as follows:

- *Long-term plans* represent a basic selection of future development strategies, although the means for achieving them are left open for later decisions. Normally these horizons are 15 years and represent a selection of driving forces for socioeconomic development.

- *Medium-term (or five year) plans* specify the particular programs for implementing long-term policies. At this level, technologies are selected and targets specified. Decisions at this stage imply a foreclosure of alternative futures. Their legal status requires mandatory fulfillment by the implementing bodies in the whole economy. Planning for five-year horizons represents the most important decision process in the Soviet Union, which is reflected in the very careful preparation of these plans.

- *Short-term (or one-year) plans* represent the mechanism to review and update the five-year plans, and provide a mechanism to introduce corrections and steer plans. However, it is assumed that the yearly disaggregation of the current Five-Year Plan provides the reference level for the definition of annual plans. In this context annual plans play the role of a policy instrument as well as that of a control device.

Supporting each of these plan elaboration processes is an extensive network of "intelligence" organizations preparing alternatives and substantiating programs. Long-term forecastings, design activities, and so on are part of this preparatory work. This "preplanning" stage provides the analytic support for the elaboration of each type of plan. Thus, preplanning operates in parallel to planning and on a continuous basis.

Finally, the instruments for plan implementation are called "operative plans" which do not follow all the steps for plan approval, and are prepared for quarters, months, weeks, and days. In this paper we focus on the processes supporting plan elaboration for the three primary time horizons mentioned above.

The Structure of Planning

Planning in the Soviet Union is done by the so-called "planning organs", which are embedded within all the administrative structures. At the top is the State Planning Committee of the Soviet Council of Ministries (GOSPLAN). Each of the 15 Soviet Republics has its own GOSPLAN. Within the Republics, and in the regions (oblasts) we find OBPLANS and at a more local level we find district and city planning commissions (see Figure 2).*

*Other structural complexities have not been reported for the sake of simplicity.

We were informed that GOSPLAN has approximately 60 departments with a total staff of no less than 3000, excluding the computer center. Most of the departments are sectorial and represent interfaces with sectorial Ministries; for example, the Department for Energy Planning works jointly with the different Ministries concerned with energy. There are at least four types of coordinating departments, and one department which produces summaries of all work. The four coordinating departments are: capital investment, economic balances, manpower and wages, and the territorial department.

Planning for the BITPC is influenced by the activities of the planning organs of three districts and two cities reporting to the OBPLAN of the Irkutsk Oblast. In its turn OBPLAN is supporting both GOSPLAN of the Russian Federation (RSFSR) and GOSPLAN.

A second and parallel line of planning is sectorial. The All-Union Ministries have their "planning departments" reproduced down the structural ladder in departments, combinats, and enterprises of the respective Ministries. Planning decisions for All-Union Ministries set the parameters for the plans of affected Republics; in this context, they are at a higher hierarchical level.

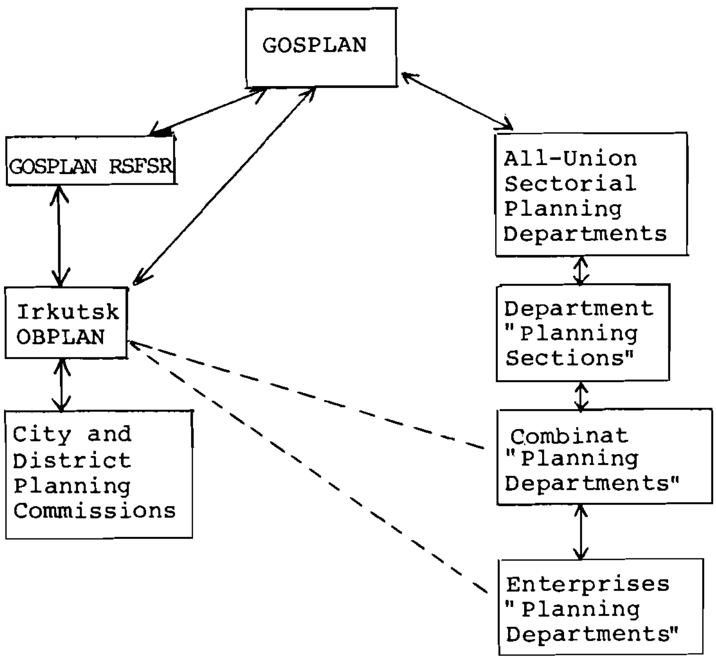

Figure 2. General structure of planning organs for the BITPC.

Preplanning

Scientific and technological support to these planning organs is provided by the many research and design organizations in the Soviet Union which do preplanning research and substantiation of alternatives for economic development. Their initiating role in the planning process is of particular relevance in understanding the overall structure.

Preplanning for long-term plans is handled mainly by the research institutes of the Academy of Sciences and the State Committee for Science and Technology (SCST). Other plans draw mainly on the activities of institutes under the various GOSPLANs, the sectorial Ministries, and the State Committee on Construction (GOSSTROI). However in the regions, branches of the Academy of Sciences also seem to have an important input to the Five-Year Plan.

The substance of preplanning research is outlined to the preplanning institutes by the planning organs as "tasks". The main coordinative mechanism for tasks is the coordination plan. After much interaction the coordination plan, approved by GOSPLAN, and by the SCST, sets four parameters of preplanning activity: (a) the hierarchy of institutes for preplanning; (b) the institutes or commissions with primary responsibility for substantive questions; (c) the allocation of resources for preplanning research; and (d) the form and timing of results.

In organizational terms, coordination of preplanning activities for particular substantive questions or tasks (b above) is accomplished either by selected institutions or special commissions appointed for resolving particular problems. Within these activities an important role is played by the following bodies.

The Council for the Study of Production Forces (SOPS) is a research institute for GOSPLAN. SOPS main task is the coordination of activities for elaborating the Master Scheme for the development and location of productive forces. It coordinates preplanning activities of approximately 600 research and design institutes, and develops and provides the unified methodology for forecasting. The main parameters of this methodology correspond to the indicators of the long-term and the five-year plans.

Another unit for preplanning consideration is the *Committee of Production Forces and Natural Resources (KEPS)* which is under the Presidium of the USSR Academy of Sciences. The main task of this committee is to define the natural resources (e.g., minerals, land, water, and forests) within the context of requirements for the development of the national economy, and corresponding to the regional structure of the country. KEPS is also responsible for the preparation of forecasts for the efficient utilization of these resources. Its activities correspond to the main strategies for the development of the national economy.

Special commissions are appointed for coordinating the elaboration of various national projects. Usually they act as organs either of the Academy of Sciences or of the SCST; however, leading representatives of GOSPLAN, of Ministries, and of other administrative units also take part. Such commissions coordinate the activities of research and design institutes addressing major subproblems. Final documents are then sent to GOSPLAN and other decisionmaking units. There are two examples that are particularly relevant to the BITPC development.

For the elaboration of the forecasts of the Angara-Yenisei Region, an interdepartmental commission was appointed in 1972. The commission, organized by the SCST, was headed by Academician Melnikov (the head of KEPS) and involved representatives of Ministries, departments, and party organs as well as scientists. The commission has prepared forecasts for the development of the region. Its results were presented in a special conference in Moscow and passed on to GOSPLAN.

There is also a special commission for the preparation of forecasts of scientific and research investigations for the Baikal-Amur Railway (BAM) zone. The commission, appointed by the Academy of Sciences, is headed by Academician Aganbegyan. Approximately 40 research and design institutes (e.g. SOPS) participate in its work. The leading role is played by the Institute of Economics and Industrial Engineering (IEOIP) in Novosibirsk.

The nature of the interaction between planning organs and institutes who carry out preplanning research can vary. Sometimes the interactions are direct and quite close; sometimes interaction occurs through intermediary coordinating organizations or commissions. Additionally, a given institute may interact with a number of organizations in either of these modes.

As an example we can observe the preplanning activity of the Central Economic Research Institute (CERI) of the GOSPLAN RSFSR with respect to the BAM project. Previously, CERI was involved in the long-term preplanning for the BAM. However, as the construction for the railroad commenced, CERI became involved in preplanning for annual plans for the project, and is presently involved in both.

Of particular relevance for TPCs are the two design institutes of GOSSTROI, namely the Institute of Industrial Planning (PROMSTROI) and the Town Planning Institute (GIPROGOR). Their activities, mainly for industrial development and social infrastructure, are an important input for regional planning at the oblast level. These institutes have regional agencies supporting design in the localities, e.g., the PROMSTROI project in Irkutsk.

The Process of Planning

As we have noted, the planning process considers three time horizons. The main objectives of the long-term plan (15 years) are to provide the parameters for the main directions of economic development, and to provide a mechanism with which continuity of medium-term plans can be achieved. The long-term plan is updated before each five-year plan in the form of new preplanning schemes, which do not have the status of plans. To the degree it is updated, however, each succeeding five-year segment of the long-term plan initiates a new 15-year planning outlook. By and large, the most important planning activities are related to structuring the five-year plans. Thus we will focus mainly on this time horizon. The leading role for all the planning horizons is played by GOSPLAN.

GOSPLAN focuses its decisionmaking processes within the context of four groups of nationwide balances: *material balances*, (physical balances of the major types of goods), *manpower balances*, *financial balances* (the state budget, the aggregate financial plan), and the *national economic balance* considering principally the intersectorial balance of production and assets. A fuller scheme of the balances used as criteria in this decisionmaking process is presented in Figure 3. The computer center of GOSPLAN supports the automization of the system of balances using input/output models.

Five-year plans are prepared within the framework set by the long-term plans. However, the most important input to this process is the factual information on the results of the previous planning period and the propositions of the many preplanning institutions at the time five-year plan preparation begins. The process, up to the moment the plan is approved, can be represented by three iterations:

- *Identification of alternatives.* Planning organs, at all levels and supported by research and design institutes, prepare propositions without restrictions for submission to the higher planning organs. Thus propositions of a regional and a sectorial nature are submitted to GOSPLAN, where the first balancing occurs. GOSPLAN then sets general parameters to Ministries and oblasts. It is at these levels where major disaggregation happens, providing the basis for the second and most important iteration.

- *Definition of control figures.* A new set of general proposals, now constrained by the need for socio-territorial-economic balance, is prepared by the planning organs. Detailed elaboration is done at GOSPLAN with the result that control figures are provided to Ministries and oblasts. This implies basic decisions on the allocation of resources and targets of production, and provides the basis for the third and final iteration. This second

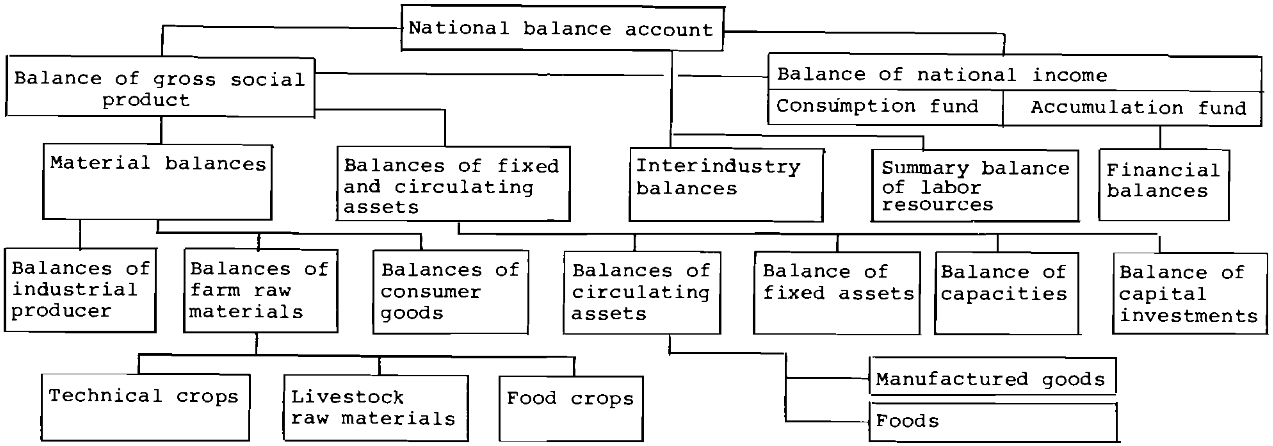

Figure 3. System of balances used in the development of the national economic plans of the USSR.

Source: [6]

iteration takes approximately two years before the definition of control figures is approved formally by the Council of Ministers.

- *Approval of the Plan.* On the basis of control figures the planning organs prepare "draft plans" which are consolidated and balanced in GOSPLAN. The output of GOSPLAN is the so-called draft directives which, after they are approved by the Government, are submitted to the Congress of the Communist Party of the Soviet Union (CPSU). The Congress approves the directives. On that basis GOSPLAN prepares the draft plan which is finally approved by the Supreme Soviet. At this stage the new Five-Year Plan is law. To complete this stage takes about one year and is done in close collaboration with the preplanning organizations.

Figure 4 summarizes all three iterations which together take no less than four years. The end result is one plan built up on the basis of more detailed plans elaborated by the different planning organs. A "line" in the plan, i.e., a decision incorporated in the plan, is mandatory for the affected organizations. In our discussions on the decisions related to the development of the BITPC we learned that the complex has had a line in the GOSPLAN plan since the 8th Five-Year Plan. This means that there is no explicit reference to the BITPC in the plan approved by the Supreme Soviet according to the above procedure, but it does appear as an explicit line in the GOSPLAN elaboration of that plan and was approved by the Council of Ministers. This line is mandatory for the All-Union Ministries and territorial authorities.

The plan prescribes some 250 to 300 key indicators or normatives of industrial output which account jointly for approximately 80 percent of the total national productive-capacity projected to be available during the five-year period. The remaining 20 percent relate to what are considered to be less critical areas, which can be properly defined at the level of the Ministry and lower.

The key indicators are transmitted to the Ministries and the Republics. On the basis of these indicators, industrial combinats, enterprises, and oblasts receive their indicators for the next five-year period. These indicators are disaggregated on a yearly basis for control purposes and to allow for corrections which might be necessary.

Only about 5 percent of the output is discretionary at the enterprise level. However, incentives are provided both to individuals and to groups at all levels to motivate production of high quality and in excess of planned levels. Various contingency factors and cushions are built into plans; plans are often exceeded by significant amounts.

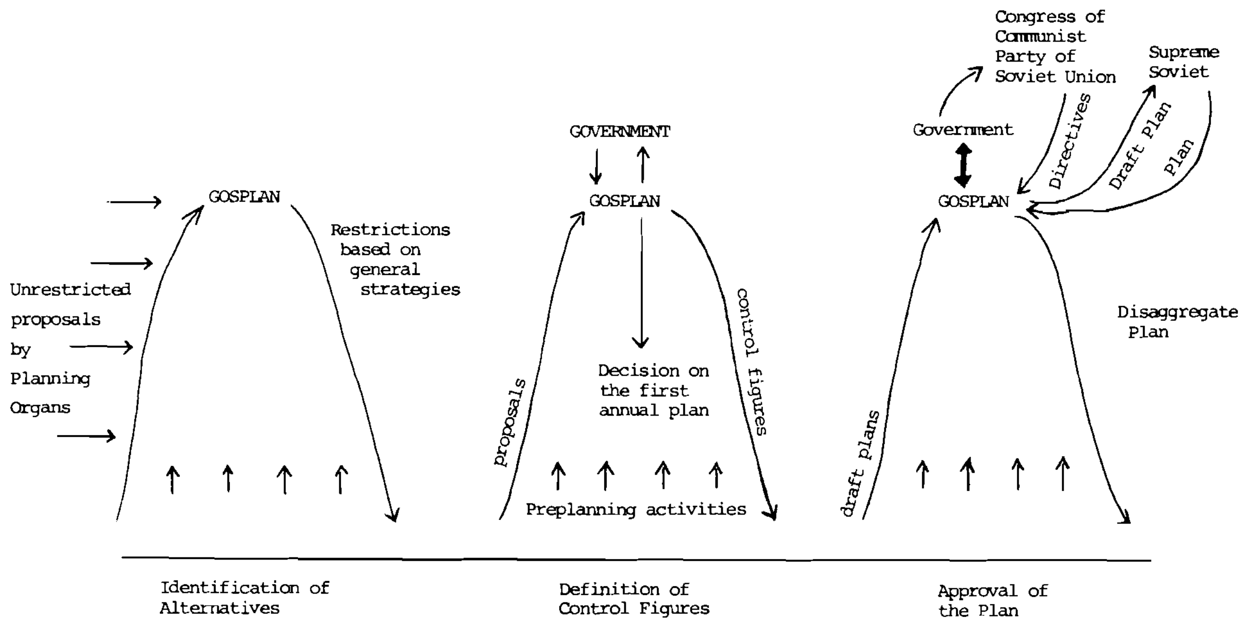

Figure 4. Iterations of the planning stage.

The five-year plan is the framework for annual plans. In theory the year's plan should be as close to the reference defined by the five-year plan as possible. Unsubstantiated deviations violate law. The trend has been to reduce the number of indicators for agglomerations and enterprises and to move towards their operation as profit centers. The detailed plans prepared on the basis of the indicators are submitted to the Ministries who can approve them or make changes. Combinats and enterprises have the right to appeal to GOSPLAN and to the Council of Ministers.

The basic indicators provided by the Ministries are:

- Production: volume of sales at fixed prices. This indicator is given according to an industrial nomenclature, and may contain hundreds of items for an enterprise.

- Profit and rentability: including the contribution of the enterprise to the State Budget.

- Wages fund (maximum level): including indicators of productivity.

- Capital investment: defined in accordance with the mechanisms described earlier (preplanning stage).

Decisions on territorial variables such as social infrastructure and local services, e.g. housing, medical, civic, social and recreational services, schooling, and transportation, are taken at the oblast level, i.e., they are incorporated in their plans. For this purpose sectorial organizations also submit their plans to oblast authorities. Unresolved conflicts between interests at this level may be referred as high as to the USSR Council of Ministers.

An additional output of the five-year planning process is the annual plan for the first year of the considered period. This decision is taken in the second of the already-mentioned iterations for the five-year plan. All other one-year plans follow iterations similar to the latter plan, and their approval is gained from the highest governmental levels.

Summary

The comprehensive elaboration of plans poses important organizational and informational problems. We can observe that, through its hierarchical structure, the complex network supporting this process is simultaneously taking decisions at many levels. Problems of policy at different planning levels, discretion, and consistency among them are important to understand. However, as noted, we have not intended to do a comprehensive assessment of these issues here. Our description of the system has provided only a sense of the design of the planning process and did not attempt a critical discussion of the way it actually works. In the analytic part of this Report we will make an assessment of its implications for TPCs. The following section presents the nature of the planning specific to the BITPC. The structure of this section parallels that of the preceding section.

THE BITPC AS AN OBJECT OF PLANNING

The treatment of the BITPC by the planning system is of particular importance to our understanding of the capability of the Soviet system to meet the challenges of planning for other TPCs in the future.

It is important to reiterate here the relationship between the strategy of TPC development and the activity at Bratsk. In the early phases of the Bratsk development, the concept of TPC, as we now understand it, was not the operative strategy. Most attention was then focused on planning for sectorial objects located in Bratsk; most infrastructure was considered only in the context of direct support for these industrial objects. During the 1960s, with the incorporation of planning for urban communities into the development, the notion of the BITPC took on more meaning. It is this dual focus that defines planning for complex, TPC development, rather than industrial development.

The BITPC in Preplanning

Several different bodies elaborated long-term planning perspectives for Bratsk. In 1954, the Gidroprojekt prepared detailed plans for the dam at Bratsk and defined the primary industrial consumers of the hydroelectric power, i.e. the main lines of sectorial specialization. SOPS, the coordinator of long-term preplanning research, was involved at that time in the preparation of a long-term prospectus for Bratsk. During the period 1962-1970, the East Siberia Commission carried on this work. This Commission was one of a nationwide set of commissions created at this time and later disbanded.*

More recently, an interdepartmental commission within GOSPLAN was involved in this activity for Bratsk. Appointed in 1972, its purview has been described as long-term planning for the Angara-Yenisei Region, with particular respect to the location of the natural resource, lignite, in that region. Members of this Commission included Academician Melnikov (Head), Academician Aganbegyan (Deputy Director), and representatives from Ministries,

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*A nationwide set of regional commissions was created in 1962 with the purpose of preparing long-term preplanning forecasts. These were short-lived and many of their functions were transferred to territorial bodies.

the SCST, the Siberian Branch of the Academy of Sciences, and the BITPC management. Various planning bodies, with the participation of research and design institutes, worked out proposals for the complex development of the BITPC, covering various time frames.

We have a sense, from descriptions of the planning process, of the nature of the work of these various organizations and commissions. Our understanding of the status of current TPC preplanning support is increased by a paper by Bandman [1] whose work on the spatial modeling of TPCs is well-known. He states:

> The main preplanning document is the general scheme of a TPC.... The general scheme will be... a basis for designing the long-term (general) and five-year plans, and...an obligatory initial document for forecasting research carried out by the institutions concerned with the respective TPCs. Both functions of the general scheme seem to be of extreme importance, since it is only by keeping to them that continuity of the plans and mutual agreement in concepts of preplanning research...can be guaranteed. [1,pp.9-10].
>
> Unfortunately, such a document exists for one of the large-scale TPCs of the country. [1,p.10].

Bandman's criticism is directed to recent preplanning for new TPCs in Siberia. In fact, his comments reflect one side of ongoing discussion in the Soviet Union. The discussion addresses the adequacy of schemes now being produced in the light of the complexity of TPC development as it is now understood. Although schemes are in preparation, we have the impression that they may be insufficiently comprehensive for the role of the "General Scheme" in the light of the complexity of the development which will follow from them.

In the case of the BITPC, whose development activity began in 1954, preparation of a general scheme per se, prior to development, is a moot point. The Gidroprojekt plans appear to have served this purpose. However, as we look towards generalizing the experience gained in the BITPC, we may focus on the necessity of a process which insures status at the earliest stages of planning so that a comprehensive policy framework can be prepared.

In terms of the future development of the BITPC, there appear to be four instances which assure the inclusion of the complex in the preplanning phase as a unit for consideration. First, the BITPC is a key factor in the development of the Angara-Yenisei Region as a whole; this is expressed in the development of the Bogouchany node. Both SOPS and KEPS, who are planning for this development, would include the BITPC in their consideration. The focus of these groups will be on linking the BITPC with other

TPCs in a system of TPCs that will provide the basis for the exploitation of Siberian resources. Second, the BITPC is also a key element in the scheme for the BAM development. In this context, both the commission for the long-term research plan for the BAM (Academician Aganbegyan, Director) and CERI of the Russian Federation (one of the institutes preparing alternative investment schemes for the BAM), will focus on the role of the BITPC. In this context, the development of a long-term policy framework appears to be well in hand.

With regard to future internal development, two additional points arise. Third, there is some question of the definition of the Bogouchany development as another node of the already defined BITPC or as a separate TPC. Fourth, we learned that discussion of construction of a chemical complex within the Bratsk node is very much alive. These two decisions will lead to specific focus on the future of the BITPC's internal development. Unlike the first two instances, however, the forum in which discussions will occur and/or decisions will be taken is not clear. While the first two instances involve national needs and will be included in national planning for the BAM and Angara-Yenisei Region, the same cannot be so clearly predicted for these internal considerations.

Five-Year Planning

The preplanning and planning processes involve organizations at all levels throughout the Soviet administration system. Figure 5 summarizes that group of organizations which have been involved in current five-year planning for the BITPC. The left portion of the scheme refers to the preplanning phase; the right portion presents the five-year process in the third iteration (see Figure 4) when propositions are being forwarded upwards in preparation for their consolidation into the Draft Plan. GOSPLAN forwarded this through the Government to the Congress of the CPSU for consideration and to the Supreme Soviet for approval. Research support for units involved in planning for the BITPC are indicated; their role will be explained later in this paper.

As has been described, the five-year plan is the major planning document in the Soviet Union. Inclusion as a specific item in the plan accords a project official status and specific commitments. In the case of Bratsk, first the East Siberia Region and then the BITPC appeared as lines in the 8th (1966-1970) and the 9th (1971-1975) Five-Year Plans, respectively. These "lines in the plan" usually signify mandatory attention by Ministries and Republics.*

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*In general, in addition to GOSPLAN, the USSR Council of Ministers, after commissioning particular research to the SCST on and to the Academy of Sciences, might decide to develop a particular line in the plan for a high priority program. At present, there are around 200 such programs, one of them being the territorial development of the area affected by the BAM.

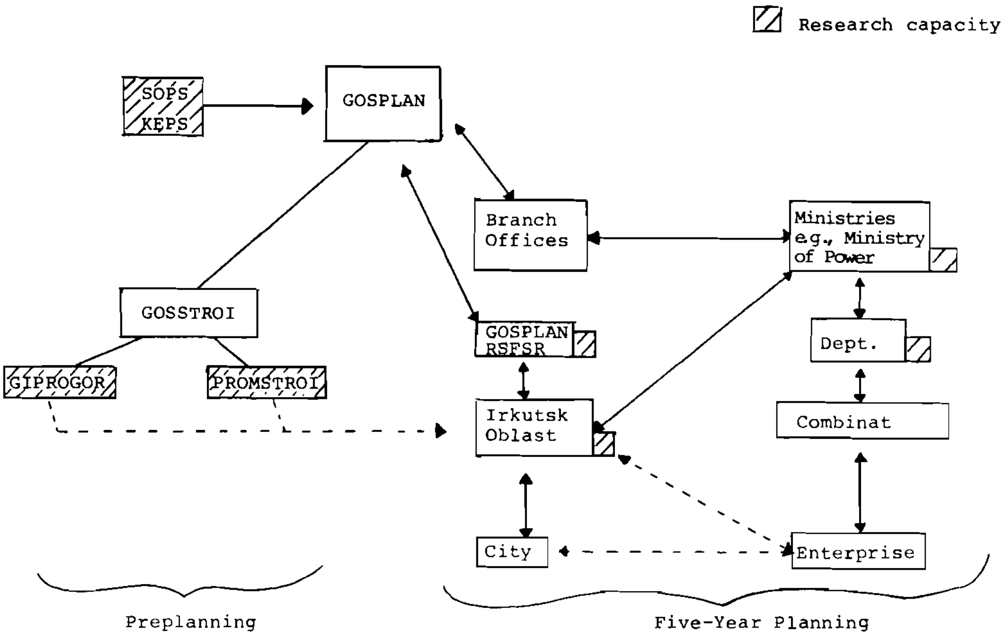

Figure 5. Five-year planning process related to the BITPC.

Based on our interview data and on the comments by Bandman, our interpretation is that in the 8th Five-Year Plan there was an explicit mention of investments to be carried out by sectorial Ministries in Bratsk. That is, the indicators of the Plan went beyond the usual global definition of investment and location. Although mandatory for the affected Ministries, it represented planning for industries and did not focus on the TPC dimensions of the project. This era in the development thus attended to industrial development and in that context identified Bratsk as the location of development of nationwide importance.

Sectorial administrative structures still largely handle the planning for industrial development in Bratsk. The far right flow in Figure 5 illustrates this process. However, in addition, both infrastructure development and the synchronization of infrastructure construction with industrial construction are now important aspects of the Bratsk development. It is this evolution which presently defines the BITPC.

Irkutsk Oblast has major responsibility for reviewing enterprise and agglomeration plans in terms of infrastructure and other matters such as the environment. In this process, the Oblast has several research resources. It is free to call upon GIPROGOR or PROMSTROI (who prepared plans for Bratsk in an early preplanning cycle) or the Irkutsk Branch of IEOIP which is part of the Siberian Branch of the USSR Academy of Sciences, and which collaborates with the OBPLAN in a more continuing mode. The OBPLAN has a department which consolidates figures in terms of the TPC as a unit for infrastructure planning purposes, and which makes some recommendations regarding industries of national specialization in the BITPC.

In general for questions of the BITPC development, the Irkutsk OBPLAN coordinates its activity with the territorial departments of GOSPLAN and GOSPLAN RSFSR. However, our interview data indicate no parallel unit at the RSFSR level to that of the OBPLAN group for the BITPC. Approval of a clothing factory for the BITPC suggests that there might exist a body at that level which regards the BITPC as a unit; however, GOSPLAN RSFSR may simply have acted on the recommendation of the Irkutsk OBPLAN. The import of that clothing factory was as much the provision of employment opportunities for second and third family members as it was the manufacture of clothing and thus would have interested the OBPLAN in the context of social infrastructure.

Our information with respect to the role of GOSPLAN in this process yields no clear picture. We have learned of a department within GOSPLAN whose responsibility is an overview of TPC development. A small section of the regional department oversees plan development for all TPCs in the East Siberia Region. We have no information as to the level of staff or research support provided, although we understand that the responsibility of the department is to consolidate sectorial data from GOSPLAN branches.

Within the Ministries themselves there appears to be only one instance where the BITPC appears as a unit for consideration--in the planning of the Ministry of Power. The construction organization for the BITPC is formally subordinated to the Ministry of Power, and in the process of handling the planning of this agglomeration the Ministry has an overview of construction activities in the complex. This overview, however, represents an input to the Ministry's own planning in resource allocation, rather than a responsibility for the BITPC plan development.

From this examination of the planning process thus far it appears that with the exception of the Irkutsk Oblast, whose responsibility is primarily infrastructure, it is only within GOSPLAN that an overview of both industrial development and social and technical infrastructure development is possible. Thus, the main responsibility for the BITPC as a complex appears to rest with GOSPLAN, in conjunction with GOSPLAN RSFSR. There appear to be no other groups who have access to the complete set of data to support such an overview.

For future TPCs, an experiment is presently underway within GOSPLAN which shows promise of providing the overview so essential to appropriate commitment of resources over the time periods involved. For the 1977 Plan, the key TPCs have been divided into two groups and construction plans elaborated either as a simple list of construction projects, or as a complex specification of all activity. The BITPC preceded this experiment by a good many years, and members of GOSPLAN confirmed that the Ministries and the local Soviets elaborated plans on the basis of the general lines of development for Ministries.

Annual Plans: Plan Implementation

As we have described, the elaboration of the one-year plans are carried out within the sectorial administrative structures. This is true also in the case of the BITPC, and the implication is that there is one organization which considers the BITPC as a complete unit in this phase of planning. The Ministry of Power has responsibility for the major construction organization in the BITPC, Bratskgesstroi, and in this capacity approves construction activities for all sectorial projects and some infrastructure. Irkutsk OBPLAN makes some input to this process.

There are a number of organizations whose focus is broader than enterprise activity, and a number whose activities coincide with the boundaries of the BITPC. None of these, however, represents an overview of the TPC in its short-term planning. Thus, an overview of the activities within the complex, and their interactions, exists in no finer detail than that of the five-year and annual plan, which is consolidated at GOSPLAN. Clearly, the quantity of planning data with which GOSPLAN must cope precludes a detailed and comprehensive consolidation of the interconnections of the various activities in the TPC.

Within the three spheres of activity (i.e., industrial activity, provision of both technical and social infrastructure) there are five organizations whose roles partially fulfill this function. Two of these deal with technical infrastructure: the Railway Board, and the Airway Board. These are units of a nationwide transport system whose jurisdiction happens to coincide with the region of the TPC. Angarstroi, the organization responsible for the construction of the railroad, is subordinate to the Ministry of Transport Construction.

Three organizations will be described in detail in a later section: Bratskgesstroi, the Director of Housing for Bratsk city, and the Board of Directors. Bratskgesstroi was given responsibility for the management of construction for all enterprises within the BITPC by virtue of a ministerial decision early in the development of the TPC. Thus, within the planning process of Bratskgesstroi a minimum of operational overview is provided for much of the technical infrastructure.

The Director of Housing, whose mandate is the collection of funds and supervision of housing design and construction, was created in the early 1960s. This office, in conjunction with Bratskgesstroi operations in housing construction, provides an overview of a major segment of the social infrastructure.

Within activities there are organizations which consider the BITPC as a unit. Difficulties arise, however, as a result of the lack of planning interaction in the short term between major activities. In addition to management of technical infrastructure, social infrastructure, and industry, there is a need for comprehensive short-term consolidation of the activities which interface between these.

The Role of Research in Planning

Discussion of the preplanning and planning process has highlighted the role of research in the definition of the BITPC as a unit. The significance of research is straightforward: without adequate economic and spatial models the potential of a TPC, as compared with industrial node development, cannot be realized. Insertion of research capacity into the planning process is important both for determination of long-term policy and for specification of a particular development strategy. Research support is needed to integrate long-term ministerial planning, to elaborate corollary infrastructure development, and to specify the extent of resource commitment.

On the basis of this logic one would expect to find research specifically directed at TPC unit development at the ministerial level, at the level of GOSPLAN, and within territorial administrative structures. To our satisfaction we have been able only to locate research support at the oblast level.

In addition to the obvious substantive role of research in planning for the BITPC or for any other project in the Soviet Union, one may note a function of research with respect to the power it conveys to an administrative unit to influence the planning process. The planning process involves a number of iterations both up and down, figuratively, the administrative structures of both sectors and territories. GOSPLAN is the key actor as consolidator of the output of the planning iterations as well as coordinator of planning for the policy decisions of higher bodies.

To the degree that it is unworkable for GOSPLAN to maintain a staff which matches the complexity of the research and administrative units below it, GOSPLAN must accept draft plans from both Ministries and territories as one basis for its policymaking. In this context, the ability of an administrative unit to elaborate project proposals is one factor in determining the capacity of that unit to influence GOSPLAN and thus, to control its own future. The quality of the research support available to a given administrative unit is thus an important factor in its ability to exert control.

Such influence can be exerted, however, only on projects which have already received official status via the Draft Plan. While the Siberian Branch of the USSR Academy of Sciences (in Irkutsk) may be focusing on the BITPC and thereby generating research adequate for real influence, of the units we have discussed we can identify no administrative unit who might carry this influence forward.

Summary

In this section we have intended to summarize the primary actors in the planning process and their interests in the BITPC. As is now clear a consolidated view of the BITPC is taken only within a few planning agencies. However, despite this, it is apparent that industrial development was synchronized and this can be attributed to the efforts of the respective Ministries involved and of the members of GOSPLAN for whom the BITPC was of particular concern.

PRIMARY ORGANIZATIONAL ACTORS AND THEIR ROLES IN THE MANAGEMENT OF THE BITPC

There are three sets of actors involved in the management of the activities that define the BITPC: sectorial organizations, territorial organizations, and organizations whose creation or purview are related specifically to the TPC. We will describe these oganizational actors and explain their interactions in the essential activities in the BITPC: industrial activity, and the provision of both technical and social infrastructure.

Industrial activity includes activities which are of national importance, and activities which represent "completing", i.e. secondary and support industrial activity. Technical infrastructure includes activities directly related to industrial complexes, such as the construction and maintenance of transport linkages and energy supply lines. Social infrastructure refers primarily to housing, schools, shops, and recreation facilities, but also includes such things as road construction and water supply for domestic use [1]. Sectorial administrative structures at the national and the Republic levels interact in the management of industrial activities; sectorial and territorial administrative structures at various levels interact in the planning and management of the infrastructure.

Sectorial Organizations

The majority of sectorial organizations are involved in industrial activity and are of two types: All-Union combinats, and Republic enterprises. All-Union combinats are subordinated to Ministries of the USSR, who control industrial activities which are of importance in meeting national economic development objectives. There are several administrative layers between the enterprise and its ministry, and the number of layers can vary. In general, from the bottom up the structure is: enterprise, combinat, department, and Ministry.

Thus, the timber or cellulose complex in Bratsk is a combinat which reports to a department in Moscow that is subordinated to a sectorial Ministry at the All-Union level. The major implication of the difference between All-Union and Republic industries is the location of the highest level of authority in the administrative structure. For All-Union Ministries, GOSPLAN and the USSR Council of Ministers represent the immediate highest level of authority. For Republic Ministries, whose administration parallels that of All-Union Ministries in structure, the immediate highest level authority is the Council of Ministers of the particular Republic involved. In the case of Bratsk, this is the Council of Ministers RSFSR.*

Each of the Ministries (and in many cases many of the departments), has its own research capacities which are at least in the form of design institutes, and may include institutes, either affiliated or directly subordinated, who do more basic research on longer term programs for the Ministries. The role of these institutes was mentioned in a previous section when the process of planning was described. It is the ministerial institutes that carry out the preparation of the long-term plans, and it is these same institutes who prepare the draft plans for the Ministries in the five-year and the one-year cycles.

All-Union Industries

The industrial complexes which define the TPC are managed primarily through sectorial structures at the All-Union level. In 1974, approximately 90 percent of the gross industrial output of the TPC was produced by the industries of national specialization. Industries subordinated to All-Union Ministries, represented in the TPC, include hydroelectric power stations (HEPS), timber procurement, wood chemistry, aluminium, timber production, heating equipment production, construction, and rail and air transport.

All are concerned with industrial production of national importance. Note that the construction organization (Bratskgesstroi) and the Rail and the Airway Boards are also involved

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*Of course, the USSR Council of Ministers is the ultimate level authority (excluding the Supreme Soviet); any dispute may be pushed up the administrative chain to them. Hence, we use the term "immediate" highest level authority to indicate substantive authority in usual cases; e.g. the RSFSR Council of Ministers approves Republic Ministry draft plans and forwards them to GOSPLAN.

in the provision of infrastructure, both technical and social. While formally subordinated through All-Union sectorial administrative structures, the focus of their activity is specific to the TPC; they, and in particular Bratskgesstroi, are considered in a later section. Figure 6 illustrates the administrative structures for All-Union enterprises in the BITPC. The scheme portrays only lines of management authority and does not include planning interaction, which will be indicated in a later diagram.

It is interesting to note that lateral linkages among enterprises and industries do not appear directly on the diagrams. Linkages of these sorts are accomplished primarily through interaction at the ministerial level, between All-Union Ministries, and between Republic and All-Union Ministries. At the present time, there is an informal Board of Directors operating at the TPC level, which provides some means of direct lateral communication. The role of the Board of Directors is discussed more fully later in this paper.

The planning and preplanning processes for these complexes follow sectorial channels, with the exceptions that have been noted in earlier sections. In particular the oblast authorities have a significant input in siting decisions, and in the amount of funds allocated for infrastructure development.

Indicators for the complexes derive directly from the All-Union Ministries. Since the 1965 economic reform, the number and type of indicators shifted quite dramatically in many sectors. However, in the case of the BITPC enterprises the level of control exerted through the Ministries may have decreased to a lesser degree because of the importance of these particular complexes to national development objectives.

There are usually a total of nine main indicators which are part of the five-year plan. All of the nine, save one, are specified by Ministries for enterprises for both five-year and one-year plans. Below is a list of these nine indicators, which we will then compare briefly with those received by two of the main enterprises in the BITPC.

- Volume of sales, paid for by customers;

- Level of profit, specified in roubles/units;

- Level of profits, specified as percent of costs;

- Size of wage fund, specified as maximum rouble amount;

- Capital investment, specified as budget allocation for specific objects;

- Number of different products, nomenclature: specified as a minimum product-mix figure (one-year plan only);

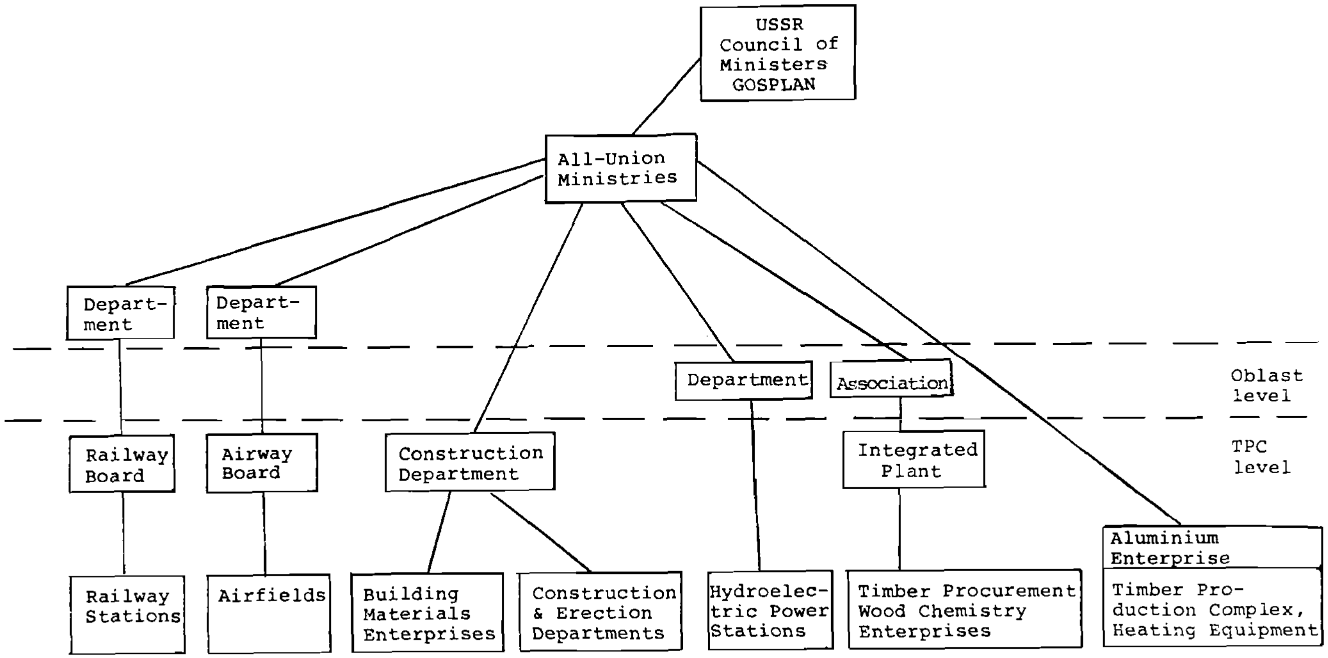

Figure 6. All-Union enterprises of the BITPC: administrative subordination.

- Product innovation, specified for most important products only;
- Increase in labor productivity, specified as a percent;
- Contribution of the complex to the State budget.

The aluminium enterprise in Bratsk is one of the major industrial complexes of this sector in the country. Our interviews indicated that planning is heavily top-down from the Aluminium Department in Moscow. The major indicators for this enterprise include the level of capital investment, repair, volume of production in both tons and roubles, and the number of workers employed. The enterprise reports daily on a few indicators to the Supervisory Department in Moscow, monthly on others, and has its primary reporting cycle on a quarterly basis. In Bratsk, enterprises contract directly with the construction enterprise in the BITPC, and these contracts are approved at the ministerial level in the course of the planning process.

The Timber Combinat also falls into the category of primary industries in national economic development and receives its output indicators and customers from the Ministry on a monthly basis. It, too, reports daily to the Ministry's computer center on some indicators.

The Bratsk Hydroelectric Power Station (HEPS), as another example, is part of a nationwide power system. It interacts with other regional power stations and is subordinated to the Siberian Power Grid.

Republic Industries

Republic industries include clothing factories, agricultural enterprises, and other enterprises which contribute to a local economy designed to support the population of the region. These support or secondary industries are often referred to as completing industries in the context of TPC formation and development.

Planning and coordinating the set of industries for the BITPC which complement one another in terms of life support for the population and the provision of adequate employment for family members is a complex task. It is the responsibility of the oblast planning committee to carry out this task, in which it can be supported by planning institutes subordinated to GOSSTROI. The Institute of Industrial Planning (PROMSTROI), and the Town Planning Institute (GIPROGOR), both interacted with the OBPLAN in developing plans for Bratsk. At the same time, suggestions for new industries have been initiated at the oblast level and approved by the Russian Federation. This occurred, for example, in the case of the clothing factory. We have no examples of actual indicators received by these enterprises; however, we do know that the structure at the national level has its parallel within the Russian Federation.

Agriculture is managed by the oblast Agricultural Department, as the output of agricultural production is consumed in a broader region than the BITPC. We have learned, however, that the oblast considers the BITPC as a unit, and in its planning process sometimes directs production in other districts to support the consumption needs of the TPC.

Figure 7 presents the administrative structure of the Republic and local enterprises represented in the BITPC.

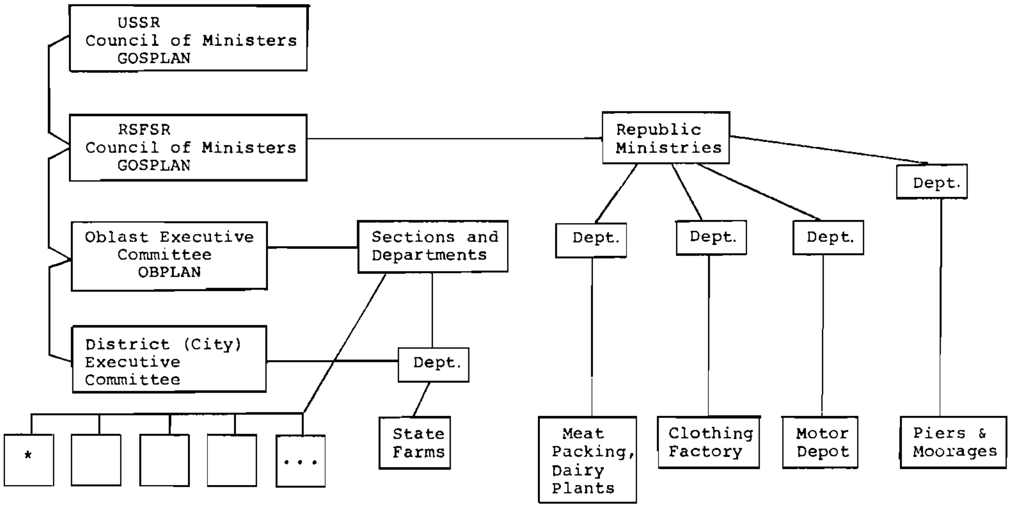

Figure 7. Republic enterprises of the BITPC: administrative subordination.

Territorial Organizational Actors

In addition to the sectorial actors, there are those who operate within the structure of territorial administration. In the case of the BITPC, they involve the following: the Russian Federation (RSFSR), the Irkutsk Oblast, the three districts that make up the BITPC--Bratsk, Ust-Ilimsk, and Nishne-Ilimsk, and the City of Bratsk (Figure 8).

Of particular importance to us are the RSFSR Council of Ministers GOSPLAN RSFSR, and the Irkutsk Oblast whose internal structure is presented in the following diagram.

Figure 9 sketches the internal administrative structure for the Irkutsk Oblast. The Oblast administration is made up of an elected Soviet which convenes three to four times a year. These Soviet Deputies then elect an Executive Committee which meets regularly and exercises administrative responsibility for the

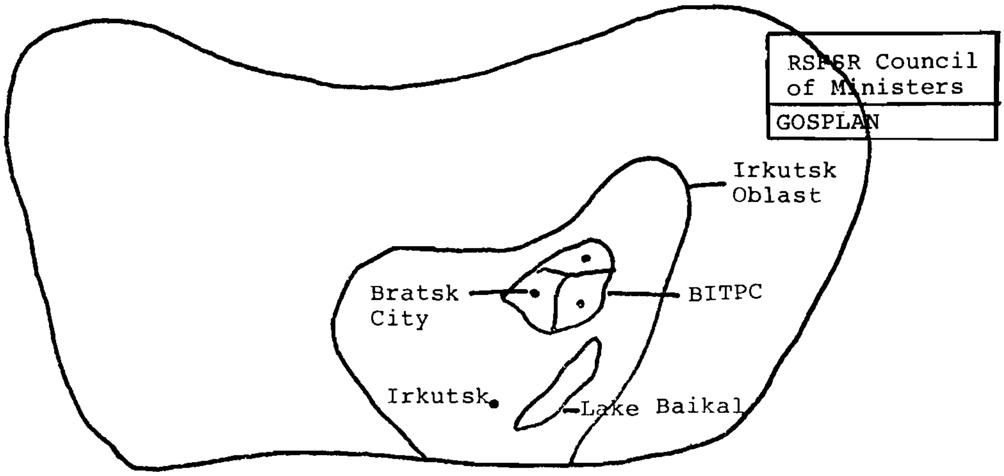

Figure 8. Scheme of territorial authorities.

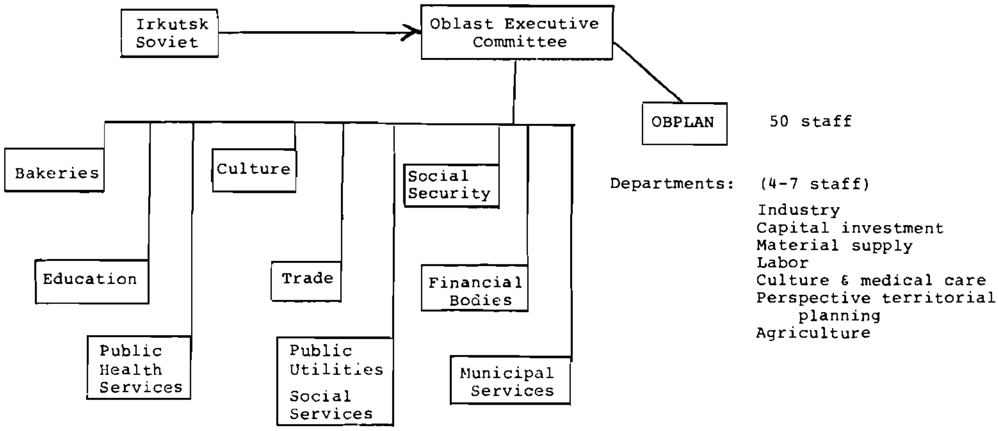

Figure 9. Irkutsk Oblast: internal administrative structure.

region of the Oblast. The Executive Committee is supported by a staff and departments. At this time, we have limited information on the Executive Committee. There is a planning committee, the OBPLAN, which provides support to the Executive Committee in the planning process. The titles of departments within OBPLAN are indicated in Figure 9. Each department has a staff of between four and seven persons.

The Oblast Soviet and its administrative structure is complemented by the local Party organization. The members of the local Party in the Oblast elect an Oblast Party Committee, which interacts with the Oblast Soviet in the full spectrum of its activities. The role of the local Party in Oblast administration and planning has been described as quite important. It is likely that some members of the Oblast Soviet, or the Soviet Executive Committee, are also members of the Oblast-Level Party Executive Committee.

There is a similar structure in the City of Bratsk. The city elects a Soviet which then elects an Executive Committee, the head of which we refer to as the Mayor of Bratsk City. There is a good deal of overlap in the membership of the City Soviet and the City Party Committee, as well as with the Oblast Soviet. Thus we can infer a level of communication and informal interaction which is more concentrated in individuals, and which provides more direct linkages than the formal structure of these various Soviets and Party committees might suggest.

The Bratsk City Soviet has 350 deputies and 17 standing committees. The committees are problem-oriented and although under the supervision of the Executive Committee of the Supreme Soviet, coordinate their work with the City Soviet as a whole. Examples of the standing committees are: Budget, Planning, Industry, Construction, Parks Commission, Education, Health, Culture, Sports, Environment, Services, Water, Transport, Communications, and Social Services. The Planning Commission parallels the work of the Irkutsk OBPLAN and works fairly closely with the OBPLAN. Indicators for planning come from GOSPLAN RSFSR, through the Irkutsk OBPLAN. Figure 10 shows both the planning and the management linkages for the activities in the BITPC, consolidating Figures 6, 7, and 9. Details of the City Soviet and of other organizations whose focus is specific to the BITPC are not included.

Organizational Actors Specific to the BITPC

There are five organizations whose activities are primarily concerned with the development and management of the TPC. Three of these represent organizational innovations designed to meet the special management requirements of TPC development in Bratsk: *Bratskgesstroi*--the construction organization; the *Direction of Housing for Bratsk*, and the *Board of Directors*. The other two, the Rail and the Airway Boards, are specific to the BITPC only because their respective purviews happen to coincide with the region of the TPC.

Bratskgesstroi

Bratskgesstroi is a construction agglomeration formally subordinate to the Ministry of Power. Orginally responsible for the construction of the dam and the HEPS at Bratsk, its responsibilities were formally extended to include the majority of construction of both technical and social infrastructure requirements in the BITPC. In this capacity, Bratskgesstroi has been

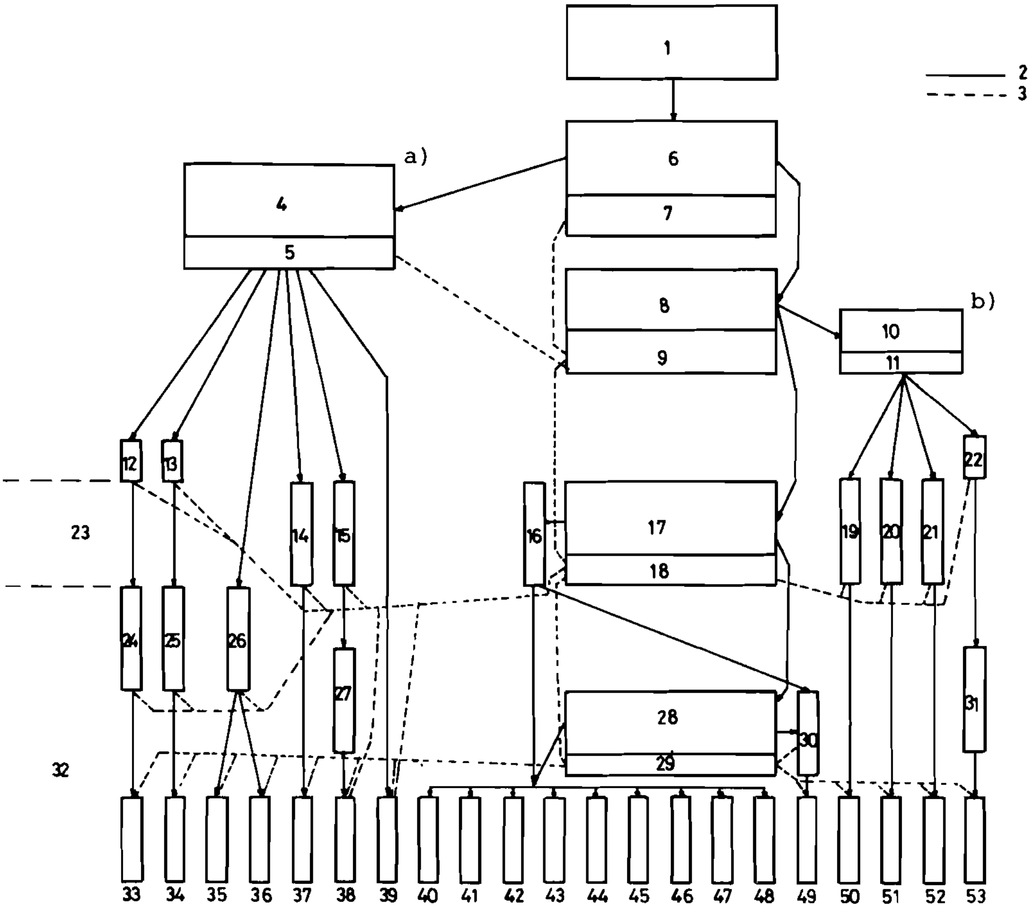

Figure 10. Organization of planning and management of BITPC activities.
(See below and next page for key.)

Source: [4]

1. Supreme Soviet;
2. Administrative Subordination;
3. Planning Connections;
4. All-Union Ministries;
5. Head Departments;
6. USSR Council of Ministers;
7. GOSPLAN;
8. RSFSR Council of Ministers;
9. GOSPLAN;
10. Republic Ministries;
11. Head Departments;
12. Department;
13. Department;
14. Department;
15. Association;
16. Sections and Departments;
17. Irkutsk Oblast Executive Committee;
18. Planning Committee;
19. Department;
20. Department;
21. Department;
22. Department;
23. Oblast Level;
24. Railroad Board;
25. Aircraft Works;
26. Construction Department;
27. Integrated Plant;

28. District (City) Executive Committee;
29. Planning Committee;
30. Department;
31. Enterprise;
32. TPC Level;
33. Railway Stations;
34. Airports;
35. Building Materials Enterprises;
36. Construction and Erection Departments;
37. Hydroelectric Power Stn., Steam Electric Station;
38. Timber Procurement, Wood Chemistry Enterps.
39. Timber Production Complex, Heating Equipment Plant, and Aluminium Enterprise;
40. Bakeries, Mechanical Bakeries;
41. Education;
42. Public Health Services;
43. Culture;
44. Trade;
45. Public Utilities, Social Services;
46. Social Security;
47. Financial Bodies;
48. Municipal Services;
49. State Farms;
50. Meat-Packing Plant, Dairy Plant;
51. Clothing Factory;
52. Motor Depot;
53. Piers and Moorages;

a) See Figure 6;
b) See Figure 7;

a major integrating and coordinative factor in the development of the BITPC. This extension of responsibility represents one of several self-conscious innovations in managing the development of the complex.

Bratskgesstroi's construction activities in the provision of the *technical infrastructure* support all industries of the complex. At the present time, the organization's projects are divided among the Ministries with about 35 percent of construction for the Ministry of Power and 65 percent for other Ministries and local bodies. Preparation of a composite plan for all these activities requires consolidation of many competing demands for construction resources. In dealing with Bratskgesstroi, the Ministry of Power has the capacity to reconcile these demands during the planning cycle. In cases where there are difficulties, decisions are made by higher authorities.

Planning for a given year begins six months prior to the period under discussion, with discussions between Bratskgesstroi and its customer enterprises. After discussions, both the organization and the customer enterprise send formal written suggestions to the Ministry of Power. Discrepancies between the two sets of recommendations are resolved at the ministerial level, and a joint "inter-board" document is forwarded to GOSPLAN (see Figure 11). GOSPLAN is the final authority with regard to conflicting requests for construction resources; however, it has the discretion to forward important questions to the Council of Ministers.

An approved plan defines both output and a deviation margin. In general, the Ministry of Power sets indicators for Bratskgesstroi in terms of volume, manpower, and resources. Bratskgesstroi in turn sets these indicators for its subordinate enterprises. The yearly planning is consistent with the process of ongoing relationships between the organization and its customers.

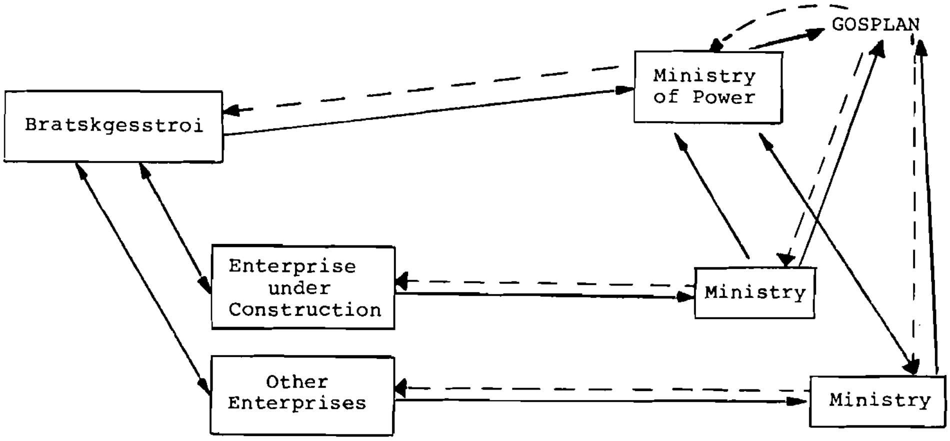

Figure 11. Bratskgesstroi: yearly planning process.

An example provided was the interaction between Bratskgesstroi and the Ministry of Pulp and Paper, for whom Bratskgesstroi is presently constructing the Timber Combinat. The local complex director has a deputy for capital construction who is the liaison with Bratskgesstroi for construction work. This deputy and the appropriate office within Bratskgesstroi set output on a monthly basis and report formally to the national statistics networks and Ministries involved.

The level of *operational discretion* which Bratskgesstroi exercises varies from project to project. General design specifications and finance are provided by the customer Ministry. The Ministry is responsible for both the purchase of equipment to be installed in its complex and the preparation of general specifications which are provided to the organization's design office for elaboration. Bratskgesstroi is responsible for the detailed specification, construction, and equipment installation; however, the level of discretion involved in this responsibility varies according to the importance of a particular project in the achievement of national objectives.

In fact, the design process for projects of All-Union importance are fairly closely controlled within the All-Union Ministries. For all projects, Bratskgesstroi must operate within the standards set by GOSSTROI. In addition, for major projects like the Timber Combinat, ministry-subordinated design institutes often work out detailed specifications. In this case the Leningrad Design Office of the Ministry of Pulp and Paper worked out specifications.

In the case of the Ust-Ilimsk HEPS planning and design occured in several distinct phases, and control is being maintained at the All-Union level. A special decree of the USSR Council of Ministers requested that the Planning Commission for the East Siberia Region develop main guidelines for developing cities and industries in connection with the construction of the Ust-Ilimsk

HEPS. The Commission in turn engaged a number of research institutes to investigate major aspects of the construction activities, including environmental impacts. Once the design was completed GOSPLAN appointed an expert commission to review the design; once construction is completed a second commission will be appointed by the USSR Council of Ministers to investigate the implementation of the plans.

After design questions are settled, distribution of implementation responsibility is at the discretion of the Head Office of Bratskgesstroi. The Planning Department within the Head Office makes personnel and task assignments for quarterly and yearly periods for the organizations that comprise Bratskgesstroi. These enterprises report monthly to the organization's departments.

Distribution of resources, and redistribution if there is a shortage of resources, is also at the discretion of Bratskgesstroi. In the event of the need for a tradeoff among activities, priority is usually given to projects approaching completion. Should an enterprise director whose project was delayed disagree with the trade-off, the customer can complain to the Ministry and seek a reallocation of resources. There have been cases where such enterprise appeals have been successful.

Bratskgesstroi is responsible to the customer Ministry for its construction activity and also to a separate organization structure within the Soviet management system which monitors the fulfillment of plans. The People's Control Organization is an authority whose structure parallels the territorial organizational structure. On projects of All-Union importance a group from this organization, which would report directly to the USSR Council of Ministers can review a situation and make recommendations.

Figure 12 presents an overview of the general organizational structure of Bratskgesstroi. As can be seen from the diagram, the diversity of Bratskgesstroi's activities is quite dramatic. (Discussion of Bratskgesstroi's role in social infrastructure follows shortly.) The enterprises within Bratskgesstroi cover the majority of infrastructure construction activities, many of which are organized on the basis of the territorial nodes of the TPC, e.g. the offices for Ust-Ilimsk and for Bratsk.

We learned that there are approximately 70,000 employees in Bratskgesstroi; Figure 13 shows the structure of the Head Office of the organization which has approximately 400 staff.

In addition to providing the technical infrastructure, Bratskgesstroi plays a central role in the provision of the *social infrastructure* working with the Direction of Housing in constructing housing, shops, and medical facilities. The implication of the 1960 decision on infrastructure funding was that no new industry could be built on the territory without provision for the funding of the social infrastructure. The oblast participates in setting the rate for infrastructure investment, which

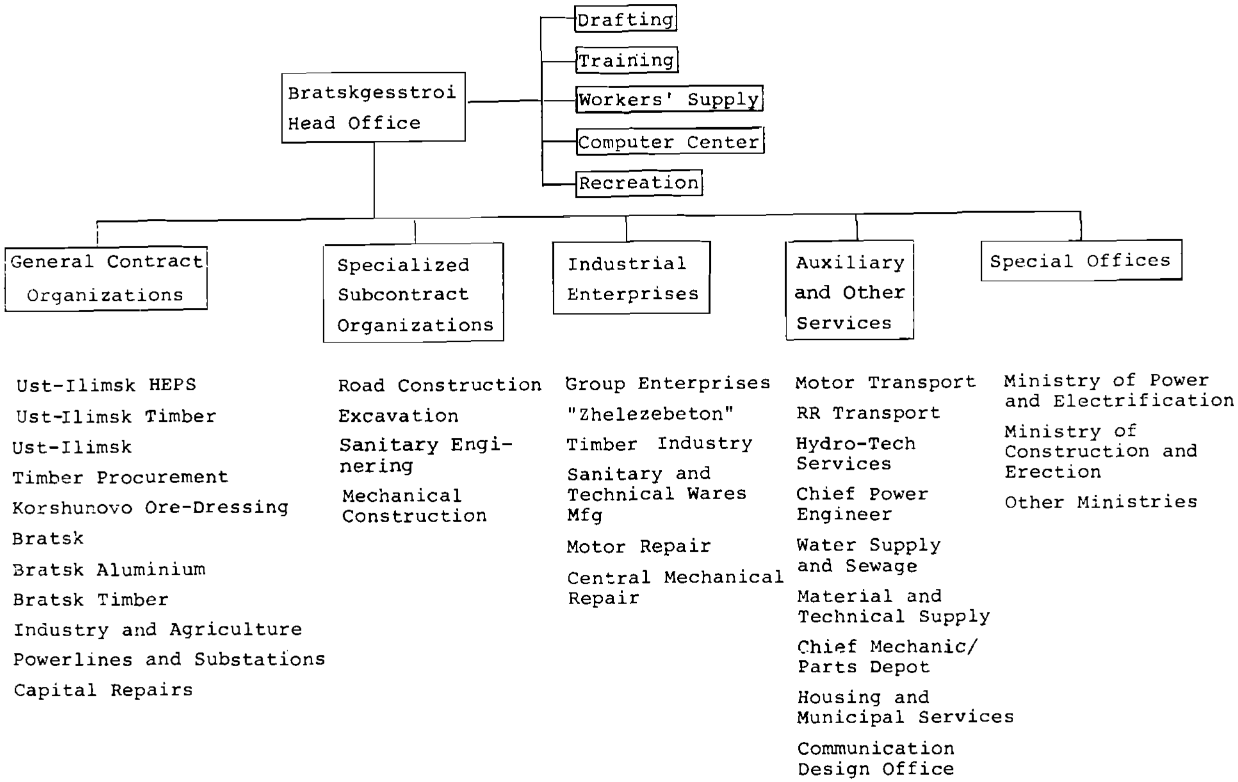

Figure 12. Bratskgesstroi: general organization structure.

Source: discussions at Bratskgesstroi.

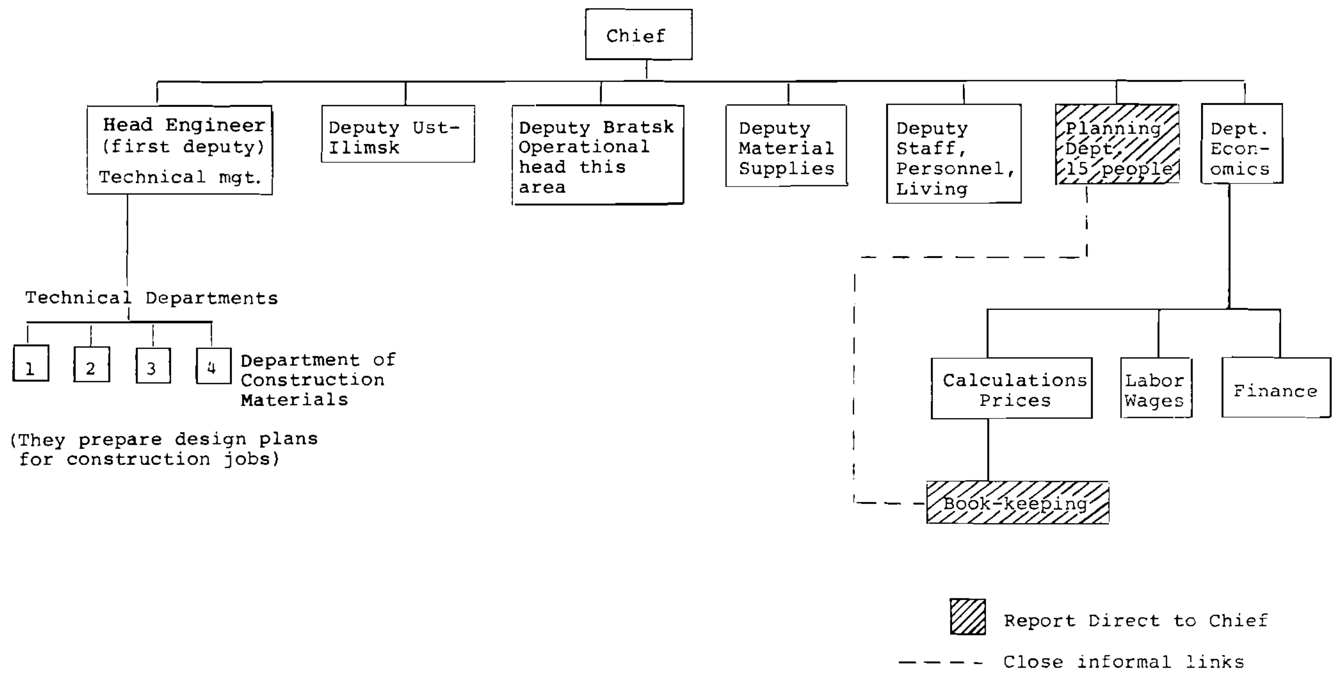

Figure 13. Head Office of Bratskgesstroi (400 Staff).

Source: Discussions in Bratsk with Head of Planning Department.

is on the order of 35 to 40 percent for the social infrastructure. Although the major portion of infrastructure funding is provided by the enterprises, some funds are also allocated through the territorial administrative structures. For example, funding for housing at the oblast level comes from four sources: the State budget, the local oblast budget, enterprise funds, and capital funds from Ministries. (A proportional breakdown of these funds was not available.)

In the early 1960s a special office for the Direction of Housing Construction for Bratsk was set up by the RSFSR Council of Ministers. The Direction of Housing is an office of 40 to 50 experts in housing construction who supervise housing design and construction in the area. The office collects infrastructure funds from the Ministries, coordinates the work of the design institutes in preparing plans, and coordinates the construction of units, presumably through Bratskgesstroi. The Director is subordinate to the City Soviet and to the Department of Capital Construction of the Irkutsk Oblast Soviet; it is the second innovation specific to the BITPC.

In populated regions, housing is usually distributed by the local soviet, and in pioneering regions it is distributed about 80 percent through Ministries. This implies that the industries of the TPC region distribute the housing among their workers themselves. In fact much of the distribution of housing for the BITPC is handled through Bratskgesstroi.

In much of the TPC, Bratskgesstroi handles most of the "landlord" functions for housing, e.g. distribution of housing, and shop management. After the HEPS in Bratsk was completed, the head office of Bratskgesstroi was given landlord functions. (This is true also for the housing in the central part of the city.) In Ust-Ilimsk where the HEPS is now under construction, Bratskgesstroi is handling the housing on the left bank of the city; housing on the right bank, which the organization is building for the Ministry of Pulp and Paper, is being run by the Ministry.

In addition, Bratskgesstroi has managed much of the trading infrastructure for the complex. As various industrial complexes were built, it extended its management activities to handle the workers' shops which each of the Ministries provides for workers in the various enterprises. Ordinarily the State Ministry of Trade establishes local offices to manage these worker supply shops; in this case Bratskgesstroi took over the role of the local office for Bratsk.

Bratskgesstroi also manages water supply and sewage facilities. As we spoke in the summer of 1976 with representatives of the organization, we learned that many of these functions will shortly be turned over to the local soviets. Until the present time, however, the major part of infrastructure management and construction has been carried out by the various suborganizations within Bratskgesstroi. In the context of a TPC where infrastructure investment is a major defining characteristic of the TPC concept, the effect of the organization's activities is to have had a major role in defining the boundaries and characteristics of the BITPC.

Transportation Boards

The other major infrastructure component is the system of transportation. While Bratskgesstroi has been handling road and automobile transport, there is both a Railroad Board and an Airway Board which operate on the geographic region of the TPC. These boards were not innovations specific to the BITPC; however, their activities coincide with and support the activity of the TPC.

The Railroad Board is part of a nationwide structure for the management of railroads, and the region of the board's responsibility is slightly larger than the area of the TPC. It was the construction organization of the Ministry of Transport Construction, Angarstroi, which built these facilities under the supervision of the Board.

Generally, a particular enterprise contracts directly with the Railroad Board for the time, route, and volume of its shipping. The Board then coordinates this through the Department above it. The railroads are the primary transport mode between Ust-Ilimsk, Schlesagorsk, and Bratsk for transporting timber to the cellulose complex (see Figure 14). We are told that the Airway Board operates in a similar manner, but we have no details for this actor in the transport system.

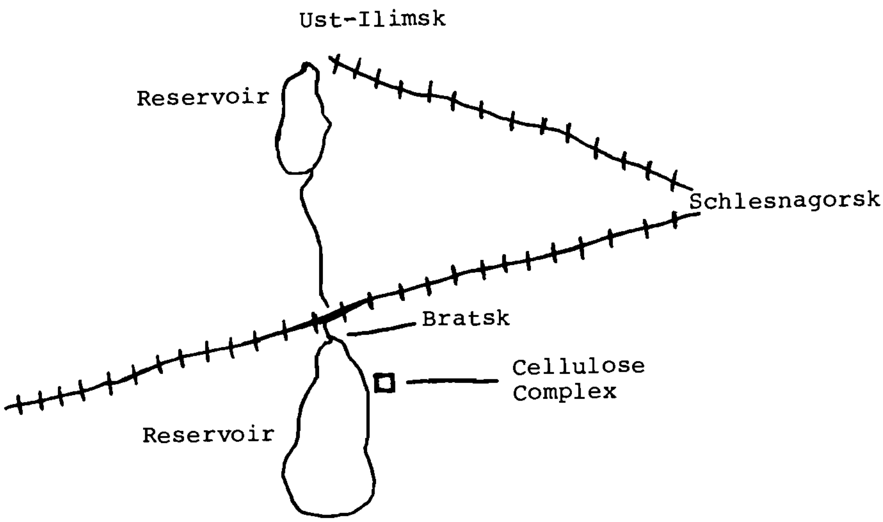

Figure 14. Rail system.

The Board of Directors

The third organizational innovation specific to the BITPC is the Board of Directors. In the course of discussion, it becomes apparent that there are no formal mechanisms for coordinating industrial capacity management. Lateral linkages among industries and reconciliation of competing demands, at least for construction resources, occur during the planning stage between Ministries. In 1970-71 an informal organization was created whose role was to facilitate communication among the major industrial actors in the TPC.

The Board of Directors has a membership of about 40 persons: the heads of the major enterprises of the TPC, members of the Oblast and City Soviets, and members of the Oblast and City Party Committees. The Director of Bratskgesstroi serves as Chairman of the Board of Directors, which meets on a monthly basis. Although an informal organization, it appears to be functionally subordinate to the City Soviet. The informal status of the Board of Directors tells us very little except that its membership appears to regard its functioning as necessary to the well-being of the TPC. Discussion focuses upon issues which are of concern to the participants, and although the Board has no formal decision-making authority, a number of members of the Board have noted that very few "suggestions" from Board meetings have ever been ignored. As a forum for peer discussion and a source of peer influence, the Board appears to be quite powerful.

An interesting dimension of the Board may be inferred from the information regarding the composition of the Oblast Executive Committee. It was noted during the discussion that at that level there was a good deal of overlap in membership between Oblast and Party Executive Committees. Such would also appear true in the case of the Board of Directors for the BITPC. Most enterprise directors tend to be members of the local Party, and most members of the City Soviet are likely to be members of the Party. Thus, a Board made up of enterprise, Soviet, and Party representatives is likely to have all three represented in one individual in a number of cases. The degree of influence, which it is alleged the Board of Directors can exert on management at various organizational levels in the BITPC, most likely derives from this overlap in peer group membership.

Summary

There are a number of different groups involved in the management of the BITPC: All-Union agglomerations, Republic enterprises, oblast and city authorities, and the local Party. By and large industrial capacity is managed through the administrative units of the All-Union and Republic Ministries. A majority of the infrastructure is managed through Bratskgesstroi, which, by virtue of the contracts it handles, manages a large segment of TPC activity.

It is through Bratskgesstroi that coordination of infrastructure development, both social and technical, is achieved at the implementation stage. The Director of Housing for Bratsk City, as an organ of the Soviet, plays an important role in social infrastructure coordination, working together with Bratskgesstroi. These two organizations provide the major formal communication links among infrastructure activities.

Finally, it is the Board of Directors that plays a primary informal coordinative role in the complex. Created out of a need for lateral communication aiming at a variety of actors involved in the TPC, the Board of Directors influences TPC management through informal peer pressure. We are aware of the important role of the local Party in this context; however, formal consideration of local Party activities was beyond the scope of this study.

As the activity of the BITPC continues to increase and become more complex, it is presently an open question whether the management structure functioning on the TPC is adequate to manage the activities. A number of proposals for TPC-focused management bodies have been forwarded at various administrative levels and are presently being considered for adoption. Before turning to a consideration of these proposals we will examine the planning and management processes governing the BITPC from several analytic perspectives in the following section.

SYSTEMIC INTERPRETATION OF TPC

Methodological Comments

Main Concepts

The purpose of this section is to provide an understanding in systemic terms of the TPC concept within the Soviet planning and management system. This is intended to give new insight into the organizational questions that TPC poses and to be helpful in assessing various organizational innovations which have been suggested by Soviet scientists for the planning and management of TPCs.

The concepts and models used for this analysis have been developed during 1976 within IIASA (drawing on externally published material), and are documented elsewhere [2,3]. Here we present an outline of the basic elements underlying our analysis.

Our analysis follows a particular approach to organization which is somewhat different from those adopted in many published studies on organization analysis. In the context of IIASA we have been aware of the need to develop an approach which makes very few assumptions specific to particular types of societies. Our approach is intended to have very wide validity. Because we are concerned with large programs that generally involve interactions between many separate organizational units, our approach is intended similarly to have the facility to handle problems of this type, problems of *multiorganization*. Further, we observe the need for an approach which goes beyond description to allow analysis that can support policymaking. Our view of much of the published work in the field of organization studies is that it does not meet these conditions.

The initial assumptions underlying the approach are:

- A management system is a system directed towards the achievement of either internally generated or externally set goals;

- It is situated in an environment that includes those factors outside of the system which somehow affect the system's possibilities for goal achievement, and which is subject to change; and

- The system is in constant exchange with its environment.

Changes in environmental state are responded to in a way conducive to goal achievement.

Viewed in this way the central issue in analyzing a management system is its capacity to respond to changes in its environment, so that its objectives can be achieved. Stated in this abstract way, these characteristics may seem unfamiliar. However, with reflection, it is not difficult to view the problems of an enterprise in this way. It has goals to achieve, and the actions it takes to achieve them are based upon feedback from its environment in terms as such factors as material costs, labor availabilities, and markets. We will demonstrate how these basic ideas can also be directed at much larger systems of organization units. In our analysis a number of units are considered as a system when they subscribe to, or their actions are influenced by, a common overall goal.

The nature of the environment of the management system is a very important consideration in our analysis, so it should be made clear what is meant by the term. In one sense system environment could be considered as including all these factors which are external to the system. However, taking this wide view we would include many things which make no impact on the system and are not relevant to it as it strives to achieve its objectives. The subset of that total environment which is relevant to objective achievement is what we mean here by *system environment*. Clearly it depends on the nature of the system's objectives. The weather is a part of the physical environment of all systems. If one is manufacturing ice-cream it may well be part of the relevant system environment. However to a steel manufacturer it probably is not. The rate of change in a factor of the total environment may determine its inclusion or not as part of the system environment. For example, many systems have objectives for which population is relevant. In situations where population is fairly constant it may be ignored. But where the task is in an area where some characteristic of the population is changing then it will need to be considered. Each factor of the environment may, of course, adopt many different states, each of which requires a particular response. And in some cases the appropriate response may not be well known. All these considerations--the number of factors in the environment, the number of states they may adopt, the rates of change, and the uncertainty of the relationship between environment change and system response--are important in considering an environment. For situations where the number of factors is high, and each has many states, high rates of change, and high uncertainty, we use the term *complex environment*. It must be remembered that this term is used in respect to a particular system objective. Thus changes in the objectives of a system, which define new "relevant" environments rather than some change in the total physical environment, are generally responsible for a system environment becoming more complex. We will argue that the system environment of TPCs is more complex than that associated with more usual sectorial investment. The important point we want to make at this stage, a point which follows directly from the way we are viewing management systems, is that as environment becomes more complex the management system will need to develop increased capacity to deal with it.

System Levels

The organizational system is defined as embedding subsystems, which in turn embed their own subsystems, and so on. The logic we use is that in following down the levels of embeddings in a system, one follows the process of objectives being specified in more and more elaborated terms. Where the overall goal statement is quite general, and is subject to much uncertainty in many factors, it will be solved in many stages. For example, take an economy as a whole whose goals may be maximizing welfare or economic growth. One would not expect to go directly from this statement to a series of machine-shop production schedules. Rather there is a multistage elaboration, and each stage is dealt with by a different system level. This can be put in another way. In problems of multiorganization (involving many units) system levels are sometimes less visible. However, we believe that the allocation of units of a system to the different system levels is a necessary starting point for analysis.

We will start with the economy as a whole, because that is relevant to the case. At this level many possible strategies will exist for achieving objectives, for example favoring industry over agriculture, and choosing between different large programs. A choice has to be made from among the considered alternatives. Once this choice has been made it is possible to consider the chosen strategies somewhat separately. We use the term *national system* for the level that elaborates overall national objectives to a set of more defined subobjectives. The defined subobjectives can then be thought of as being "handed down" to the subsystems, although this phrase does not capture the dynamic nature of the process with influence going both up and down.

At the level of the subsystems the objectives set may still be quite general and need elaboration. However they will always be more specified than the original overall goal. And at the level of the subsystem, management is concerned only with ways of achieving the subgoal; problems of balance between one subgoal and another are problems for the national system. In this way the subsystem will elaborate sub-subobjectives for the sub-subsystems. The process can be repeated an indefinite number of times until we reach a level of detail beyond that appropriate to the analysis. Each step breaks the original goal into an increased number of tasks, and the management of each task needs to be concerned only with choices or tradeoffs within the task.

Put in a very simple way, this is the basis for system structure. Of course, the logic used is general enough for many different types of structures to arise. In allocating organization units to the various levels, we consider which stage of the elaboration process they are supporting. The allocation that results is sometimes different from what one would expect through the use of other indicators, such as the name or the location of a unit. Sometimes also, in the context of different problems, the same unit may appear at more than one level.

System Functions

What we have described is just one function of a system level that we call the *policy function*. We will go on to define a set of five functions with which it appears all organization actions can be described, and which will occur at each system level. The policy function exercises discretion to choose between alternative strategies for objective achievement. When these are selected they form the basis for objectives to subsystems.

The *planning or intelligence function* generates and explores possible alternative strategies in support of the policy function. This function does not of itself have explicit decision capacity, although implicitly through the way it explores alternatives it may powerfully influence policy.

The *control function* monitors, and through resource provision, controls the subsystems against their objectives. In general the subsystems will tend to be interdependent (i.e., the activities of one will generally affect the performances of another). The control function is concerned with managing subsystem interactions. In this it is supported by a *coordination function* which provides for direct information exchange between the subsystems so that the capacity of the control function is not overloaded in resolving all subsystem interactions.

Finally, there is an *implementation function* provided by the subsystems in actually carrying out the objectives.

These functions are all somewhat familiar, although often they are somewhat differently defined. We view this list of five as being complete--i.e., we regard all organization actions as being describable in these terms.

We regard system level as having a certain autonomy, so that when its objectives are known it can be analyzed independently of the levels above it. In other words we hypothesize that each of these functions appears at each level. This idea can lead to some confusion in the language of our approach and in that of other approaches. In particular, policy and strategic decisions are sometimes thought of as occurring only at the highest system levels. Here they occur at every level. So that shop scheduling, if one is at the level of the factory, may be just as much a problem of policy and strategic decision as bigger problems are when we are looking at the national system. In the Soviet context we find that the planning system includes elements of the policy and control functions, as well as the planning (intelligence) function.

Using the language we have defined, it seems possible to unambiguously define the systemic function of apparently diverse processes in very different systems--a characteristic that we regard as a great strength of the approach.

Structure of the Analysis

We have suggested that in planning and implementing TPCs, the Soviet system is recognizing an environment of increased complexity. Our analysis will be concerned with the strategy for responding to this. That is, we will consider at what levels capacity was increased. And we will examine the adequacy of the response so that implications can be drawn from future TPC management. Within this general aim the analysis will have several elements.

The first element is to examine the distribution of management outside of the TPC. Of course we cannot do this in absolute terms. Rather we wish to set up a standard against which the new needs, and responses to, the TPC can be compared. At this stage we will examine in particular the units which support the various functions of the national system in its usual operation.

The second element is an examination of the ways in which the BITPC development, and more generally TPC development, add a complexity to system environment.

This complexity has to be met somewhere in the system and the third part of our analysis looks at what the response was in the particular case of the BITPC development. This will involve looking at the response at two levels. We consider first the national system response, and then the capacity of a subsystem concerned just with the BITPC. The main purpose of this section is to provide a springboard from which consideration of future management needs can be made.

A Systemic View of Sectorial Management

Structure

A constant theme of this paper is that the creation of a TPC makes new demands of the Soviet planning and management system which differ from the demands that system must meet in the course of its sectorial operations. An analysis of this proposition must begin by inquiring into what we regard as normal operation. We take this to be a primary division of economic investment along sectorial lines, with sectors rather than the center bearing the main load of elaboration of particular projects and responsibility for their implementation. While it is true that throughout Soviet history particularly important projects (be they concerned with regional development or quite different objectives such as electrification) have attracted concern from the center, it appears to be the case that the bulk of investment in the modern Soviet economy is correctly described as managed through sectorial structures.

In the language we use for analysis, we are saying that the sectors are subsystems of the national system (Figure 15).

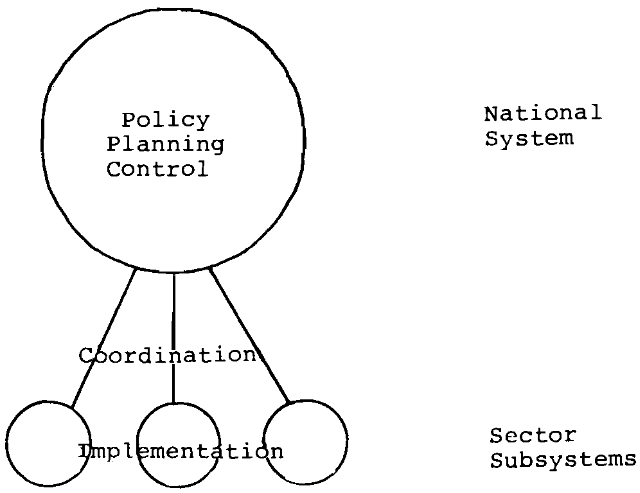

Figure 15.

The national system sets objectives to the sectors. These take the form of control figures to be achieved. But the task of elaborating these objectives and choosing between different ways of achieving them rests with the sectorial Ministries.

In addition to these sectorial subsystems, the Soviet system has other subsystems concerned with territorial management. But for the moment we will focus on the sectors.

Referring to the five functions, we can say that setting sectorial objectives is the policy function of the national system. The policy function is supported by an intelligence function that explores the possible alternatives. Having set the sectorial objectives, the national system will need a control function to provide resources to the sectors on the basis of these objectives and to monitor the performance of the sectors against objectives. It will need to provide a means by which the sectors can coordinate their activities. And, finally, from the point of view of the national system, the sectors are the means for implementing the objectives.

Functions within the National System

In this section we make some assessment of the distribution of the functions of the national system among the various organizational units comprising the system. We are using the term *national system* to denote the level at which tradeoffs are made between alternative ways of achieving national objectives, and where decisions are taken that provide the objectives to subsystems, such as national Ministries. These decisions, of course, take into account the views and proposals that the national level receives from lower levels, and in this sense many organizations at different levels of the system can be thought of as contributing to these decisions. However, responsibility for decisions on issues of this kind lies at the national system level.

A comprehensive account of functional capacity at the national system level cannot be given here for two reasons. First, the scope of our study did not allow us to become familiar with all of the units operating at this level. We can be sure that any list we give will be incomplete. Secondly, we find that there is no real correspondence between organization units and organization functions. Instead we find that a particular unit, for example, GOSPLAN, is providing the system, to some extent, with the range of functions, policy, intelligence, control, and coordination. A comprehensive description would have to take account of this.

Despite these limitations there does seem to be some value in providing an overview of the organizations with an apparently major role in providing the national system with capacity along the various functions. In this manner we provide some additional insight into the meaning of each of the organization functions.

Policy capacity at the national level, i.e., the authority to take decisions that set objectives to the subsystems, resides mainly with the Supreme Soviet, the Central Committee of the CPSU, and the Council of Ministers. When GOSPLAN is involved in determining ministerial objectives at a greater level of detail than that ratified by these three higher bodies it, too, is exercising a policy function.

The provision of an intelligence function providing support for policy decisions is a major role of GOSPLAN. Without the schemes and draft plans that GOSPLAN prepares it would be difficult for the higher bodies to take decisions. In turn GOSPLAN is supported in its task by a range of research and design agencies subordinated to different bodies. The process of preplanning, which we have previously described, is making a major contribution to the intelligence function of the national system.

The control function of the national system is concerned with providing resources to the subsystems so that they can achieve their objectives, and monitor subsystem performance against objectives.

The Council of Ministers and the Central Committee of the CPSU play some role, although in quite different modes, as does perhaps GOSPLAN. There are also nonsectorial Ministries whose major function may be control. The Ministry of Finance is likely to be a particularly important example of this. We have also learned of a People's Control Organization who provide control capacity in connection with particular projects. Finally, we would include the State Committees which exercise control over specific areas. For example, the State Committee of the Council of Ministers of the USSR on Material Technical Provision (GOSNAB) is concerned with distribution, the State Bank of the USSR (GOSBANK) with money flows, and GOSSTROI with construction and other standards.

Moving on to the coordination function we can again identify the Council of Ministers, the Central Committee of the CPSU, and GOSPLAN in their respective roles. In coordination these bodies are supported by a multiplicity of special commissions, some long-standing and some created for a specific purpose and short-lived. In addition, we have to take account of the Central Statistical Office which, through collection and distribution of statistics, plays a coordinative role.

While these comments will have provided some feeling for the complexity of the national system, we would emphasize again that as this was not the main focus of our study, they are not intended to be comprehensive.

Capability of the National System

According to our framework the need for capability of the national system is determined by the level of detail of the objectives it sets to its subsystems. For example, if objectives are set in very general terms the main responsibility for the elaboration of objectives and detailed control falls onto the subsystems. If, for example, a sectorial objective were set only in terms of a single output figure, say tons of steel, the intelligence function of the national system would not need to be involved in questions of where that steel should be produced, or what should be the mix of steel products. It would also not become involved in detailed national balances for steel products, but only in the balance at the level of bulk steel demand.

Also in a case where the objectives were set in a few parameters, the job of monitoring the sector's performance would be reduced. Further, because a general objective would allow a sector many possibilities of responding to changes in its own environment, in general the control function of the national system would be less involved in dealing with sectorial deviations from objectives. General statements of objectives also provide the sectors with increasing possibilities to take account of the activities of other sectors.

In the converse situation, if sectorial objectives were set in specific terms essentially opposite comments would apply. It should also be noted that as objectives become more specific, the demands on the national system grow very rapidly. This occurs because that system level would deal with not only increased detail for each sector, but also the multiplicative increase in intersectorial interactions that this higher level of detail engenders. In this manner the framework provides a basis for a more detailed understanding of the dynamics of the challenges.

Our view is that in the case of sectorial operations we can consider sectorial objectives as being set in general terms, and the demands on the national system for planning and control are rather relatively limited in comparison with the demands set up by the concept of TPC. This view must be carefully interpreted. On an absolute scale, and relative to anywhere else in the world, the demands on the system are high. The term "relative", therefore, is referring to the case of the TPC which is discussed in the following sections. The relatively limited demands on the national system arise from three particular conditions.

First, for the general run of industrial investment the emphasis is on the creation of somewhat separately justified new constructions, so consideration of the complex effects of one investment upon another are limited. Hence, the investment environment is somewhat straightforward.

Secondly, in planning for sectors we have learned of the advanced state of sectorial mathematical models which could assist management in meeting the complexity of their task.

Finally, in meeting the complexity that does exist, the center can take account of the capacity of the Ministries which have large planning and control capacities.

However, while general objectives to sectors reduce the need for planning and control capacity in the national system, they can imply a high need for direct coordination between the sectors. The need for this will depend upon the perceived interdependence of the activities for which separate sectors are responsible.

While we have little direct evidence of how coordination works between sectors, our interviews have suggested that it is an area which is occasionally problematic. This must be viewed in a context of legal objectives (provided by the plan) to the sectors, with control focused through sectors. It is therefore natural that sectors should try to get under their direct control all factors affecting achievement of objectives rather than depend upon the actions of other sectors. This is because the result of coordination may not generally be an outcome favorable to the objectives achieved by a particular sector, but is justified rather by benefit to the economy as a whole. For example, a slowing down of dam construction to allow an electricity-using aluminium producer to be ready at dam completion offers no benefits to the electric power sector. If, as a result, the dam is finished after the planned date, clear "disbenefits" to the sector may be perceived. Also, the size of the sectors, the fact that managers in sectors receive their training and generally spend their whole careers with the sector, may be instrumental in creating a "sector mentality".

While discussing coordination we might also observe that in the context of the Soviet system it may prove more natural, and easier, to increase the system control function rather than coordination. The plan is a very specific and powerful legal mechanism for setting objectives to a subsystem, and no problems in principle arise in creating bodies which distribute physical resources according to the plan and monitor programs against it. No parallel mechanisms seem to exist with equivalent influence to achieve coordination.

We will conclude this section with the supposition that the capacity of the national system has evolved to meet the needs of the normal investment patterns in the Soviet economy. In this context we can say that the need for planning and control capacity of the national system is moderated because it is able to set objectives at a general level to the sectorial Ministries. Our impression is that the largest part of the complexity is then managed within the sector. This is possible because the sectors are themselves very substantial organizations, and their capacity need be focused only within sector objectives rather than on the whole range of national economic possibilities. Only in meeting the need for coordination do we have any indication of strain on the system, but this falls short of a conclusive indication of a system problem.

We will proceed with our analysis by inquiring into the new demands embodied in the TPC concept, and how the system, which evolved mainly toward sectorial management, has responded to meet them.

The Complexity Introduced by a TPC

In the language of our approach the management challenges of a TPC represent an increased environmental complexity that has to be met somewhere within the management system. Just as one can identify different challenges, so can one point to different aspects of the task which give rise to increased complexity. In the Introduction to this paper five such management challenges were described. For purposes here, they have been consolidated into three: *choice of industry of national specialization, definition of infrastructure* and *completing industry,* and the *synchronization of implementation.**

Complexity of Defining TPC Specialization

The usual investment projects can be separately justified using norms for capital efficiency indicators. In these cases the total cost of a project can easily be computed because the incremental infrastructure associated with a new plant can be identified with some degree of certainty, and in any case for developed settings that secondary part of the cost is small. With TPCs in Siberia the proportion of infrastructure costs is considerably higher and is more difficult to allocate piece by piece to particular industrial projects.

Within a TPC, a project by project assessment of proposals is almost antithetic to the TPC concept which seems to us to embody direct consideration of how each project supports and is supported by all the others. Only in the initial foundation objects, for example in the BITPC--the Bratsk HEPS, is the decision to build likely to be justified on its own. For the rest, management can no longer depend on fairly simple formulae to handle the complexity of this class of investments. The powerful mathematical models that one needs to have are in process but not yet in use by policymakers.

The type of decisions that are required to meet this new complexity are not, by their nature, ones that are made everyday. In the context of the Soviet planning system they are decisions to be made in the preplanning stages. Although in the course of TPC development new objects of specialization may be added, we might expect that the substantial part of these decisions will be taken at the early stages (or even prior to) formation.

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*See Figure 2.

Definition of Infrastructure and Completing Industry Needs

Unlike normal investment in national industries in developed regions, where the existence of the social infrastructure and the secondary industrial activities to meet community needs can be assumed, in TPCs such objects are created alongside the objects of specialization. The new symbiosis between these two types of activity adds a complexity to planning social infrastructures and completing industries. Towns have to be created rather than local settlements, the supply of social infrastructure has to match the needs presented by the national specialization objects. Completing industry, in addition to satisfying the need for particular products, have to contribute to producing a balanced, complex community, for example, by providing jobs for second and third members of families.

While, in a sense, these needs are determined from the moment objects of specialization are conceived, their implementation must take place as the specialization objects are implemented. Hence complexity arises in planning for the various kinds of objects as the TPC is created. In the Soviet system this complexity might be met through the planning cycle as well as through preplanning procedures. So, unlike the case just considered, it is not a complexity arising primarily at the very early stages of (or prior to) complex formation. Rather it is a constant source of complexity, perhaps increasing in the middle stages of formation when many activities are ongoing.

Complexity arising from the Need for Synchronization

The time dimension acquires a particular importance in TPC formation. For example, not only must the right amount of infrastructure be provided but it must be provided at the time when it is needed. With sectorial objects, too, in the formation stages of a TPC a need for synchronization arises which is not characteristic of constructions in a developed setting. A primary example from the BITPC was the need to clear the reservoir site of timber before filling the HEPS reservoir. Once the HEPS is complete, however, no such close interactions occur between timber felling and electricity production. Since many objects will be sharing the same construction resources, a careful phasing of the allocation of resources is necessary to prevent waste. Again, this demand for phasing is of a degree which is untypical in normal developments, and adds a considerable complexity to the management task. It is a complexity which increases through the early stages of TPC formation, and is at its peak at the peak of construction activity and diversification. The planning process, particularly through the annual plans, can take account of some of this complexity. However, we might reasonably expect that it will call for management decisions between plans and perhaps of a day-to-day operational nature.

These, then, are the ways in which TPC generates a complexity that needs a management response. In the particular case of the BITPC, it may be unreasonable to deduce that all these needs were perceived. To an extent they reflect a current perspective of a TPC, which differs from the way in which the multiobjective development around the Bratsk HEPS was conceived in the late 1940s and early 1950s. Nevertheless, the analysis of system adaptation in meeting this development is instructive in identifying further adaptation implicit in the current TPC concept.

Systemic Response to the BITPC

Systemic Structure for the BITPC

We have noted the increased environmental complexity associated with the BITPC, and that in general the response to that complexity might occur at several levels within the system. The particular way in which the BITPC has been planned and managed suggests a rather different distribution of response than we find in the more usual case of sectorial investment. A simplified version of how we consider a multiobjective scheme such as the BITPC would look when handled in this more usual way is given in Figure 16. However, in dealing with the BITPC we observe the following changes.

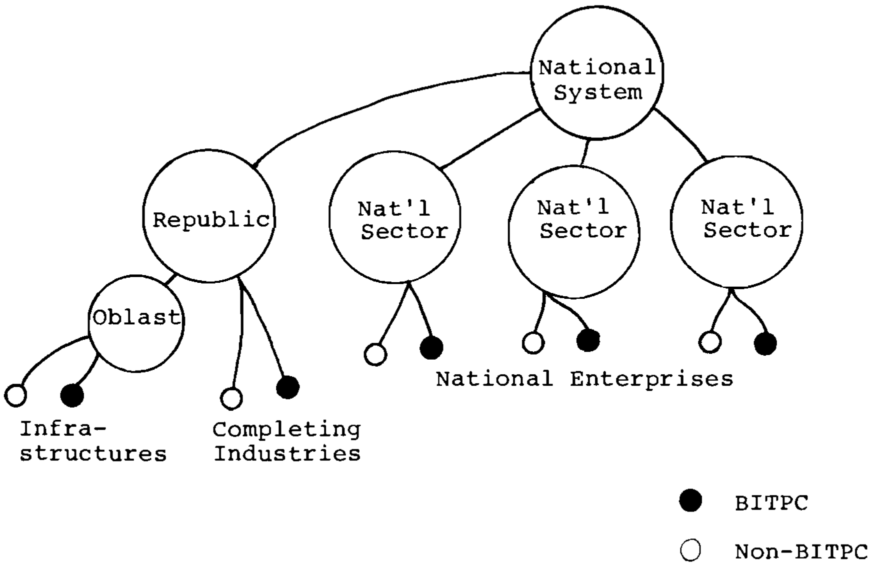

Figure 16. Scheme of one possible sectorial response to the BITPC.

First, the national sectors no longer behave as a distinct system level. The rationale for generally thinking of the sectors as a separate system level is the policy discretion that they have to choose between alternative ways of achieving their objectives, which were set in fairly aggregated control figures. Research and planning capacity, which is under the control of the Ministries, generally supports these decisions. In the BITPC case, where sectorial objects are concerned, these objectives are largely defined by the national system. Thus, for example, the nonferrous metal industry is asked to meet a set of control figures, as well as to place an aluminium plant in a particular location, the size and other parameters of the plant likely to have been already determined. So, for this particular plant, it seems most appropriate to regard the Nonferrous Metal Ministry as providing an operational control capacity to the national system to ensure that the specified national policy regarding aluminium is carried out.

The design institutes of the Ministry will be involved in determining the need for such a plant. However, instead of supporting the Ministry's policy capacity to choose between different ways of achieving objectives, they will be involved in supporting national policy on the specialization of the BITPC, which includes more than just aluminium production. The example of aluminium is, of course, paralleled by all other objects of national specialization.

Secondly, when the Republic bodies are considering the need for completing industries the emphasis appears to be on meeting the specific needs of the complex, rather than on considering the complex as one possible location among several for supplying particular goods required within the Republic or the oblast. For example, local industry such as food production is largely geared to meeting the needs of the TPC. Even where such industry supplies a wider area, as for example the meat processing plant, building the plant was justified in terms of the demand on the BITPC territory. The clothing plant in the BITPC is an example of a completing industry which provides for a larger market. After production and siting considerations, the construction of this plant was justified in terms of providing jobs for second and third family members, in addition to supplying this larger market.

Similarly, in considering infrastructural needs for the TPC, the oblast considers the BITPC as a unit. Because there are no tradeoffs to be made between infrastructure on the BITPC territory and infrastructure elsewhere, the oblast is not behaving as a separate level above the TPC.

In the cases of infrastructure and completing industries, we can think of the bodies involved as forming part of a local system concerned only with the BITPC. This is different from their more usual roles, when the competing interests of many parts of the Republic may be considered.

We can go one step further. The needs for this type of investment arise totally from the direct and indirect demands made through the decision to locate a national specialization enterprise on the territory. In a sense the territories are elaborating in ways relevant to them implicit objectives or needs arising from national level decisions on specialization. For this reason it is justified to consider the local system concerned with the BITPC as being directly embedded in the national system. Again this is different from more usual cases when the oblast would have its direct embedding within the Republic subsystem. These ideas are summarized in Figure 17.

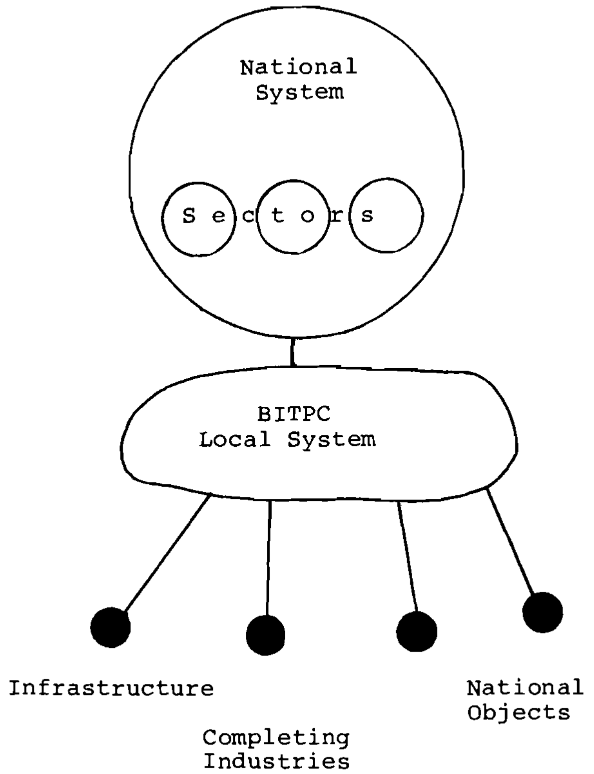

Figure 17. Observed systemic response to the BITPC.

It differs significantly from Figure 16 and this change represents a particular systemic response to the BITPC. We are now concerned with two system levels--the *national level*, and a *level local to the BITPC*. The response to the environmental complexity of the BITPC will be distributed between these two levels. In the following stages of the analysis we will examine, in turn, the response at each level.

National System Response to the BITPC

Since the BITPC is conceived as a strategy for meeting national economic goals, the need for defining objects of specialization lies with the national system. This section examines the ways in which its intelligence and control capacities were expanded to meet this need.

The *intelligence function* at the national systemic level is carried out through the preplanning process and the production of the five-year plans. The planning response of the national system must primarily meet the increased complexity arising out of defining objects of specialization. Since this need arises very largely in the early stages of TPC formation, we are making a large jump in expecting the experience of development around Bratsk to provide a good model. Clearly, even 25 to 30 years ago very substantial research resources were directed at this development. Supporting the national system are the many scientific institutes coordinated by SOPS, KEPS, and other organizations including sectorial institutes; the latter institutes were probably separately supporting specific aspects of development as well. Although the task of definition is complex, there appear to be substantial resources available to the national system. Probably nowhere else in the world could a more impressive array of research capacity be related to a national development problem. Somewhat unclear is the extent to which this was focused on Bratsk-Ilimsk as a particular object. One example of a specific focus is the special commission, headed by a senior member of GOSPLAN, which visited the territory in the 1960s to provide policy support for the further development of the BITPC. Other commissions or studies seem to be concerned with the BITPC development only as part of a larger context--e.g. East Siberian development, Angara-Yenisei regional development, or development of the BAM.

While the work coordinated by SOPS in the late 1940s undoubtedly provided support for eventual development, the main objects of the Bratsk's development seem to have received their most concrete expression through a scheme elaborated by the Gidroprojekt in 1953 [5]. We are unable to assess the extent to which this drew on early work. The special commission referred to above reported to the GOSPLAN department concerned with power rather than that concerned with regional development; this, too, suggests that the full resources available to SOPS and fed into the GOSPLAN regional department may not have effectively been brought to bear on the BITPC as a complex unit.

Moving to the present time we find indications that the further development of the BITPC is not fully supported by the preplanning process. At Bogouchany a new dam is being built supported by the BITPC resources. However, although the construction phase has been started we were told that it was as yet unclear whether or not a Bogouchany node would eventually form part of the BITPC.

The lack of obvious integration at the preplanning stage may make it more difficult for the BITPC to be considered a whole within the State five-year plans. We have learned that in GOSPLAN documents there is a unified representation of the BITPC. This occurs in the Territorial Department of GOSPLAN and includes totals for the volume of capital investments, amount of labor, and volumes of production by major sectors. However, these seem to be prepared primarily on the basis of addition of separate sectorial and territorial lines. Our interviews within GOSPLAN suggest that there is no capacity to take a unified view of the BITPC prior to sectorial planning in such a way that would provide a logic according to which sectorial activities of the BITPC could be planned.

In reviewing the intelligence capacity of the national system to set specific objectives for BITPC development, we found no lack of planning resources, but rather a lack of a framework through which these resources can be specifically focused on BITPC development. This lack seems to persist to the present.

We can move on to examine the evolution of the *control capacity of the national system* to meet BITPC demands. We observe a capacity that is matched to control objects separately conceived rather than that matched to control complex formation. Because Bratskgesstroi is subordinated to the Ministry of Power, the Ministry is exercising control over BITPC activities. However, other Ministries also exercise control over their own particular objects. These Ministries thus add to the control capacity of the national system. However, the lack of an integrated statement for the BITPC in the five-year plans leaves these separate control agencies without an overall logic to meet complex effects.

The new interdependencies between BITPC objects greatly increase the demands for coordination among Ministries. This relates not only to specialization objects but also to infrastructure which, although designed outside the national system, is funded and largely controlled by this system. Altering the rates at which individual specialization objects proceed can undermine assumptions on which social infrastructure plans were based and lead to unbalanced development. Few new mechanisms seem to have been created that can provide a new unity at the level of annual plans. One mechanism should be mentioned which we were told about but have not been able to assess. The annual objectives of Bratskgesstroi are determined by the Ministry of Power and agreed by GOSPLAN, but proposals are put to each of the other Ministries involved for comment. This is one way that coordination of control could be achieved at the annual level, at least between sectorial objects. It is more doubtful whether the needs for social infrastructure could be adequately considered in this process.

In summary, we see a substantially unmet need to provide the national system with a mechanism for coordinating sectorial control agencies and for meeting the added complexity of TPC formation. Outside the Ministries we observe no unit that appears to exhibit the potential for this control capacity. Thus this function may have to be met through organizational innovation.

The Capacity of the BITPC Subsystem

In this section we will examine the extent of development of a local management system for supplementing the national system in meeting the complexity of the implementation of the BITPC. "Local management" is used in the sense of management focused only on issues related to the development of the complex, rather than on the consideration of these issues together with other national concerns.

We have seen that the objectives of the TPC are set in terms of particular objects of national specialization. This limits both the extent of *policy discretion* and the need for *intelligence capacity* which can exist locally; however, the view of the local system can influence specialization. The policy capacity that exists is related mainly to the complexity associated with the creation of balanced complex communities. This is reflected in producing infrastructure plans which meet local demand in an acceptable way, and in producing initiatives for completing industries which meet other complex needs. The example of the clothing plant has already been noted; the creation of an agricultural base to sustain the BITPC population and the inclusion in Bratsk of a polytechnic institute to provide needed skills are additional examples. For all of these issues the Irkutsk Oblast is the most important unit. It has policy authority either directly or indirectly through its influence at the republic level where the policy authority resides. Only within the Oblast did we find consideration of the BITPC as a whole. Although the planning and intelligence capacity of the Oblast Planning Committee is limited in these issues, it receives support from other units. In the design of the towns it receives support from GIPROGOR.

This support extends to issues that are outside the policy discretion of the local system, but allow the local system to express views which may influence national decisions. For example, suggestions for the inclusion of a chemical complex on the territory seem to have been initiated locally; the national system does not as yet have data to justify the efficiency of this specialization industry, and it is now being discussed at the national level and may be included in future plans.

The local system appears to have meaningful policy capacity to deal with some aspects of the BITPC complexity; we turn now to consider the *control and coordination functions of the local* *system*. Because many of these aspects are funded through the national sectors, and because the construction agency is controlled by the national system, possibilities for realizing local policy objectives may be more limited.

Although shorter-term plans provide the major means for operational control, these are generally produced within sectors. In considering complex effects a more relevant instrument for operational control is the one-year plan. For the construction activities on the BITPC territory the relevant one-year plan is that of Bratskgesstroi which is approved finally by the Ministry of Power; the OBPLAN must also approve environmental and urban dimensions. The rate of infrastructure construction provided for in the annual plans depends upon the rate of construction of the separate sectorial objects that give the funding. The infrastructure plans are updated each five-year period to provide consistency over this period with the five-year sectorial plans. However, there is evidence that along the period the assumptions made about the progress of sectorial development progressively diverge from the cumulative of the annual plans for sectors. This gives rise to a progressive divergence between infrastructure plans and infrastructure funding which cannot be resolved in drawing up the annual plans. (The reworking of infrastructure plans on a two-year rather than five-year basis has been suggested as a possible solution.)

Where deviations occur within one-year plans, necessary control may be initiated by the national system through short-term plans or by the local system, mainly through Bratskgesstroi. In fact, we did not find a comprehensive capacity in the TPC to so define priorities among activities. In constructing sectorial objects, Bratskgesstroi is dealing with local enterprises which are characterized by strong vertical links to the Ministries. Thus, for example, changes in the rate of construction of the aluminium plant would have to be approved by the aluminium department in Moscow. Sectors that disagree with any reallocation that Bratskgesstroi makes can appeal to the Council of Ministers, thus reducing the effective application of discretion by Bratskgesstroi. The direct subordination of this agency to the Ministry of Power has also lead to suggestions that it may favor power interests over other interests. Nevertheless, there have been clear examples where local priorities have been defined by Bratskgesstroi, supported (in housing matters) by the Direction of Housing. The creation of this multipurpose construction agency appears to be the most significant innovation toward achieving an appropriate degree of local control and coordinative capacity.

An indication of a limited control role at the local level can be found in the planning for the construction of the town of Bratsk. The town plans were drawn up based on forecasts of population age structure, which turned out to be incorrect. As a result not enough child care facilities were initially included in the plans. Over time these deficiences were, of course, corrected but this involved a reallocation of funding by the

Ministries. While the local system should be involved in perceiving the need for this correction, it did not have the capacity to implement it without the approval of the national system.

A further innovation has more recently come about on the territory: the creation of the Board of Directors. The Board has no formal powers, but has a strong capacity to influence operational decisions. It meets once a month and has been described as a first attempt to create a unified management for the BITPC. At the moment its primary role seems to be coordinative.

The Soviet system has an additional mechanism, not yet mentioned, to support the decision process. The organization of the CPSU maps the already described management structure. The complexity of its organization is huge. The CPSU at the City of Bratsk is supported by professionals and scientists spanning the different production activities and social aspects of the city. They will normally be aware of problems, opportunities, and challenges; presumably they will find their way both to support coordination and to report these aspects to higher levels. The CPSU has always exercised its policy through decisionmaking bodies. In this way, the Party is providing not only a mechanism for local coordination but also a channel to the national level for information on complex formation effects that would otherwise not reach this level. Since these effects do not follow directly from the formal objectives set for other local organizations, they would not, therefore, be reported on by them. The Party may be viewed as strengthening the management mechanism. No doubt the directives of the 25th Congress of the CPSU to improve the management of TPCs reflect in some way the role of the Party's territorial branches.

In summary we can say that organizational innovation, supported by organic growth of local bodies, has provided the BITPC with a capacity for self-management. This is seen mainly with respect to policy for infrastructure and other aspects of complex community formation. However, the particular way in which these aspects are funded by national enterprises has limited the possibilities locally to ensure effective implementation. In addition, the close links between local enterprises and their parent (national) Ministries and the specific way objectives are set may have inhibited the growth of local control capacity within Bratskgesstroi.

Summary

It is inappropriate for us to make any assessment of the BITPC on the basis of the limited study we have made. However, it is useful to compare the implications of our analysis with the very frank comments of our Soviet sources.

We have reached some conclusions on the response to the additional environmental complexity of the BITPC within the system. The complexity arising in the definition of the BITPC specialization has been responded to entirely by the national system. The second cause of complexity, that of meeting the need for complex community development, has been met by a local system as far as policy is concerned, but the implementation of this policy is largely controlled by the national system through sectorial funding. The complexity of achieving synchroneity has been responded to within both the national system and the local system. Figure 18 contains the main elements of these responses and indicates the processes that have been used to realize them. It is, of course, a somewhat simplified version of the fuller picture that has already been presented. We examine, in turn, the response to each of the management challenges.

The definition of complex specialization places very great demands on the planning resources of the national system. In fact, considerable resources through the many research institutes are available, and it is difficult to assess whether the demands could potentially be met. It is probably true that as techniques improve, for example as more sophisticated mathematical models become available, there will be more confidence in the efficiency of the TPC development. For the present, however, the main problem with the BITPC seems to be an insufficient focus of planning capacity on that particular object. In particular, there is no general scheme for the TPC which could provide a policy framework for later results of that focus. While the BITPC was largely defined over 20 years ago, current uncertainty regarding the efficiency of the Bogouchany HEPS raises questions for the present.

Turning to the second challenge, that of planning for complex effects of town construction, we have identified the oblast as playing the key role. Our analysis leads to no obvious inadequacies in this response; however, actual experience is mixed. Together with notable successes we find questionable areas. This relates not only to the past but recently to Ust-Ilimsk HEPS.

In the words of A.N. Semionov, Chief of Bratskgesstroi [7]:

> Unfortunately, Bratsk's errors were repeated also in Ust-Ilimsk. In developing the technical economic basis for building a HEPS, not a single department gave notice to its enterprises, and thus the draft plans did not provide for cooperation in building common production facilities and engineering installations, and in building up a transportation network and the city.

The final comment regarding draft plans for the city suggests that the role Irkutsk Oblast plays is not sufficient. This is possibly because the national concern for the key specialization objects and the concern of the Ministries to minimize costs, or take a rather narrow view, prevail, despite laws defining its rights.

Management Challenge	System Responding/Functions	Process
1. Defining Specialization	National - Policy and Planning Functions	Preplanning stages State long-term and Five-Year Plans
2. Defining Complex Community Development (a) Infrastructure; (b) Completing Industries and other	Local - Policy and (Oblast) Planning Functions	Local preplanning Drawing up of town plans Local Five-Year Plans
3. Synchronization of Construction (a) between sectorial objects; (b) between sectorial and territorial objects	National - Control Coordination and Local - Control Coordination	Annual Plans for Bratskgesstroi from Ministry of Power Operative Plans Operational decisions of Bratskgesstroi Direction of Housing

Figure 18. Scheme of organizational response.

However, it is with the third area of complexity, that of meeting synchroneity, that our analysis is most suggestive of inadequate response. This complexity is dealt with both at the national level and at the local level. The influence of the local level is more focused on short-term considerations, that is, within the annual plans. Definition of the annual plans is a demand mainly on the national system. Here the only response we have found is in the procedure for reaching agreement with respect to Bratskgesstroi's annual plans, led by the Ministry of Power but involving other customer Ministries, territorial bodies, and GOSPLAN. We do not know how well this works for phasing sectorial objects against one another, but we do have evidence concerning the social infrastructure. The rather rigid way infrastructure funding is allocated limits the flexibility of rates of infrastructure construction. No capacity exists to exercise independent control over this key factor. We assess this as the main explanation for remarks such as these by Bandman: "For the present infrastructure is one of the bottlenecks in the process of assimilating the new areas."

Within the local system elements exist which make a significant contribution to the management of aspects of the environmental complexity. Key among these is Bratskgesstroi; the Board of Directors and the Direction of Housing also make contributions which are limited, however, because of the constraints in the objectives set by the national system--explicitly in terms of specialization objects and implicitly through these objects in terms of the social infrastructure. Overall, our analysis suggests that the national system response is not quite sufficient to meet the needs following from these rather specific objectives. At the same time, these objectives have had a somewhat inhibiting affect on the growth of capacity of a local system.

We would end our analysis by following others in emphasizing the magnitude of the achievement in the BITPC. Comments that relate to problems cannot diminish this achievement, which is a solid reality. We have taken this for granted and have proceeded in the spirit of the many Soviet scientists concerned with TPC, with the aim of producing positive indications for future management development.

Within the Soviet Union there is an awareness of many of the points we have discussed in the course of the analysis. This awareness has led to discussion in the press and within scientific and management bodies on how TPC management can be strengthened. In the following section we will examine several suggestions that have arisen in these Soviet discussions.

Future Management Alternatives for TPCs

Approach

A TPC is an evolving concept in the Soviet economy. Our analysis has been directed toward elucidating the present level of realization of the concept, from the organizational perspective. In doing this we have taken as our reference the characteristic challenges of TPCs, identified earlier, which we assume would be fully met for effective TPC development. In fact our analysis has indicated that in the BITPC case these are not fully met, and this is consistent with opinions expressed by many in the Soviet Union who are involved with TPCs. The directives of the 25th Congress of the CPSU relating to TPC management may be taken as recognition of these problems.

In the course of our study, both from discussions and published material, we have noted many suggestions from Soviet planners, managers, and scientists for strengthening TPC planning and management. It is likely that many more possibilities exist which differ from one another to a greater or lesser degree. However, here we will focus on just three types of suggestions that are representative of the larger range of possibilities we encountered, and represent the most important ways of meeting TPC challenges through the different system levels.

The three suggestions are:

- *Strengthen preplanning and planning of TPCs only at the center.* The supporters of this proposition do not think that the creation of a "management body" for each TPC is necessary. Rather, the emphasis is more on improvements of existing planning mechanisms.

- *Create an "operational management body" for TPCs.* This body would be responsible for solving questions of capital construction and the formation of infrastructure. It would be subordinated to the Regional Executive Committee, i.e. the oblast, and would have the right to apply directly to the GOSPLAN and GOSPLAN RSFSR to solve various problems of sectorial specialization.

- *Create a "comprehensive management body" for TPCs.* This has been suggested in the form of a Soviet of Working People's Deputies for each large TPC, consisting of a "planning committee" responsible for arranging the whole process of preparing and creating the TPC. It would support the different sectors by providing them with additional information, coordinate the preplanning process, control and implement plans, and be responsible for the economic development of sectorial and completing industries, social and technical infrastructures, and environmental protection.

The challenges that have to be met--the synchronized implementation of sectorial programs and the social and technical infrastructures, the preparation of plans and their substantiation--are continuous processes supported by existing organizations. If the phasing of implementation is poor or if the substantiation of plans and related decisions are considered inadequate, in principle there are many alternative strategies to improve these processes. In our analysis we have indicated that these strategies correspond to different ways of distributing the response between system levels. However, in practice not all of these possibilities may be equally realizable. Among other things structural (e.g. the country's administrative structure), informational (data availability), and technological (availability of computers and models) factors may all act to limit the possibility of a particular strategy to contribute to better TPC planning and management. The approach used in our analysis allows us to address such issues. In our examination of the three strategies mentioned above, these factors will be considered.

Strengthening Preplanning and Planning of TPCs in the National System

The strategy implicit in this proposition is to meet the managerial and planning challenges by increasing the capacity of the national system. As our analysis has indicated, this would be a direct development of the strategy hitherto adopted. The emphasis here is on improving the process at the center which supports the plans for a TPC. This suggestion does not address the implementation of these plans.

Strengthening of preplanning and planning might actually suggest the preparation of general schemes, at least for the most important TPCs. In any case it implies a strengthening of the planning function of the national system. Since TPC schemes are essentially multisectorial and sectorial-territorial, it is unlikely that they could be the output of sectorial ministries. Rather a role for GOSPLAN is indicated. The strengthening of the planning capacity might therefore be within the territorial department of GOSPLAN and its research institute SOPS.

In practice, the problem of planning TPCs is so complex that the support of territorial models may be required to justify confidence in the resulting plans. The evidence we have suggests that territorial models are lagging behind sectorial models; thus this alternative implies an increase in research efforts before the territorial dimension can match the sectorial influence in the decision process. However, a trend in this direction and a more explicit consideration of the territorial complexity in the design of sectorial programs should represent a progress in the definition of territorial lines of specialization. Eventually, this should also have a positive impact in the design of the technical and social infrastructures. Standard setting and approvals would benefit from this better understanding at the center of territorial aspects.

Since this suggestion does not relate to issues of implementation, we can assume that control of implementation would be according to present mechanisms. Hence, to the extent that problems are currently observable in this area, if this alternative alone were followed, these problems would remain.

Creation of an Operational Management Body for TPCs

In this type of solution the main directions of specialization of a TPC would still be defined by the national system, but the complexity arising from infrastructure balance and phasing considerations would be met by a local system.

Because specialization is defined nationally, the above comments on the need for more focused preplanning and planning still apply. But here problems arising in operational control are explicitly considered.

This solution involves the creation of some local body with sufficient decision discretion to deal with complex effects related to infrastructure and phasing. The prerequisite for achieving this is a delinking of infrastructure funding from the actual rate at which sectorial objects are created. Effectively, a Soviet infrastructure fund would be created, subscribed to by the national Ministries, but controlled by the local body. Through this step, planning and control of the social infrastructure would be at the same system level.

To give the management body meaningful discretion in allocating resources of TPC territory, it might be necessary to loosen customer-ministry control over their objects, while those objects are being constructed. Hence, the time for ministerial comment would be when the annual construction plans are being drawn up.

The new management body might also be the sensible authority to which an agency such as Bratskgesstroi could be subordinated. This does not necessarily imply that the body would take over the role of infrastructure planning from the oblast. However, its embedding in the oblast should support a more effective consideration of the TPC in the planning process.

The strategy of this proposition is to increase the operational capacity of the TPC. The national system might simultaneously improve its decision mechanisms relevant to TPC formation. Although this arrangement does not alter the logic of the system of planning, it could create some problems of control at the national level.

If the management body is going to exercise operational discretion, sometimes against the wishes of individual Ministries, then clearly it must get its authority from a high level. GOSPLAN seems to be the most appropriate agency. As a minimum, GOSPLAN would be involved in formulating the annual plans for the management body, and may be further involved if conflicts arise due to deviations occuring from those plans. Especially as GOSPLAN may be dealing with several such bodies, for the major TPCs, some strengthening of GOSPLAN capacity to meet the coordination and conflict resolution would need to occur. However, if this is feasible, this particular solution to the management of TPCs seems to pose no major problems.

In summary, this proposition is particularly supporting the strengthening of the control and coordination functions in the TPC, thus permitting a more synchronized implementation of sectorial programs and infrastructure. Construction capacity and financial control over infrastructure development would be the basic mechanisms of the management body. The body would have limited policy and intelligence capacity to consider problems of community formation and completing industries. The former still would be the role of the oblast, and the latter of the Republic. The impact of this proposition in the national system seems to be an increased need for operational control at the GOSPLAN level.

Creation of a Comprehensive Management Body for TPCs

Decisions on the lines of specialization of a TPC are inherently of a national nature. There are therefore limitations on the extent to which any body particular to the TPC can fully meet the challenges that the TPC poses. However, within these limitations, the third suggestion sets out to meet TPC complexity. So while policy decisions of sectorial specialization would be made at the center, policies on territorial formation and completing industries would be supported by the creation of a planning and management body for major TPCs. Indirectly, this should permit the evolution of a local capacity to influence the selection and the substantiation of possible lines of TPC specialization.

This body would have the capacity to coordinate the contract preplanning designs, in particular to support community and industrial formations. Eventually this increasing understanding of the TPC planning problems should permit this body to support central planning with local intelligence capacity. In addition, this body would have similar control and coordination mechanisms to those of the management body discussed above.

Altogether a solution of this nature implies a policy and intelligence capacity as well as control, coordination, and implementation functions at the TPC level. While policy and intelligence would be primarily related to community formation and completing industries, eventually it could evolve to influence the preplanning and planning processes of the national system.

The requirements for strengthening control and coordination capacities at the center, which were implicit in the second suggestion, are also implicit here. However, in addition, the body suggested here would, in effect, be a new planning and management level in the system of territorial administration. Problems of consistency with the overall system of planning in the Soviet Union might, therefore, arise.

Conclusion

These suggestions are not mutually exclusive. On the contrary the introduction of any one may support the conditions in which another is viewed favorably. Or viewed simultaneously, two of the above may more realistically meet the complexity of TPCs than any one on its own. However, of one thing we can be confident--the complexity of TPCs is great enough to make any final optimal solution illusory.

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Models for Regional Development Planning

INTRODUCTION AND BACKGROUND

This paper gives a view of economic modeling in the Soviet Union, with specific reference to territorial and regional problems. We have not tried to review all research in this domain in the Soviet Union, as it would not be possible here; rather we have focussed on specific issues and models. We have tried to assess the model system that is being created in one of the strongest scientific institutions in the field--the Institute of Economics and Industrial Engineering (IEOIP) in Novosibirsk. We have deliberately left out or treated in less detail the activities of other scientific institutions so as to present the intellectual framework in which the given model system has been created, since the regional modeling problems of great interest to us are treated more extensively in IEOIP.

The logic of the presentation is as follows: First the problem area is delineated and the major or most difficult questions of regional planning and modeling (as viewed by the Soviet scientists and in our opinion) are specified. Then we proceed to exemplify solutions to the above problems, proposed by different modeling groups. It is at this point that the concept of the model system emerges. A fairly well elaborated solution--a model system provide by IEOIP, and its applications and applicability, described and analyzed.

Subsequent sections include an introduction giving a few hints on the sources of regional problems and modeling implications thereof, together with a short characterization of the organizational framework in which economic modeling for national and regional planning takes place. Finally, discussion is devoted to the modeling rationale underlying the efforts of the Soviet modelers. Different groups of models forming a hypothetical model system, their characteristics and interconnections, are also presented. The state of development and composition of different groups and of the whole set are analyzed.

Attention is also centered on the subsystem for territorial production complex (TPC) preplanning studies. The place and role of the subsystem in the overall system are assessed, and a report is given on the present state of work and possible future developments. Some applications of the regional subsystem are presented, and examples of results are cited. The conditions for application in the real-life planning process are assessed. The final section comments on possible generalizations of the Soviet experience in modeling territorial production entities. They concern both capacities and limitations inherent to models and to whole system construction as well as those resulting from external conditions.

Appearance of the Regional Problem

After a period of domination of sectorial considerations in economic planning and management, regional or territorial problems have made their way to the surface, owing to various social and economic phenomena. Accordingly, a variety of economic and administrative mechanisms emerge or are applied to solve these problems in many circumstances. The same holds for modeling (see [44]). Let us cite *three causes that may bring the regional dimension to the attention of central planners or administrators:*

- *Differences in the development level*, notably present in regions underdeveloped in relation to others (e.g., the Tennessee Valley Authority (TVA) in the USA).

- *Differences in the socio-economic setting and natural endowment* that make it impossible to treat all sectors as if centered on one "average" point (e.g., regionally differentiated countries such as the USSR). In general, differentiation here should be understood not only in geographical terms but also in relation to the socio-economic development level.

- *Presence of opportunities for national development*, usually rich natural resources (e.g., Siberia).

The three cases represent three domains on a certain continuum, where transition is geared by various factors including investment limitations and physical efforts on the national scale, as was pointed out earlier in this Report. Certainly, not all distinguishable regions of a country, their sum covering its whole surface, con be treated as special, even if they should be differentiated in economic planning.

While the case of the TVA and that of Siberia may lead to a regional development program or a project, the case of regionally differentiated countries merely necessitates the inclusion of territorial considerations in national planning and administration. However, there are direct modeling implications for any kind of a national input/output model that one would like to construct (see [16, p. 5]). The need arises for the regionalization of technical coefficients. The cases of regional development programs or projects are usually difficult to account for in their full scope, at the national level (presumably reflected only through changes in investment levels, resources available, migration, etc.), and require special regional project or program models e.g. a network type of model (see [9, p. 71]; [25, p. 958].

Besides the causes that bring about regional problems there are different perspectives from which to view these problems. Different approaches to a solution appear as a result of the conjunction of problems and the perspectives in which they are perceived. Examples of such perspectives are as follows:

- *National investment allocation perspective*--optimization of certain national criteria involving such territorial tradeoffs as environmental protection versus scale or aggregation effect, transportation versus capital investments in processing, labor force availability, and infrastructure problems, etc.--seen in geographical space;

- *Distribution of wealth and growth perspective*--an effort toward levelling out inequalities in job opportunities, social infrastructure, individual and social consumption, etc.

- *Local development perspective*--optimization of certain local criteria within the national framework (see [15], pp. 324-325; [39], p. 33).

Of course, through adequate mathematical techniques all these perspectives could potentially be coordinated, if not unified. In practice, the question is still there as it involves not only one local optimization problem, but also those concerning the entire planning and management system. A number of solutions have been proposed (for gaming models), see for example [22,47], but evidently new mechanisms have to be created for future generations of mathematical models that constitute part of the national economic planning model system. (For further discussion of this subject see [1,29]). This concerns first of all the coordination of the solution of models of lower levels--interpretation of optimal estimates (shadow prices) and the design of consistent optimality criteria. We shall come back to the subject of the objective function in this section when we describe the modeling rationale of Soviet modelers, and thereafter when we speak of the various groups of models in the hypothetical model system of IEOIP.

If the case of a differing socio-economic setting is viewed from the perspective of the national investment allocation, then one easily ends up with a sectorial/regional allocation model for determining the best directions of investment in the space of economic and physical dimensions. When the regional coefficients of a number of industries are influenced by the existence of special opportunities for the development of these industries in a given region (with a resulting benefit to the country), then, in the optimal solution, these industries and the region will obtain more investments with expectations for more output. Furthermore, if the resources are vast enough to justify installation of a complex of interrelated extraction, generating, and processing plants, so that the scale or agglomeration effect gives additional marginal benefits to the national output criterion, we arrive at the concept of territorial production combinations, one of which is referred to as a TPC. The concept consists in stating that isolated sectorial locational optima do not ensure global national optimality in utilization of physically located resources. Additional benefit can be achieved only when potentially interrelated industries are considered together and within the specifics of a given territory. As we can see, the *appearance of a TPC does not require formulation of any objective function qualitatively different from the national one;* this conclusion is corroborated for example by [17]. This issue will be discussed later in this paper.

A number of differing territorial production entities are referred to in Soviet literature. Two levels can easily be identified: the so-called *industrial center* or node, in a spatial dimension usually corresponding to a town or to an interlinked set of towns or agglomeration (hence also called an industrial agglomeration), and the higher level in which the TPC belongs. This rough distinction of two levels refers to an intuitive notion of intraurban and interurban dimension. When we try to go further into details of the TPC definition, we encounter a number of difficulties. Characteristics usually given the TPC (see [9, p. 16]) can be regarded as delimitating only when given adequate measures. Difficulties in the clear-cut definition seem to be prevalent (see [9, p. 15]); proof of this exists in models or methods (e.g. [33]) for recognizing boundaries and qualification of various TP entities. We shall return later to the question of and need for definition.

Internal coherence of the TPC approach to regional development seems to make it one of the most suitable for integrated development planning, especially in virgin territories, as well as for advanced and effective model use.

The approach has been tested for a number of areas in Siberia. The experience gained is of importance and interest not only for planning in Siberia (or even all for national planning) but also as a contribution to the general theory and practice of regional development planning. The concept of a TPC is continuously being improved and elaborated and, since it is a fairly recent one it has not reached full implementation. It is only at the 25th Congress of the Communist Party of the Soviet Union (CPSU) that the directives for the general completion in the near future of the first TPC in the Soviet Union--the Bratsk-Ilimsk (or Middle Angara) TPC were formulated. Any integrated development venture--and the TPC approach among them--must involve the extensive use of planning procedures oriented specifically toward the given object.

If the models are to serve the real needs of planning and managing bodies, their role in linking the governing system should be clarified. In the case of regional models, the question of their relation to sectorial considerations should be answered. In regional planning, emphasis is placed on longer-term considerations rather than on short-term problems. Most of the regional activities take place within the objects of sectorial consideration for all time horizons. While the regional intervention can be quite limited in the short term to local tertiary activities and the coordination of sectorial plants), it certainly cannot in the long run, where the regional structure may undergo essential changes.

Institutional Framework of Long- and Medium-Term Modeling for Preplanning Studies

At this point we want to draw attention to this element of the planning process, which is of interest to us mainly from the points of view of economic modeling, regional development planning, and model systems. Figure 1 shows the set of activities and institutions connected with the elaboration of the General (or Master) Scheme for the Development and Distribution of Productive Forces. In these institutions, which have a modeling input to above, we are in turn interested in the more general model system research. This research is oriented toward creating a unique, consistent model system for all levels and all time horizons of national economic planning (see [14, p. 16]). Therefore we will look at the model application to large-scale planning and at model system creation for these applications.

Recently, the results obtained in the development of economic models--i.e., the introduction of a modeling language and rationale into planning circles and the recognition of the need for systematic tools matching the complexity of the economic tasks--have led to the formulation of the concept of Automated System of Plan Calculations (ASPC). ASPC is meant to become one of the main subsystems of the National All-Purpose Automated Management System*.

Construction of ASPC is coordinated through a central plan, with GOSPLAN playing the major role [27]. Various institutes of GOSPLANS of different levels are given leading roles in the execution of ASPC; for example computing centers such as the Central Computing Center of GOSPLAN, and economic institutes such as the Central Economic Research Institute (CERI) will be the main users, along with sectorial planning and design bodies, of the future system. In December 1976, the so-called first order of ASPC was to be put into operation. This very important step would consist in expert evaluations of a large number of proposals by various institutions, to be included in ASPC within the framework of the coordinative plan mentioned above. Accepted models will then constitute the first order of ASPC. Many of these are currently being used by GOSPLANS and by sectorial institutions, and therefore form the core of the future ASPC. A vast majority of the models currently considered were developed before the plan of ASPC was formally adopted.

On its lower levels and in shorter time horizons, ASPC will inevitably interact with another subsystem of OGAS--ASU**, meant for managerial information and operative planning purposes. Some characteristics of this subsystem will be discussed elsewhere in this Report.

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*The Russian designation for this system is Obschegosudarstvnenjaya Automatizirovanaja Systiema (OGAS).

**The Russian designation for computer use in improving management is Avtomaticheskaya Systiema Upravlenia (ASU).

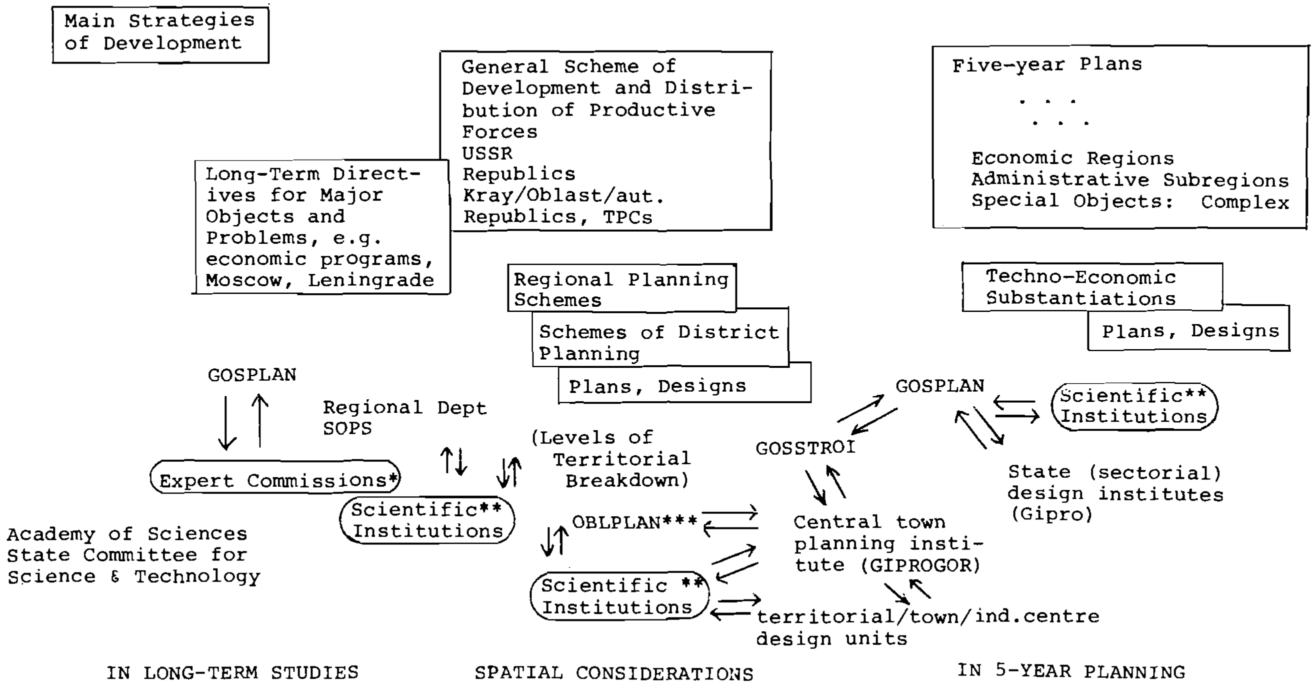


Figure 1. The elaboration of the Master Scheme for the Development and Distribution of Production Forces.

*Participation of personalities from the Institute of Economics and Industrial Engineering (IEOIP)

**The work of IEOIP teams

***Planning unit of the Oblast

The example of a coordinative plan for ASPC construction is a characteristic one for the Soviet Union. Such plans are established for dealing with important scientific problems (i.e., also in the domain of modeling), summing up ongoing research, introducing certain goal orientations on a braoder scale, and for avoiding duplicate effort.

Among the leading scientific institutions where work is conducted on methodological questions of constructing systems of economic models are the following:

- The Council for the Study of Production Forces (SOPS) with GOSPLAN;
- The Central Economic Mathematical Institute (CEMI) in Moscow;
- IEOIP in Novosibirsk;
- CERI in Moscow;
- The Institute of Management and Control in Moscow; and
- The Institute of Cybernetics in Kiev.

Within this partly formalized set of research teams coordinated through the above mechanisms, there is a variety of modeling approaches, resulting largely from the institutional environment of the groups and tasks thereof. We tried to put together a picture of these approaches and their potential outcome.

With shorter-term sectorial planning, the use of models becomes more definite than participation in studies for the elaboration of preplanning documents. A large number of sectorial planning problems have been successfully solved with the help of computer models (see [13, p. 25]). These models, however, still do not enter into the current practice of planning i.e., they are not treated as formal tools. Their importance is nevertheless growing, proof of which is the design of ASPC which will be put into operation at the beginning of the next five-year plan. (Its completion is planned for the end of this five-year period). ASPC should provide the calculatory basis for national economic planning with emphasis on functions performed by GOSPLAN.

To visualize the kinds of models that will enter ASPC, an example may be cited of a model developed together with CEMI. The model is mainly meant for ten-year projections; with its help, however, longer and shorter time horizon calculations have been performed. It covers 100 products, 24 regions, and 7 kinds of resources. The model of the central planner in the form of a linear program (LP), maximizes total accumulation. The sectorial level, determining what and where to produce, maximizes the benefits of the sectors; it has a quadratic programming formulation with 25,000 variables and 2400 constraints. Minimal production levels and maximal utilizations are given for about 20 percent of the goods. All resources consumed are paid for by the sectors. Obtained optimal plans are transmitted to regional models stratum where regional consumption is maximized. Afterwards interregional balance conditions are established. Finally, once again the model of the central planner verifies the sectorial/regional balance, and sets adequate flow limits and transportation prices. The model is currently undergoing tests in the Central Computer Center of GOSPLAN.

Modeling Approaches for Economic Planning

We shall give here an overview of some of the issues that have arisen in connection with model building for economic planning and the way in which they are viewed in the Soviet Union. The discussions concern possible directions for building new models or for changing old ones, many of which though simple have proved useful.

As is also true for other countries, the beginnings of practical national economic modeling in the Soviet Union were to a large extent connected with linear input/output (I/O) formulations which so far play a key role in national calculations as a widely accepted first generation of national models. On subnational levels, beginnings were made with production and transportation linear programs in the late 1950s and 1960s.

Obviously an I/O table represents the state of the economy to the effect that certain amounts of resources and commodities are utilized by given activities, which in turn produce a certain output. There may be several types of relations between utilized input and produced output. It is possible, however, that for the well chosen arguments of the table and a representative time period for which the table was constructed, linear approximations may be satisfactory for some time in the future. Medium- and even long-term linear models should therefore be adequate only if appropriate *balance is maintained between the degree of aggregation* and the *time horizon* (and adequate procedures provide for capital formation and depreciation). This means that for longer time horizons, more aggregated models should be constructed since aggregated sectors of the economy do not undergo abrupt changes (e.g., technological demand) that can occur in an individual branch. Thus, utlimately, propositions are formulated to switch from the empirical to theory-based modeling for long-range models (e.g. [2, p. 127]). The question is whether the degree of aggregation resulting from the above considerations will be satisfactory for planning purposes. This problem becomes even more acute when we take into account the spatial dimensions of the economy, which are indispensable when performing not only forecasting studies but also real optimization of national economy development ([15, p. 323]). *Regionalization* imposes an additional breakdown of the I/O table which may make linearity assumptions obsolete. This is in partial agreement with opinions (see CEMI in [34]) that while sectorial models can and in the nearest future will be linear, the same cannot be said of regional models. The reappearance of the linearity/aggregation problem in long-range perspective may be illustrated by the example of a two-level model described by Alexeev and Kozlov [5]. According to Alexeev, long-term project considerations cannot be based on time-constant activity costs [5, p. 63]. Hence, in the network model of regional project realization *time-variable activity costs* are assumed. It seems inevitable then that in the long-term perspective in which regional problems are seen, disaggregation and related variability, nonlinearity, and uncertainty problems appear. On the national level, long-term considerations make important changes appear in I/O relations.

Long-term national models account for macroproportions of the economy over the next 15 or more years. They should abstract from specific sectors of the economy and deal with functional blocks (various resources, labor force, etc.), though some formulations with a limited number of sectors (30 to 50) point out that the place for classic I/O relations in longer perspective is still seen. This ambiguity is connected with the existing questions of what should be the long-term plan, and how to ensure that the five-year plans be its stages. (See [14] and CEMI in [34].) Changes in I/O coefficients over longer periods in conditions of the Soviet Union (scale of the country, availability of resources, limited ratio of foreign exchange, no inflation) are brought about mainly through technological and scientific progress. We are not speaking, for example, of changes in life-style and in final demand composition, as these are treated exogenously in the LP I/O framework through objective functions and constraints. The need for connecting long-term economic planning with technology forecasting has been emphasized several times. Such connections will allow one to forecast or even plan parameters of I/O tables. This would be an important breakthrough in comparison with usual parameter identification on the basis of dynamic time series. Ways of endogenization of technical progress have not yet been devised, but it is believed that through the application of objective laws of socio-economic development this would be possible (see IEOIP in [34] and [45]). Mathematically, it could be realized through the identification of switchpoints in production function based trajectories. This question is closely connected with the problem of equilibrium discussed below.

Another source of nonlinearities is dealt with in the model system proposed by Albegov [3], which will be described in this section. The model is linked with the boundaries of the linearity zone of a static I/O table. Albegov argues that in reality often the "cost/activity magnitude" relation becomes nonlinear either because of resource limitations or because of high intensity of activity.

More profound difficulties with the use of models that presuppose the existence or the attainment of certain equilibrium (and to which group most of the I/O applications certainly belong) are discussed by Valtukh [45]. The objections concern first of all basic economic justifications for equilibrium assumptions. According to Valtukh, the momentary state of any economy is a result of push-pull influences of equilibrating and disequilibrating forces. Hence, an I/O balance table may ultimately represent the real state of the economy for only an infinite time horizon, which is inconsistent with the linearization prerequisites discussed. Developing further consequences of this view one might state that the I/O relations hold for only unitary activities, while for greater complexes sequential analysis should be performed. Though this methodological discussion is basically outside the scope of this Report, our opinion is that the whole problem can be reduced to a question of balancing technological and other changes against a time horizon and disaggregation so as to maintain fidelity of the model. For the present, the equilibrium concept prevails in modeling formulations (see [39, p. 34; and 47]).

Other questions that arise are connected with human and social imponderables of the economy. These include both the need for a social life which must be taken into consideration in economic planning and which rarely are easily formalizable, and the participation of various people, with differing views and interests, in the planning and implementation processes. Some of the social aspects can be handled as constraints (e.g., on maximum discrepancies in economic growth of various regions). Generally, however, model output is by no means a ready-made plan and modeling, in general, is only an instrument of planning technology, so that the main "social amendments" should be made by human planners. Those involved in economic modeling in the Soviet Union believe that irrespective of the differing concepts and ideas of decision-makers to whom the model results may be addressed, and who can and usually have very profound knowledge of economic processes, there exists a certain level of invariability of model structure (see CEMI in [34]). In socialist conditions this level of invariability may often be so high as to justify neglecting some simulation techniques (e.g., sequence modeling; see [2, p. 133]) that are very popular in Western countries. This is true, for example, for the I/O technique in a planned economy. Indeed, detailed overall balances of raw materials, production, capital effectiveness, etc., were the usual practice of planners long before the introduction of economic modeling. More generally, conditions formed by a centrally planned economy are especially favorable for forming the information base needed for the creation of planning models; as far as the models are concerned, these conditions greatly facilitate a solution to the coordination problem.

Human and social aspects in optimizing models have usually the greatest impact on *objective function* formulations. Recent Soviet modeling literature proves that the problem of the optimal objective function or rather that of consistent relations between objective functions of various models still exists. The solution, at least for national level models, proposed by Fedorenko [15, pp. 87-88] would consist in formulating a set of simplified criteria for which alternative runs will be performed. The final decision will be shaped primarily by the human planner on the basis of the results. Of course, this solution by no means facilitates the problem of intermodel or interlevel consistency of objective functions. The logical and mathematical consequence of each choice of criterion on the national level is the appropriate choice of criteria for other levels. According to Kossov [25, p. 954] there is still no consensus as to what should be the principles of construction of the system of criteria. For an assessment of the general concept see [19,41]. Usually, on the national level the *output objective* in some form is attained, and on the lower levels the efficiency of its attainment is optimized. Such problems can certainly be regarded as dual ones. The main point of discussion here is whether the lower level criteria can really differ from the national ones. This has an important bearing on the understanding of the planning process through its modeling reflection. If optimization of local, together with upper-level, criteria is allowed for on the lower levels, then certainly the plan obtained by running the whole set of models will be nearer to the implemental one, though it will require additional effort in establishing optimal interelement linkages. Implementability could also be importantly increased through the formation of goals (at least partially) along the planning process [38]. Analytic difficulties connected with such formulation would actually lead to simulation approaches. Currently, though, the output/efficiency concept dominates, as we shall see from the examples cited in the next section.

Another new issue related to problems of goals and objectives concerns *goal-oriented programs*. This notion, introduced recently into Soviet economic planning and management, is discussed in detail elsewhere in this Report. At present, there is a search for appropriate methodologies that will allow the introduction of programs into routine planning procedures and a determination of their contents and ways of managing. Programs are regarded as ways of fulfilling the tasks directly resulting from longer-term goals of the social and economic development (see [14] and in [34]). That is, if the longer-term task is identified as being connected with a set of clear-cut objectives to be attained, such that it requires intersectorial cooperation and cannot be easily broken down to quantitative sectorial target levels, it can be treated as a program. Practically, it concerns those situations in which the complexity and magnitude of the task requires abandoning the traditional atomized, sectorial, or territorial methods of management and planning. Progrmas can therefore be considered as medium level in a hypothetical *goal tree*, between major social objectives and sectorial targets. In order to ensure the connection of programs with routine planning, their realization is divided into stages corresponding to planning periods, be it five-years or yearly. More information will be given about the efforts to include goal-oriented programs in national planning models later when we describe the approaches to economic modeling presented by different groups.

Practical questions connected with economic modeling on a greater scale are numerous. Once we go down from national macro-considerations for long-time horizons, there appears the problem of dimensionality, already touched upon in connection with the linearity issue. Currently in the Soviet Union about 20 million kinds of production are recognized. Yearly planning at GOSPLAN involves 800 to 900 variables while five-year plans involve about 300 variables (see [15, p. 84]). Current medium-term models typically account for tens of sectors and from 10 to 20 regions or a few hundred sectors (100 to 200). The question of the number of variables in long-term plans is virtually open; since there is no such formal document, it could presumably be somewhere between 30 and 100. In economic modeling, the problem of passage from aggregations to basic entities and back must be positively solved. Because of this factor and of the need to coordinate solutions referring to various sectors and aspects of the economy, whole systems of models are devised. On the other hand, multilevel and multistage models are designed for parts of the economy.

As we have already said, independent of the above problems which are now (or always) under discussion and for which solutions must be found, first generation models that were accepted some time before are run; they are accompanied either by a number of conditions connected with their limitations or by certain procedures for overcoming the above problems.

According to [13, p. 13] "...CEMI and IEOIP are engaged in the elaboration of a *hierarchical system of models for the optimum planning of the national economy as a whole*", or, more precisely, its methodological foundations. Many other institutions working in this domain are either more implementation oriented or are interested in more specific objects.

Work done at CEMI has a clear methodological character. A number of algorithms have been devised there for solving economic-mathematical problems. These algorithms have been widely used in more applied ventures (see e.g. [16, p. 17; and 28, p. 27]). Of special interest to CEMI scientists seem to be problems of constructing the multilevel national planning model system in a mathematically consistent way (see [15]). Recently, methodological research has been conducted on goal-oriented programs. As these are treated more extensively elsewhere in this Report, we shall draw attention here to only those aspects of the studies that are connected with modeling. The development of the goal tree ends up with a determination of the requirements for commodities or services provided by definite sectors of the economy. The balancing of the plan is performed through the use of an I/O model for sectors. It is interesting to observe that while programs are realized through appropriate stages corresponding to planning periods and, for these periods, define a portion of plan requirements, they constitute stages or steps of fulfilling long-term plans. They may therefore serve as a link in the creation of recursive (stepwise planning) or iterative (in rolling) procedures. For such procedures, coordination of program and non-program tasks must be performed. The analysis of a fully quantifiable goal tree would lead to a formulation of an objective function expressing discrepancy between the quantitative goal and the actual state.

The system of models for perspective planning, including regional considerations, is shown in Figure 2. It is easy to see that the system of models proposed [15] tries to represent and interlink economic subproblems according to the following simple hierarchy:

Long-Term Strategy

Sectorially Balanced Plan	National Spatial Allocation
Development of Main Sectors or Program Complexes	Regional Allocation
Development of Sectors and Programs	Location of Production

Within this hierarchy problems of goals and targets, constraints and pricing must be solved. Work on models of different types presented in Figure 2 is conducted in various institutions, and not necessarily at CEMI. The Figure can therefore be regarded more as visualizations of certain ideas for putting together the modeling efforts of various Soviet institutions. As far as CEMI is concerned, its main directions of research (especially in the section of the institute that deals with forecasting and planning methodology) are schematically shown in Figure 3. Individual blocks of the figure are characterized below:

- *Scientific and Technical Progress.* CEMI acts as integrator within the Academy of Sciences of the USSR in a work on the complex plan for scientific and technical progress, which is a preparatory step to the elaboration of a long-term complex or integrated plan. First stages were completed in 1972-1974.

- *Level of Life Forecasts and Consumption and Demand Forecasts and Plans.* For preparation of long-term projections additional forecasts of a social character are necessary. These forecasts are also produced by CEMI. Forecasts for the five year period 1981-1985 and long-term forecasts up to 1990 are being formulated.

- *Aggregated Long- and Medium-Term National Models.* Some work is done, for example, on I/O models of the entire economy. Subsequent steps consisted in creating a ten-sector and a thirty-sector model;

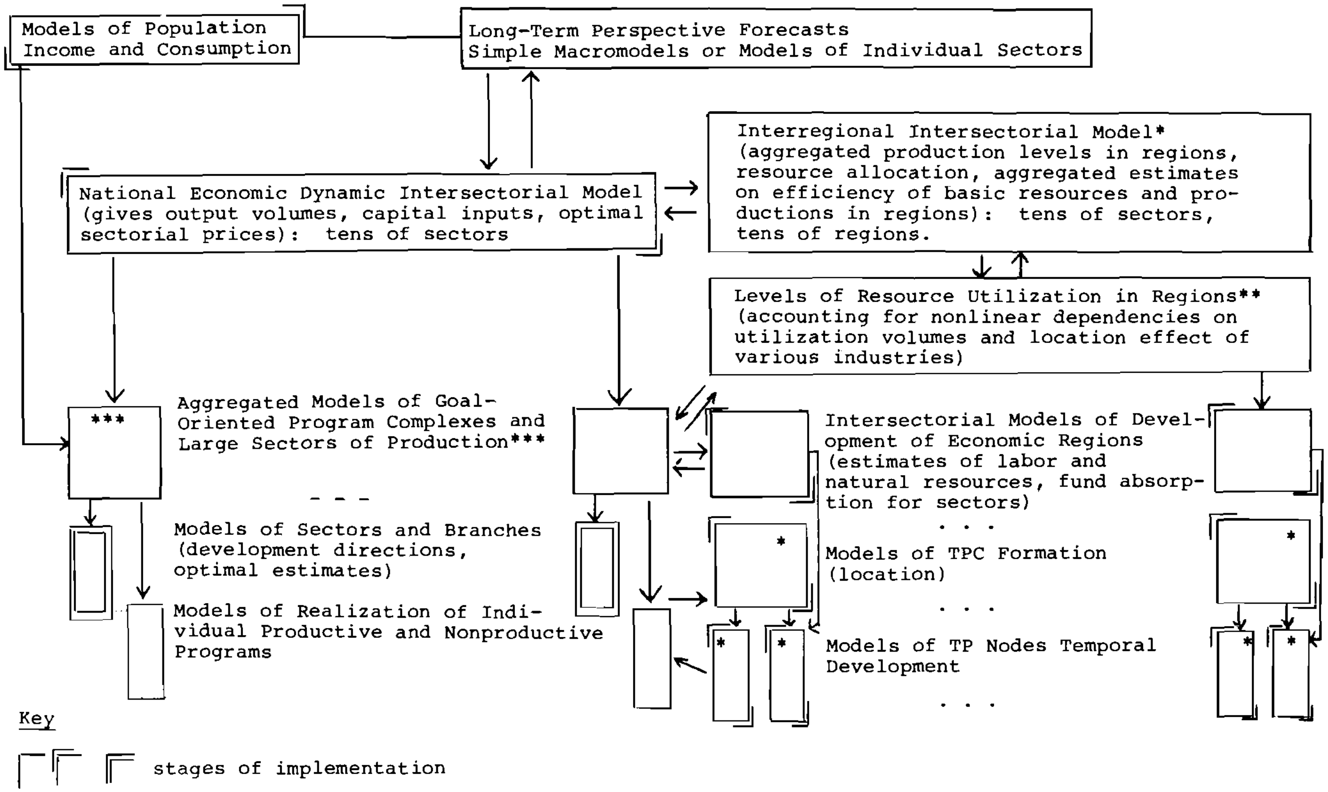


Figure 2. System of models for perspective planning.

*Developed by IEOIP
**Developed by SOPS
***Fuel/Power Complex Model

presently work is being conducted on a model that would follow GOSPLAN specifications. More detailed work in this direction is based on I/O tables for 1966 covering about 100 sectors and all economic regions (see [34]). (Preparation of the tables for 1972 has not been terminated yet.) The model mentioned above as an example of the element is currently being elaborated.

- *Automated System of Plan Calculations.* ASPC also utilizes these tables. This model constitutes major CEMI output for ASPC purposes. In the future, ASPC should provide a calculatory basis for working out an integrated intersectorial plan.

- *Sectorial Models and Management Information Systems* constitute traditional directions of work, in which a passage is observed from scientific investigations to technically applicable solutions. In the ASU domain recent interest has been in direct data bank application to decisionmaking.

- *Goal-Oriented Programs.* This direction has been briefly described both in this sector and elsewhere in this Report.

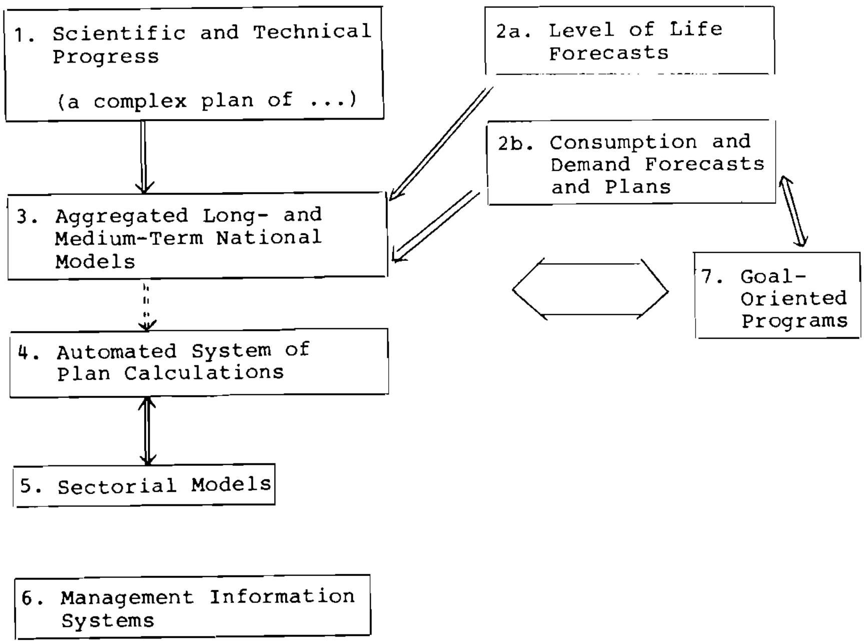


Figure 3. Major research directions of CEMI.

Generally, it may be stated that the modeling work conducted at CEMI is oriented more toward central planning problems than toward spatial or regional ones. The TPC level is not seen from there, and if it is, it is usually through somebody else's eyes, as can be seen from the example of Figure 2. This figure may serve to illustrate certain compromises between existing approaches to regional modeling: the inclusion of both intraregional intersectorial models and TPC formation models (see [9,25]) into one framework. More details about differences between these two approaches will be given later in the description of the IEOIP regional subsystem.

According to the statement from [13] ...SOPS with GOSPLAN is not directly involved in the work on the whole of the "hierarchical system of models...", its place in the institutional structure and the needs to which it is responding result in the fact that the modeling group of SOPS is also working on models that constitute a specific subsystem. The concept of this subsystem is shown in Figure 4 [3]. The subsystem is meant for sectorial/regional coordination, with the regional dimension introduced mainly to account for resource utilization quotas and costs, and for the agglomeration effect in production location. Studies on intersectorial interregional modling were begun in SOPS in 1971 under S.A. Nikolaev [16]. Present models result from a continuation of this research direction. Great emphasis is put on elaborating models of type 3 and 4 in Figure 4, and there is a determination of principles governing iterative procedure between sectorial models and regional allocation ($2 \rightleftarrows 4$).

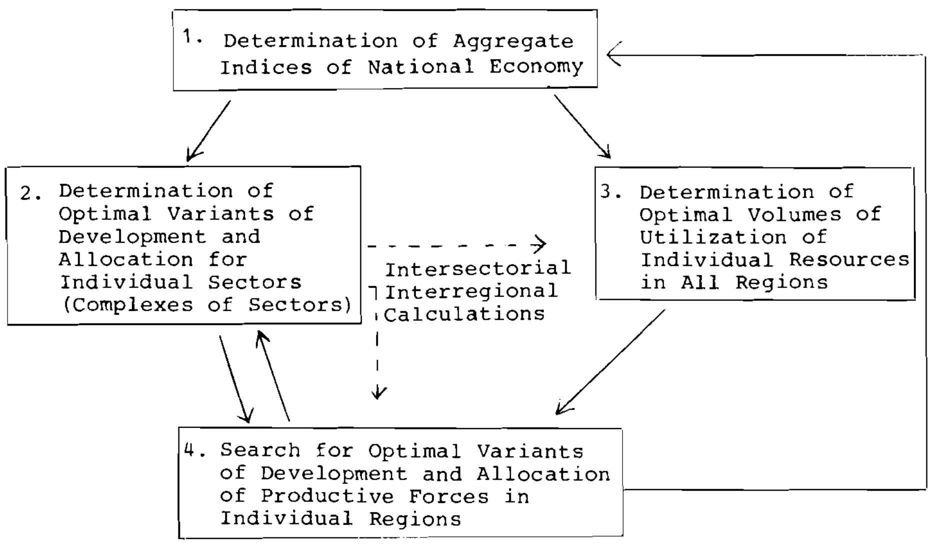


Figure 4.

Sectorial models are assumed to exist beforehand and must fulfil only certain fairly weak assumptions. As to the national level model, it is only assumed that there will be one, serving first of all for the determination of the production quota.

In general, the system should work as follows:

- Optimal sectorial solutions are determined together with parameterized magnitudes of losses depending on the distance from the solution, primarily as a function of location changes (model 2 in Figure 4).

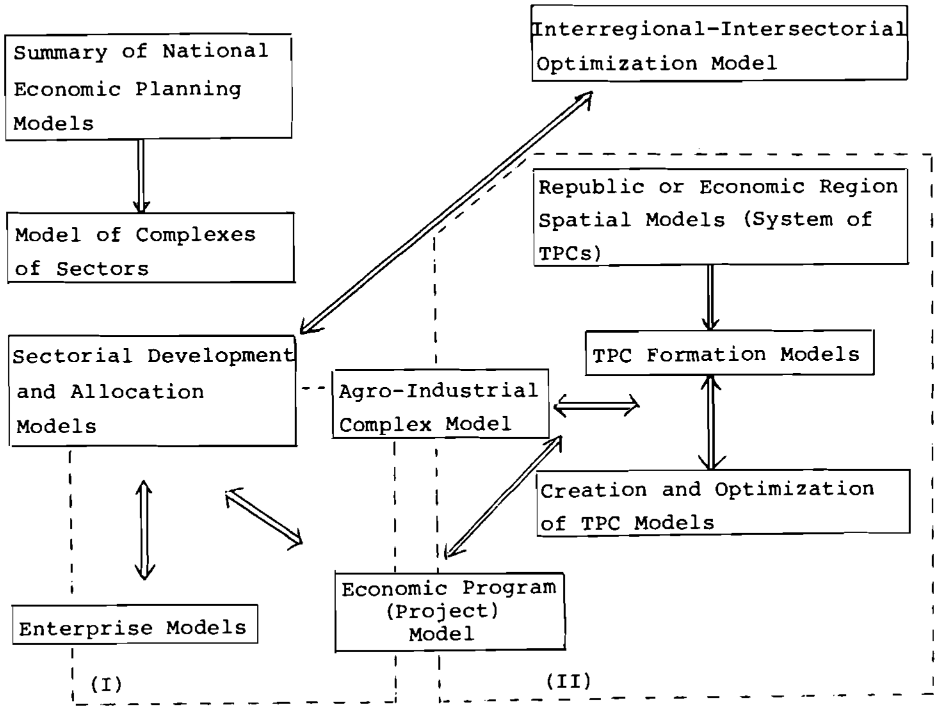
- For resources having nonlinear relation, "costs/ utilization volume" limits are determined on the basis of use in individual regions. This task should be connected with the consideration of resources needed for intraregional purposes (model 3 in Figure 4).

- Subsequent intraregional optimization tasks minimize sectorial losses mentioned above and consumption of resources not accounted for in sectorial solutions, with the additional term of heuristically computed agglomeration effect (see [34]).

Recently an intersectorial interregional model for 80 industries and 60 regions has been introduced, providing the link for sectorial models with other models, especially resource distribution ones.

Other models which have been developed or are under development at SOPS and which deal with regional or related problems are more specific, but do not refer directly to the system; at present they are mainly at the analytic stage (see [34]). One of the models concerns the production complex optimization, that is the choice of production intensities and locations in time. It was formulated as a combinatorial problem.

Since the model system under development at IEOIP will be treated in more detail in the following sections, for the sake of completeness we shall give here only a simplified scheme of current IEOIP activities in economic modeling (Figure 5). It can be easily concluded from the scheme that a large degree of consistency exists between this system and the one proposed by Fedorenko [15] (see Figure 2). Some differences, however, should be noted as they concern regional aspects of planning and modeling. First, the two hierarchies that exist in both systems (sectorial and regional) are equalized in the IEOIP scheme, that is both begin at the top. The IEOIP system does not contain the intraregional intersectorial model proposed by Fedorenko after Kossov. Furthermore, there exist a number of "program models" (see the middle of Figure 5) of a special, diversified character that cannot be directly incorporated in any of the two hierarchies. This can be justified by their special functions rather than by the objects they concern.



I. Research on two- and three-level sectorial models

II. Elaboration of a model system for regional planning

Figure 5. Current economic modeling activities of IEOIP.

Methodologically interesting research on economic modeling is being conducted in other institutions (see [34]). Let us give some "systemically" interesting examples. In the Institute of Mathematics of the Siberian Branch of the Academy of Sciences, USSR, an approach was proposed for integrating elements of implementation into planning models. A sectorial LP model is linked with a simulation model of the real plan preparation process in the sector. The optimum solution should provide a balance between "development and location" optimum and ease of implementation. In the Siberian Power Institute (SPI), a method was elaborated for decentralized coordination in multilevel models, advantageous from the point of view of oscillations (i.e., the decrease of oscillations, and of a number of iterations. (In practice less effort would be needed to devise mechanisms preventing oscillations.) The method requires greater exchange of information which, however, is importantly decreased in the case of technologically closely linked elements. The Institute of Management and Control in Moscow is an important source of methodological progress where usually control-theory-related approaches are worked out.

The above summary was intended to give a sample of research directions in economic mathematical modeling in the Soviet Union. In general, it may be stated that the main efforts are in two domains. The first is the provision of a data basis for achieving adequate technical precision in the construction of actual planning models (for potential inclusion in the ASPC) mainly for medium term (5 to 10 year) purposes. Medium- and short-term considerations which constitute the whole of the planning process in the USSR concern primarily sectorial expansion and its balancing. Long-term studies of national, sectorial, and regional strategic issues form the so-called preplanning process which as yet does not have a formalized character comparable to the five-year or yearly planning mechanism. It is to this strategic thinking and to its progressing formalization that the second kind of research is devoted. The model systems mentioned are mainly devised for it, along with adequate propositions as to the organization of long-term planning (e.g. [14]). If we consider that operative control is performed "below" the actual planning process, we obtain the scheme of Figure 6. In the space presented in the figure,

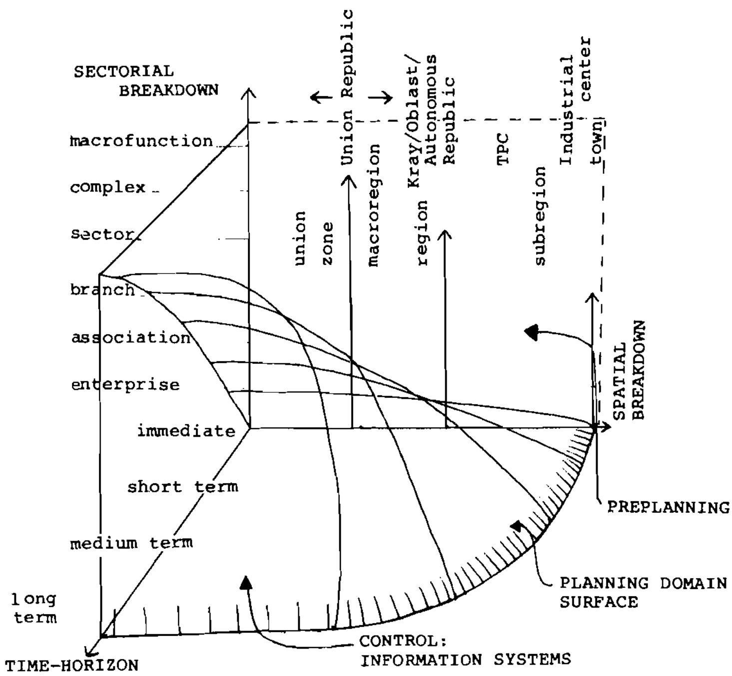


Figure 6.

the planning process and model system must be organized, beginning with the main socioeconomic goals and ending with functional targets or regional development allocations. The questions that must be answered are both fundamental and technical: How to create the system? Is it possible to design it as a whole? What should be the level of connectedness and consistency? Can objective functions differ? And so on. Some of these problems have been or will be discussed elsewhere in this Report.

Regional problems are thus seen as a whole in preplanning studies. In planning and especially in operations they become primarily objects of sectorial considerations, and in a limited (complementary) scope they are objects of local management. (We are witnessing now a tendency toward the introduction of short-term territorial plans through adequate departments of GOSPLANS, with such plans summing up the development conditions of a territory, originating from various sources.) It should be noted here, though, that also in preplanning such territorial entities as TPCs are viewed as resource-providing or production units. They are not programs but complexes, that is, constructions which emerge as a result of optimization of homogeneous national criteria. It is therefore less common to consider regional models by themselves. IEOIP provides at this point an outstanding exception. The place taken in its work by regional models and systems of models acquires special significance when we consider that as recently as two years ago, no regional models were among those regarded by some Soviet authors ([14, p. 15]) as prepared for practical planning applications. Now many of these models have been used in preplanning studies and will be included in ASPC in the near future.

We have thus presented some features of mathematical modeling of the economy in the Soviet Union, and it is by no means peculiar that, while we are primarily interested in regional modeling, this section was to a large extent devoted to national models. Regional economies are seen within the perspective of national objectives.

As for the general issue of mathematical and computer modeling of socioeconomic phenomena for planning purposes, we want to make two points. *First*, the growing complexity of the systems governed and the tasks thereof necessitates the gradual abandonment, or at least modification, of intuitive approaches and the introduction of formal tools for describing accurately the complex systematic interrelationships and for processing large amounts of information. This need is entirely understood in the Soviet Union and, based on directives of highest governmental and party organs, programs have been adopted for the construction of all-level planning, management and information-processing-oriented systems (OGAS, ASPC, ASU). Realization of these systems is, however, difficult and lengthy.

The *second* point which we want to raise in this connection is that while some of the elements of the systems are being put into operation, others are subject to a thorough discussion, an outline of which has been provided. It is important to bear in mind that a final model formulation resulting from such discussion will, in conditions of a planned economy, have direct influence on the planning decisions, that is on the shape of the economy. To arrive at such formulations, however, one should be able to obtain from economics all the necessary quantifiable answers. That is, though the models are merely tools of planning, they more or less directly and importantly influence the concepts of planning. In the formulation phase they make all the basic questions of economy reappear in a systematic, quantitative format [38]. Once imbedded in a certain process, for which they were designed, they influence it through the imposition of information flows, language, and thinking habits.

HIERARCHY OF MODELS FOR PREPLANNING STUDIES AT IEOIP

The models presented in this section result from research begun in the early 1960s, and procede along the following four main directions:

- National "point" models,
- Sectorial models,
- National spatial models,
- Regional or territorial models.

In our analysis we have grouped these models according to the hierarchy shown in Figure 5, which represents the national model system concept of IEOIP. The models are in various stages of development and implementation; as to the system as a whole, its construction has barely begun, though rich experience has been collected on a methodological basis of ensuring consistency and coordination (see [13, p. 33-34]) and on the design of specific subsystems. As has been mentioned, the models do not actually enter fully into the planning process as formal tools. Some of them are run from time to time by appropriate authorities and treated as a source of additional well-defined planning information, therefore forming a starting point for further implementation. Usually they are in the hands of their designers who use them for analytic purposes and formulating recommendations to planning bodies.

The use of the word "preplanning" in the above title could imply that we mean a formal procedure in which the models are incorporated. In reality, *preplanning means* here both *all the activities that occur prior to planning and (may) influence it* (see the space above the planning domain surface in Figure 6) *and those activities that have a more formal character*, i.e., preparation of the General Scheme, studies for regional and district schemes, and the like.

Future model development will certainly focus on two problems. The first is the preparation of individual models and an appropriate data base for inclusion in routine planning applications. The second is the elaboration of principles for the construction of the system of models. Research in these two directions represents a case of a dialectical approach to design, or the creation of the whole applicable model system.

In our analysis we have chosen the way similar to the one used in the case of the TVA Case Study (see [21,36]). That is, we have first of all prepared the table of models illustrating those model characteristics that are of interest to us (e.g., purpose, utilization, stage of implementation, connections with other models). (For information on the first attempt to draw the table for IEOIP regional subsystem, see [37].) We are not that much interested in methods underlying the development of individual models but rather in the identification of concepts concerning the utilization of models and their imbedding in the decisionmaking process in general. That is: What was the long-term development of the general methodology and its rationale? What is the approach to model system design or evolution and how has this changed over time? How is the perspective utilization of individual models and their system viewed, and how does it actually look [43]?

In drawing the table on the construction of national system and its subsystems, (which could provide us with some basic information for answering the above questions), we specifically used the table that was prepared by the Soviet scientists ([13, p. 36]) and which, luckily, was much similar to the ones we used. We had, however, to compress the information from this table and verify it against other sources. Its detail resulted in several misprints and omissions which were not corroborated by appropriate texts.

We are fully aware of the existence of other modeling efforts within the IEOIP besides those listed in the table cited, but as those listed were evidently considered most advanced and system-bound by IEOIP scientists, we added only very few, which, though not developed yet, will become integral parts of the regional subsystem.

Below we have provided clarification of notations used in Tables 1, 2, 3, and 4. The whole of the hypothetical system, its structure and way of creation, implications thereof, links with planning, and other problems are discussed in the final part of this section.

National Level

The models of the national economy as a whole presented here (see Table 1) constitute an integral part of the work on the system of national economic mathematical models elaborated at IEOIP ([2, p. 6]). On the other hand, according to Valtukh [45] not only is the whole national system a future question, but also its

Notations Utilized in Tables 1, 2, 3, and 4.

Main Areas (N, P, S, PR, G, QL)

N^{n}_{it1}	:	national macro-level,
P^{asn}_{it1}	:	sectorial production models of various levels,
S^{asn}_{it1}	:	spatial allocation,
PR^{asn}_{it1}	:	regional production development and structure,
G^{asn}_{it1}	:	program models of various levels,
QL^{asn}_{cqt1}	:	population/labor force.

Superscripts

s	:	sector or specific area.
s = 1	:	power and fuel,
2	:	agriculture,
3	:	construction,
4	:	transportation,
5	:	services,
6	:	other,
X	:	various industries.

not specified: sector or specific area not specified

a	:	level,
a = 1	:	national or subnational,
2	:	sectorial,
3	:	subsectorial,
4	:	regional,
5	:	subregional.
n	:	number of model in group defined by main area and other superscripts.
n = x	:	number of models > 1, not fixed.

Subscripts

i : i	:	commodity breakdown specified in the model,
(i)	:	partially specified (branch/sector),
	:	not specified.

t : t	:	time dimension specified in the model (dynamic model),
(t)	:	partially specified (semi-dynamic model),
	:	not specified (static model).
1 : 1	:	locations specified in the model,
(1)	:	locations specified in the model in a rough way,
	:	locations not specified.
c	:	age/sex cohort.
q	:	skill.

Example

$PR^{431}_{(i)(1)}$: regional-level static transportation development model with rough commodity and location specifications.

Utilization/Development

XXX	.	model fully operationalized and prepared for practical utilization or currently applied to practical problems.
xxx	.	model being tested.
...	.	in planning, theoretical formulation or early testing stage.

Number of above symbols in a case indicates the extent to which a given model may be used for a given purpose.

Connections

	.	without brackets : existing.
	.	in brackets : methodological, planned or in preparation.
	.	in double brackets : potential according to IEOIP plans.
↓	.	unilateral link with model specified to the left of the arrow receiving information.
↑	.	as above: providing information.
↔ C	.	coordination of solutions.
↔ I	.	identity.
← M	.	model to the left of the arrow is lower level in multi-level model in which the model for which the connection is specified forms upper level (Master).
→ S	.	model to the left of the arrow is Master for the sub-ordinate model for which the connection is specified.
W	.	the model to the left of the symbol is a part of the whole constituted by the model for which the connection was specified.

IEOIP Code: is taken from [13, pp. 37-40] with our additions symbolized by asterisks.

Methods

LP	:	linear programming.
IP	:	integer programming.
NLP	:	nonlinear programming.
DP	:	dynamic programming.

top level subsystem is far from being achieved. Let us look closer at this self-critical statement. The concept of the system is evolving. (It suffices to look at the overall system structures presented in (1,13,17]), none of which was presumably thought of as the only or the best one to be fully implemented.) It is therefore not "the system" that Valtukh has in mind, but "a system", that is, a certain qualitative change in model interaction. The conceptual bases for a system creation are there, and provide invariant features. Now it is a question of implementing them.

Very important steps have been made (e.g. the dynamic intersectorial I/0 model and its optimizing versions) along the line of development sketched in the previous section, from static I/0 tables to dynamic optimization. The core of the future national-level subsystem was created in this way. There is still much to be done, however, both in the formulation of individual models and in the design of the subsystem. As for the latter, the future structure of the subsystem is not defined, except for the methodological links connecting the dynamic I/O model with optimizing models and procedures. A link that existed between the basic dynamic I/O model and the first version of the optimizing Intersectorial Interregional Model (OIIM) was disrupted after the elaboration of OIIMb, because no extra information from the intersectorial model could be transmitted to the OIIM ([16, p. 16]).

Evaluation in [2, p. 13], certainly true for national models in all countries, states that the models elaborated at IEOIP are not yet concrete enough to be included in the planning routine for short time horizons. In Table 1 shown here, the national level models are referred to as long or medium term. Distinction between these two time horizons is by no means easy, especially if we consider that the models differ only in technical details. The options expressed in [2, pp. 130-140], which certainly shaped the assignment of a long- or medium-term character to individual models, says that the model is medium term as long as it precisely reflects the economic process through I/O, as an intersectorial I/O model can be utilized. If the information on technical coefficients (future technologies) does not allow one to define precisely individual I/O coefficients, we have to switch to more

Table 1. Models for preplanning studies at the national level.*

Sources: [1, 2, 13, 17, 45]

Code		Name/Object	Characteristics/Purpose	Utilization/Development					Connections	Remarks
IEOIP	analytic			Analysis	Forecast	Balancing	Optimization	Information processing		
IA1	$N^{1}_{(i)t}$	Intersectorial dynamic model DMISIOT	National long-term I/O balance table + dynamization procedures (depreciation, fixed assets' growth, minimum investment, nonproductive consumption). Model complemented with manpower balances	XXX	XXX	XXX			(IA2) (IA4) (IA3) (IA5,IA6) IA7,IA8 IIA1a↓	Core or base model for a number of subsequent models. Currently 35 sectors
IA4	N^{2}_{t}	Aggregated Intersectorial dynamic model	As IA1	XXX	XXX	XXX			(IA1)	35 sectors
IA2	$N^{3}_{(i)t}$	Optimizing intersectorial dynamic model	As above, with provision of optimization procedures. Medium term	XXX	XXX		XXX		(IA1)	
IA5 IA6	$N^{4}_{(i)t}$ N^{5}_{t}	Consumption structure optimization model	Intersectorial dynamic model based methodologically on IA1. Utilizes indifference surfaces in special form. Final product structure changes according to consumption level.	XXX XXX	XXX XXX		XXX XXX		(IA1) (IA5) ↔ (IA6)	
IA7 IA8	$N^{6}_{(i)(t)}$ $N^{7}_{(i)(t)}$	Net production investment share optimizing model	Intersectorial semi-dynamic model based on IA1 projections. Complemented with procedures for calculating efficiency of investments	XXX XXX	XXX XXX	XXX	XXX XXX		IA1 ((IA2)) (IA7) ↔ (IA8)	

*Key for Table 1 is given on page 157.

/Cont.

Table 1. (continued)

Code: IEOIP	Code: analytic	Name/Object	Characteristics/Purpose	Utilization/Development: Analysis	Forecast	Balancing	Optimization	Information processing	Connections	Remarks
IA3 a	$N^{8}_{(i)}$	Physical-monetary intersectorial model	Physical-monetary I/O production capacity balance model. A master model for others of the kind. Medium and short term	XXX	XXX	XXX	XXX		(IA1)	
b	$N^{9}_{(i)(t)}$			XXX	XXX	XXX	XXX		IB1 ↔ I	
c	$N^{10}_{(\cdot)t}$			...	...	...	...			
IA9	$N^{11}_{(i)t}$	Macroeconometric dynamic model	Economic-statistical I/O model of macroeconomic indices. Medium term	XXX	XXX					55 variables
IA10	$N^{12}_{(i)(t)}$	Econometric intersectorial model	Adaptive economic-statistical I/O intersectorial model for various countries. Includes optimization. Meant for demand formation forecasting							
a		USSR		XXX	XXX	XXX	XXX			
b		Japan		XXX	XXX	XXX	XXX			
c		USA		XXX	XXX	XXX	XXX			
IIA1 a	$N^{13}_{(t)(l)}$	Optimization intersectorial interregional model OIIM	Optimizes development and its allocation among regions. Calculates output and consumption volumes, increase in capital investments and interregional output deliveries. LP	XXX	XXX	XXX	XXX		(IA1) (IA2)↑ ((IA5,IA6)) ((IA7,IA8))	a: aggregated 11 regions, 16 sectors
b	$N^{14}_{(i)(t)(l)}$			XXX	XXX	XXX	XXX		(IC1,IC2)↕	b: disaggregated 16 regions, 50 sectors

aggregate long-term models. Following this line, one may say that at the same time we have defined time horizons in national planning, and hence if we succeed in endogenizing technological progress the medium term will undergo an important extension. In intersectorial I/O models, those technologies are therefore accounted for that are known with enough precision at the moment of data definition and will not change in the planning period considered. This does not mean, of course, that the I/O coefficients should remain unchanged for the whole period: they may change according to the introduction of new (but already known) technologies, and remain stable only within yearly steps. This is the procedure used in most of the national models of IEOIP. There is therefore a partial solution to the linearity problem touched on in the introductory section of this paper. An important question is connected with the definition of application domains of simulation and optimization models. It is, of course, not a simple question of where an optimization procedure is technically feasible. In [2, pp. 134-135], it is argued that simulation (sequence modeling) should be used more in longer-term models, where the arguments (e.g., the technologies or the substitutive commodities) may disappear; with a shortening of the time horizon optimization should play a more important role. This is tightly connected with the uncertainty of information and the resulting probabilistic features of the hypothetical optimum. It is important to see that such simulation-like models as dynamic I/O balances, and most simulation models in general, very loosely define the future, determining only wide domains inside certain constraints. In order to define conditions of development with an accuracy sufficient for policy formulation, one has to resort to optimizing or to other choice-bound techniques. Bearing this in mind we have noted an apparent absence of a scenario approach for the halfway solution for nonoptimizable situations (see e.g. [12]). As may be seen for the example of research conducted at the Institute of Mathematics in Siberia, however, even in some shorter-term models optimization may be difficult, just because the simulation is performed with a non-analytic model. (See also discussion in [34] in connection with objective function formulation considered below.)

We have spoken of objective functions and the importance of their choice and consistency for the whole of the system. In general, IEOIP models follow the concept of output maximization/efficient achievement of maximum already discussed. Both types of optimizing models based on the dynamic I/O table, DMISIOT, maximize an output, though through somewhat different formulations. (For example, in an investment share optimization model accumulation is maximized with certain balance conditions on consumption and resource investments holding.) Other examples of output/efficiency logic are provided by:

- Albegov [3, pp. 148-149]: max. of final consumption goods production/min. costs or max. volume of production in case of deficit commodities;

- Fedorenko [15, pp. 88-89]: max. of final product/min. of complete reduced costs for given production.

Even such formulations as maximal "savings in total labor expenditure" ([13, p. 34]), complemented with the obvious condition of "fixing a band-like level of summary social needs satisfaction" [4] should be regarded as dual to the above ones. Another seemingly different national criterion is taken in the OIIM (nonproductive consumption), but its loose conditioning through the role it plays in production level constraints does only allow one to treat it as a certain surplus output not directly used for reinvestment. In reality, for the early runs the shares of nonproductive consumption were determined within the sectors and only then distributed among the regions. This logic results from the need to create the "...model system for planning corresponding to the system of real socioeconomic conditions in which planning is performed, corresponding to real economic mechanism" [2, p. 136]. That is, "technical and economic calculations carried out by lower-level units are considered not as their economic decisions (...), but merely as basic information for taking decisions at the upper level..." [2, p. 136]. Further consequences of this are the treatment of sectorial and regional units as "resource elements", and the resulting definition of tasks belonging to Republic and local bodies [14, pp. 14ff]. With all that, one should certainly avoid such "...a shortcoming of an important number of works [as] *objectivization of functioning of economic laws...*" [25].

The development of a complex of national models is aimed at including further socioeconomic dimensions and subsystems such as the service sector (see [16, p. 16]), endogenous population, manpower calculations, social processes, individual and societal needs, consumption [2, p. 131; 13, pp. 18-19; 45, p. 7], and financial considerations. The need for explicit consideration of political and world economic factors is pointed out in [14,16]. There is, however, a great variety of difficulties arising from the introduction of different factors into modeling, especially when we want to endogenize these factors. As mentioned, one of the most important and challenging questions is the endogenization of technical progress. K.K. Valtukh proposes an approach based on the disequilibrating influence of technical innovations (see [45, pp. 16-18]). According to A.G. Granberg, the solution to this problem would simply mean determining switchpoints and appropriate parameters in production-function-based trajectories.

As far as the territorial aspects are concerned, represented here by the OIIM, it is interesting to quote from [15]: "intersectorial models without a territorial aspect (...), though often optimizing in form, reflect a relatively low number of real degrees of freedom and (...) play the role of forecasting-simulatory tools, as far as their input information has a forecasting character and is based on a series of hypotheses".

Sectorial Models

According to the classification of models from [13, p. 37], all the production or functional models below the national level are divided into three main categories:

- Models of complexes of sectors;
- Models of individual sectors; and
- Models of individual production units (enterprises).

Within the sectors category there is an additional division between models for groups of sectors (broad sectors) and models of particular industry sectors (branches). From the point of view of model system building and its rationale, it is interesting to look at the first category--*models of complexes*.

If we recall the structures presented in Figures 2 and 5, we shall see that complexes of sectors belong to a level lying between the national and the sectorial levels, and that they may be associated with goal-oriented program planning. Models of complexes can therefore balance or optimize the functioning of a large sector of the economy that cannot be governed by one or two Ministries and that may include activities of a fairly diversified character (intersectorial submodels). On the other hand, models of complexes can represent planning for the fulfillment of national or subnational goals. In the latter case, while the relations of such a program complex model with "supply" or "executive" sectorial models is clear, the question of its connection with upper level balancing and optimizing intersectorial models must be clarified. (See the links of models of complexes in Figure 2.) Two types of models shown as models of complexes of sectors in the IEOIP table (Table 2) are directly related to the two-fold character of possible utilization of these models discussed above. The first model, an I/O table of production capacities, is identical to the one used for the whole of the economy (IA3), and is therefore an example of an intersectorial submodel. The second model, the one for agro-industrial complex, is identical to that used for program planning (IIIA1). While this juxtaposition solves the problem of the interrelations needed for the internal functioning of the whole sectorial or production model subsystem, it certainly leaves out the question of integrating goal-oriented and usual planning reflected by two types of models mentioned.

There is always the problem of basic definitions of individual sectors and their complexes. On the one hand, there is an existing management and planning structure; on the other hand, there is the reality of resources, technologies, and types of commodities produced [4, pp. 27ff]. Even if this problem is somehow solved for the sake of results, there remains the question of substitutability on the lower levels, its measurement and consistency with upper level classifications. This fundamental question of choice of elements for the system is to a large extent shaped by the existing structures.

Table 2. Sectorial preplanning models*.

Sources: [4, 13, 26, 28]

Code: IEOIP	Code: analytic	Name/Object	Characteristics/Purpose	Utilization/Development: Analysis	Forecast	Balancing	Optimization	Information processing	Connections	Remarks
IB1 a b c	 $P^{1x1}_{(i)}$ $P^{1x2}_{(i)(t)}$ $P^{1x3}_{(i)t}$	Physical-monetary intersectorial model	Physical-monetary I/O production capacity balance models. Medium and short term.	 XXX XXX ...	 XXX XXX ...	 XXX XXX ...	 XXX XXX ...		IA3(abc)↔I	Can be used as a part of global model and separately
IB2	$P^{121}_{(i)(t)(1)}$	Agricultural-industrial complex optimization model	LP optimal coordination model for regional economy. Long or medium term.	XXX	XXX	XXX	XXX		IIIA1↔I IIC4*↔I	
IC1,2	$P^{2xx}_{(i)(t)(1)}$	Sectorial longer-term models	LP models of development (choice in technological variants) and territorial distribution (choice of locations) of sectors, with respect to regional units (basins, complexes). Long and medium term.	XXX	X	XX	XXX		ID3* ← M ID4* ← MW (IIIB1)→S } for some (IIA1b)↕	Various LP/IP production or production-transportation models 4+4 models (for large & narrow sectors)
IC3	$P^{211}_{(i)t(1)}$	Gas industry dynamic shorter	Dynamic model of development and location of gas industry accounting for adaptation characteristics. Short and medium term.	XXX	X	XXX	XXX			
ID1	$P^{3xx}_{i(t)}$	Information enterprise models	Economic-statistical models for various types of production units (producing various goods). Medium term and operational.	XXX	XXX			XXX		6 models

*Key for Table 2 is given on page 157.

/Cont.

Table 2. (Continued)

Code		Name/Object	Characteristics/Purpose	Utilization/Development					Connections	Remarks
IEOIP	analytic			Analysis	Forecast	Balancing	Optimi-zation	Informa-tion pro-cessing		
ID2	$P^{361}_{i(t)}$	Optimizing enterprise model	Economic-statistical optimization model for timeber-logging enterprises. Medium term and operational.	XXX	XXX		XXX	XXX		
ID3*	P^{3xx}_{it}	Integrated operational enterprise model	Operational chart of the process of production unit functioning in time. Graph model. DP optimization.	XXX	XXX		...	XXX	IC1,2→ S (simplified versions)	
ID4*	$P^{3xx}_{i(t)}$	Optimal regression enterprise model	Linear regression model of production unit functioning. Treated as submodel to sectorial LP	XXX	XXX			XXX	IC1,2→ SP (simplified versions)	

As far as the *sectorial models* are concerned, they represent a range of linear or integer programming formulations of production or production-transportation problems. Usually some temporal stages are taken into account, in most cases describing technological changes over time (e.g., cost/effectiveness curve in mineral extraction) rather than various intensities in the use of chosen technologies or locations, which are constant. Though the general form of models remains stable[13, pp. 26-27] a lot of details has obviously to be devised for each specific case. As to the objective functions, the sectorial models follow the general line presented here. They minimize costs of attaining prescribed volume targets defined by upper level models. Proposals have been forwarded to optimize sectorial or subsectorial economies through maximization of differences between output and costs. In practical calculations, however, cost minimization prevails.

The practical calculations mentioned were conducted for a number of industries and rich experience has been collected after solving about 80 major sectorial problems over the last 15 years [26, p. 4]. The calculations were performed, however, in relative isolation from other considerations, mainly national ones. Some of the sectorial tasks (e.g., for the forest and the machine industries) were solved together with OIIM calculations. Solutions obtained from national models had a great influence on setting the constraints for sectorial models. The connections between the sectorial models were mainly oriented at the coordination of broad and narrow sectors (e.g., the gas-oil complex and the oil, gas, oil-processing and petrochemical industries, or the fuel-power complex model of SPI coordinated with the coal industry model of IEOIP). Important progress has been made, though most of the outside links for determining relative efficiencies of using specific resources, locations, etc., will only be provided in the future. Furthermore, mainly isolated models and estimation methods were used for large-scale sectorial problems [4, pp. 145, 150, 157].

It is of special importance then to observe first attempts to create multilevel models that would provide interlinkages both within the sectorial model subsystem and with some upper level models [26, pp. 11-12]. Similar efforts have been undertaken first by SOPS with GOSPLAN [26, p. 6] in 1970-1971. Research began with the construction of two-level models of two types. In the first a sectorial LP or integer model was the upper level, while a model of production unit (ID3* or ID4*) on the lower level provided data on technical coefficients. In the second type a sectorial model responded to a demand formation model resulting from program realization requirements. These two types of models were combined to form a three-level model, as shown in Figure 7 [28, p. 33]. A first example of the three-level analysis was a study of the planning of geophysical investigations on a large scale [4, p. 181]. Based on the approach chosen, other configurations for multilevel models have been proposed [4] (see Figure 7). Software implementation, however, was only realized for the previously mentioned models.

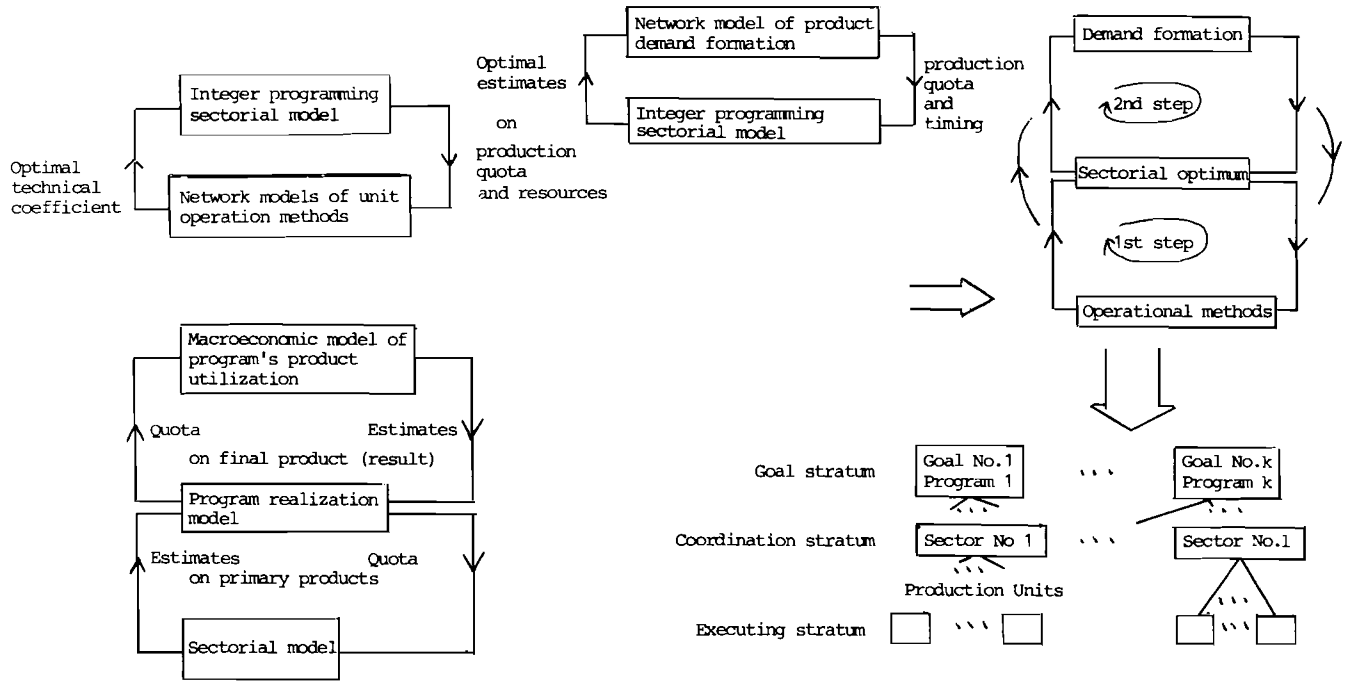


Figure 7. Multilevel structures based on integer-network linkage models.

Within the three-level structure the forms of models chosen were: the integer program on the medium (sectorial) level, and the graph-linear formulations on the other two levels. According to the general rule, the sector is minimizing the costs of producing goods, the volume of which can be determined by the upper level, if, for example, this level is minimizing resources utilized [28]. On the lowest level, the difference between production value and production costs can be maximized. Modifications of the forms of the objective functions in various models in the structure involve changes in the character of information transmitted between the levels (estimates, shadow prices, etc.); but these considerations do not enter into our scope of interests here. We would only draw attention to the fact that implementation of multilevel models, just because of information exchange necessities, requires additional efforts in data definition and interpretation, a task which is already cumbersome for long- and medium-term sectorial models.

Important are the implications of the construction of multilevel models that not only encompass a sectorial model subsystem but also involve some upper level problems. A direct attempt of interlinking goal dimensions with productive implementation has been made. If a goal creation model (goal tree) is conjugated with an upper level network model, then a whole national economic hierarchy would be spanned (with the obvious exclusion of many aspects). This, however, would blow the model up to a presently intractable magnitude (number of program-like goals × number of sectors × number of production units). On the other hand, the problem of interprogram coordination on the sectorial level would have to be solved, leading to a formulation of sectorial plans that correspond to yearly or five-year periods. On a slightly more modest scale, great progress has been made in connecting sectorial optimization with requirements for the realization of a regional program (see [28]). This is, of course, a local problem, both regionally and sectorially, but it is interesting to observe efforts to bring coordination into the sectorial/regional breakdown originating from the sectorial source. One must add to the above goal-oriented considerations the fact that, besides requirements as to sectorially produced commodities, regions should formulate their estimates as to relative efficiency levels, and both of the interconnections must be accounted for in designing the sectorial/regions interface.

An interesting question of recursion arises in connection with three-level models, especially in cases where the upper level segment is oriented toward a realization of the sectorial program (as in the case of the geophysical investigations previously mentioned). Ultimately, the model than becomes a two-level one with additional feedback, and there is no need to explicitate the third level. Such a need arises only when a goal is taken into consideration that cannot be internalized by the sector.

Regional Models

The development of the regional planning models (Table 3) constitutes one of the major research domains of IEOIP. The magnitude of the effort and the results obtained in elaborating these models make IEOIP outstanding among other modeling-oriented institutions. The work on regional planning models should end up with a calculatory tool enabling one to formulate (optional) district and town plans, concerned first of all with the location and intensity of productive activities.

The main objects of consideration in regional models are obviously spatial or territorial units of various types. A range of spatial units is accounted for such as an economic region or Republic, TPC or similar TP combinations, and an industrial center (IC), and an agglomeration or assimilation zone (see [9, p. 52]). We see, however, that while the first of the units mentioned (a Republic or economic region) presently finds its reflection in the administrative or at least in the planning structure, the definitions of two other types of spatial units result from model calculations. TPCs and ICs should represent optimal variants of interrelated location and development of the productive forces of the region. On the other hand, there exist administrative units such as kray/autonomous Republic/oblast, district and town. Speaking for the first time about the difficulties of precisely defining TP combinations (in general and for specific cases) we have said that TPCs roughly correspond to interurban (district or even oblast) dimensions, while ICs encompass one town or an urban agglomeration. No strict correspondence can, of course, be observed. The same holds for the classification of TP combinations themselves--that is, there is no clear-cut way of saying what is the spatial allocation and hierarchy of the combinations in a given area (For the results of pattern recognition methods see [33] and for classifications see [8]). What is more, each of the emerging combinations should be viewed in its dynamics which may lead to its elevation to a higher level or association with a neighboring combination. As in the case of sectors, we have again touched on the basic problem of element definition. TP combinations, however, cannot be viewed as primary, atomic elements because they result from an aggregation of smaller units, referred to as areals*, sites**, and grounds [9, p. 60]. TP combinations are therefore optimal, medium-level elements and their relation to higher-level elements should be clarified.

One of the main questions that emerges in connection with the above problem is *coordination*. What should be the input of sectorial and local authorities to the definition and development of TP combinations? Large geographically focused investment projects involving several sectors and resulting in the creation of a

*Areals are high territorial units including sites.

**Sites are territorial units corresponding to the location of individual industrial plants or complexes.

Table 3. Regional preplanning models.*

Sources: [8, 9, 10, 13, 17, 31, 35]

Code		Name/Object	Characteristics/Purpose	Utilization/Development					Connections	Remarks
IEOIP	analytic			Analysis	Forecast	Balancing	Optimization	Information processing		
IIB1	$PR^{4x1}_{(i)(l)}$	Regional production/spatial structure model	Optimization model for determining production/spatial structure of a region (Republic). Long term.	XXX	X	XXX	XXX		IIA1 $\leftrightarrow$ I	100 sectors 15 oblasts
IIB2	$S^{4x1}_{(i)(t)(l)}$	Regional TPCs system spatial structure model	Optimization LP model for determining regional TPCs--locations and production structure. Long and medium term.	XXX		XXX	XXX		(IIC1) $\downarrow$ (IIC4*) $\downarrow$ (IIC3*) $\downarrow$	∿30 sectors ∿10 TPCs
IIC1	$PR^{4x2}_{(i)(t)}$	TPC parameters formation model	Optimization LP model determining rates and scopes of development of specialization and infrastructure activities. Long and medium term.	XXX		XXX	XXX		(IIC2) $\downarrow$ (IIE1*)	15-20 sectors 10-15 industrial centers
IIC2	$S^{4x2}_{(i)(t)}$	TPC spatial structure model	Optimization LP model determining locations and development of spatial TPC elements. Long and medium term.	XXX		XXX	XXX		(IIC1) $\uparrow$ (IIC4*) $\leftrightarrow$ C (IID1*) $\downarrow$ (IIE1*) $\downarrow$	15-20 sectors 10-15 industrial centers
IIC3*	$S^{4x3}_{(i)1}$	Industrial (centers) location model	Optimization LP model for locating given activities of a TPC in centers. Long and medium term.	XXX		XXX	XXX		(IIB2) $\uparrow$ (IIE1*) $\downarrow$	10 centers
IIC4*	$PR^{421}_{(i)(t)(1)}$	Regional agro-industrial complex model	Optimization LP model of development and allocation of agro-industrial activities. Long and medium term.	XXX	XXX	XXX	XXX		IIIA1 $\leftrightarrow$ I IB2 $\leftrightarrow$ I (IIB2) $\uparrow$ (IIC2) $\leftrightarrow$ C (IID1*) $\downarrow$	

/Cont.

*Key for Table 3 is given on page 157.

Table 3. (Continued)

Code: IEOIP	Code: analytic	Name/Object	Characteristics/Purpose	Utilization/Development: Analysis	Forecast	Balancing	Optimi-zation	Informa-tion pro-cessing	Connections	Remarks
IID1* a b c	$S^{5x1}_{(i)1}$	Models of sub-TPC spatial structure	Optimization LP model for determining locations and intensities of intracenter activities. a - center b - agglomeration of centers c - zone of complete assimilation. Long and medium term.	xxx		xxx	xxx		(IIC2)↑ (IIC4*)↑ (IIE1*)↔C	
IIE1*	$P^{4x3}_{(i)(t)(1)}$	TPC creation process model	Optimization LP model determining time sequence of construction activation, and development operations for the whole of TPC. Medium term.	xxx			xxx		(IIC1↔ I (IIC1)↑ (IIC2)↑ (IIC3*)↑ (IID1*)↔ ((IIE2*))↔C ((IIE3*))↔C ((IIE4*))↔C	
IIE2*	$QL^{41}_{cq(t)(1)?}$	Manpower formation model	Population and labor force model with migrations.	...	...				((IIE1*))↔C ((IIE3*))↔C ((IIE4*))↔C	
IIE3*	$PR^{431}_{i(t)(1)}$ $PR^{411}_{i(t)(1)}$ $PR^{441}_{i(t)(1)}$ $PR^{451}_{i(t)(1)}$	TPC infrastructure creation	Detailed models of infrastructural sectors for TPC scale (transportation, fuels and energy, construction, services).	construction base xxx ...	xxx | others ...	xxx	xxx ...		(ICN)→SI IIIC1 or IIIB1→S ((IIE1*))↔C ((IIE2*))↔C ((IIE4*))↔C	4 main infrastructure sectors foreseen
IIE4*		TPC plan design model	Network model for designing the final plan of TPC creation.	...					((IIE1*))↔C ((IIE2*))↔C ((IIE3*))↔C	

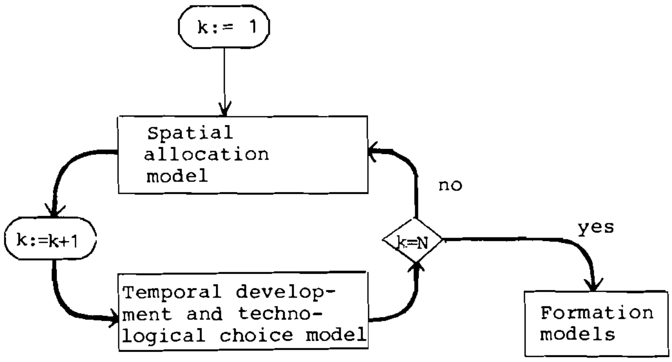
certain community must be adequately coordinated, both in the planning stage and at execution. This has important implications for models and for organizational and managerial processes. If coordination requirements are not taken into account, then loss incurring situations may occur, as described in [4, p. 146; and 10, p. 159].

Interrelations with upper levels and the coordination issue may ultimately be reduced to the question of information links and the definition of TPC planning task by other participants of the planning process. In the IEOIP regional models subsystem, it is assumed that an economic region is given quantitative tasks in terms of the production quota of specialization industries, interregional infrastructure obligations and limits on both scarce resources and investment magnitudes. The TPC community should attain a certain level of living in the planning period [9, pp. 48, 49]. Such a set of prerequisites results from an assumption that appropriate sectorial plans and their intersectorial balancing and optimization had been made beforehand, and that regional resource estimates had been obtained for the whole of the country. It is obvious, however, that none of the above solutions required for activating a regional subsystem can be made precisely without regional considerations, and that therefore a two-way communication must be established. Such a bilateral link seems to be planned for the future between the OIIM and the first "pointwise" stage of regional subsystem functioning. No specification of the form or content of this link has been made. Actually no stable interconnection of the regional models with national ones exists [9, p. 74]. According to [8, p. 17], in calculations made with different models from the regional subsystem, no use was made of OIIM results; but some input information was taken from the models of the sectorial subsystem. An interesting comparison may be made between this approach to placing regional models in the national system and the one proposed by Albegov (Figure 4). In the latter case, industries of specialization and tasks thereof are finally determined through an iterative procedure which balances the losses incurred by giving up sectorial optima and the interregional criteria including the aggregation effect and resource estimates. For this system we cannot speak of different levels of resolution or predetermined tasks. Certainly, dimensions of such a system must be compromised with the capability to attain optima.

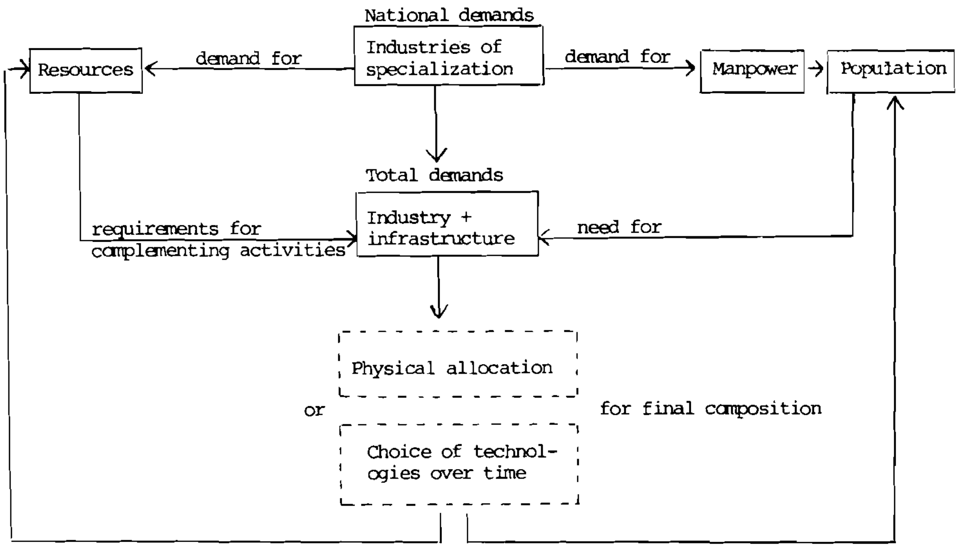
Interrelations with other elements are to a high degree defined through choice of objective functions. Within the framework of output/efficiency logic mentioned before regions stand as production units [23, p. 37], or as "resource complexes" [14, p. 14]. They are therefore equivalent to sectors and maximum efficiency is usually understood as the minimum of cost of attaining prescribed targets (tasks specified above). Equivalence to sectors cannot, however, be complete because the notion of region concerns the regional community as well. Certain ambiguity is therefore introduced [15, p. 325]. The objectives of the development of a regional economy should include an increase in the well-being of the regional population, while the efficiency target is aimed at raising the national well-being. The first problem can then be stated as: Is there a need for introducing a regional objective different from the national one? There are partisans of a unified objective function (A.Ye. Probst), but most scientists agree that the introduction of specific region-oriented criteria is not only mathematically and economically feasible, but also needed. N.P. Fedorenko, D.M. Kazakevich, V.V. Kossov, and others have stated that "not only what the region produced, but what it gained as well" is important [25]. The problem consists in having one system with different objective functions which are not principally dual, but necessitate special reconciliation procedures, based, e.g., on the gaming approach proposed by Volkonski [47]. In general, though, the output/efficiency logic continues to be widely applied, especially by pragmatically oriented researchers (see [3, p. 149]): maximum of output if national efficiency measures are known, minimum costs of producing given quota otherwise; and for subregional tasks: maximization of agglomeration effect. It must be added that the inclusion of regional (or, in general, of a particular) objective function may also be treated as a means for ensuring better implementation of the upper level plan through the anticipation of the behavior of lower level units (see [25, p. 957]). As the discussion has not led so far to a positive formulation of specific regional criteria, the minimization of costs--taken as the main objective in IEOIP models--is a rational choice that is consistent with the place of regional models within the IEOIP national model system and with the present planning concept.

The general scheme of the approach to regional planning with the help of models and the sequence of basic steps is shown in Figure 8. Since the subsystem will be described in more detail in the next section, we shall only make some general remarks on the state of the work. Presently, a number of models have been developed and used for formulating recommendations to appropriate bodies as regards regional plans of different levels. However, the models do not constitute more than a quarter of the whole subsystem according to [9]. Other models have been developed and thoroughly tested, but their results did not reach the planning bodies. The final group of existing models is formed by those that have not yet been adequately tested. Almost one half of the system remains then to be created, though the *most important models already function*. Although more is to be done in the domain of interconnections, we still may say that this group of models is very near to a systemic level.

Ultimately the models will not form a unified (mathematically or through software) overall model; that is, intermediate information will be processed and transmitted indirectly. So far there is no experience with running existing parts of the subsystem for one multilevel task with one multilevel set of information, and judging from the forms of input data needed by individual models there is work to be done in this domain to form a consistent regional model system. To do this, though, will require not only a modeling effort but also the design or creation of a regional



A: Stages k = 1 : economic region or Union Republic
2 : TPC
3 : industrial center



B: Aspects considered on individual stages

Figure 8.

planning process or its core that would ensure utility and the possibility of a thorough testing of the subsystems.

Special Purpose Models

This group includes three models (Table 4), of which the IIIA1 agro-industrial complex coordination model and the IIIC1 TPC creation and operation model are very closely related to other subsystems, namely to sectorial and regional ones, respectively. If we recall the nature of the programs, their orientation toward the achievement of a concrete goal rather than abstract growth levels and their resulting intersectorial or extra-sectorial position, then the nature of the three program models becomes clear.

The *first group of models spans the sectors*, be it on the national or the regional level, *that provide the population with foodstuffs*. Because of the formulation of the population food supply objective as a constraint, this model can be treated as an usual development (technology plus intensity) and location sectorial model. In this respect it can hardly be treated as a proper "goal-oriented-program" model. Because of its intersectorial character and its direct orientation toward social needs, it is possible to consider this model as a link between goal formulation and sectorial realization or resource provision.

The *second group of models defines volume and temporal conditions* for *the execution of a large-scale program*, that is, it sets sectorial conditions under which a certain goal will be attained. The optimization is performed on time-variable coefficients. The same can be said of the *models of the third group*, which, however, by virtue of greater precision of short-time and local scale considerations, *contain enough details to justify optimization within a LP framework*. These two models can therefore be regarded as *project models* in the broadest sense not only because of their formulation, but first of all because of their job-execution character. Program models, however, must be much more comprehensive. They should consider to a large degree sectorial conditions of sectors which are to fulfil program realization requirements. That is why in the limit when the "project" or "goal-tree" structure of the program becomes less clear and the program requirements have an important impact on the development of sectors involved, models may take on classical sectorial or intersectorial development plus location form, e.g., models of the first group.

Programs can in general be oriented toward any kind of goal, and in particular toward goals that are, or are not, physically located. To the class of physically locatable goals belong both construction of a large transportation line (e.g. Baikal-Amur Railway (BAM)) and the creation of a specific TPC. These two cases certainly differ both in scope and in their interrelations

Table 4. Special purpose models*.

Sources: [4, 13, 28, 40]

Code		Name/Object	Characteristics/Purpose	Utilization/Development					Connections	Remarks
IEOIP	analytic			Analysis	Forecast	Balancing	Optimization	Information processing		
IIIA1	$G^{121}_{(i)(t)(l)}$	Agro-industrial complex co-ordination model	Optimization LP model for co-ordination of development and allocation of agro-industrial complex elements in a region. Long and medium term.	xxx	xxx	xxx	xxx		IB2 ⟷ I IIC4* ⟷ I	
IIIB1	$G^{1x1}_{(i)t(l)}$	Large-scale program execution model	Network model of realization of a large-scale economic program. Long and medium term.	xxx		xxx	xxx	xxx	((IC1,IC2)) (IIE3*) ← M	
IIIC1	$G^{4x1}_{(i)(t)(l)}$	TPC creation and operation model	Two-criteria optimization LP model of TPC creation and operation.	xxx		xxx	xxx	xxx	IIE1* ⟷ 1 (IIC1) ↑ (IIE3*) ← M ((IC,ID)) ← M	

*Key for Table 4 is given on page 157.

with sectorial planning. We may state that a hierarchy of programs, and models thereof, can be created (Figure 9). Along the hierarchy, models would change their formulations and the nature of their interconnections with sectorial economies.

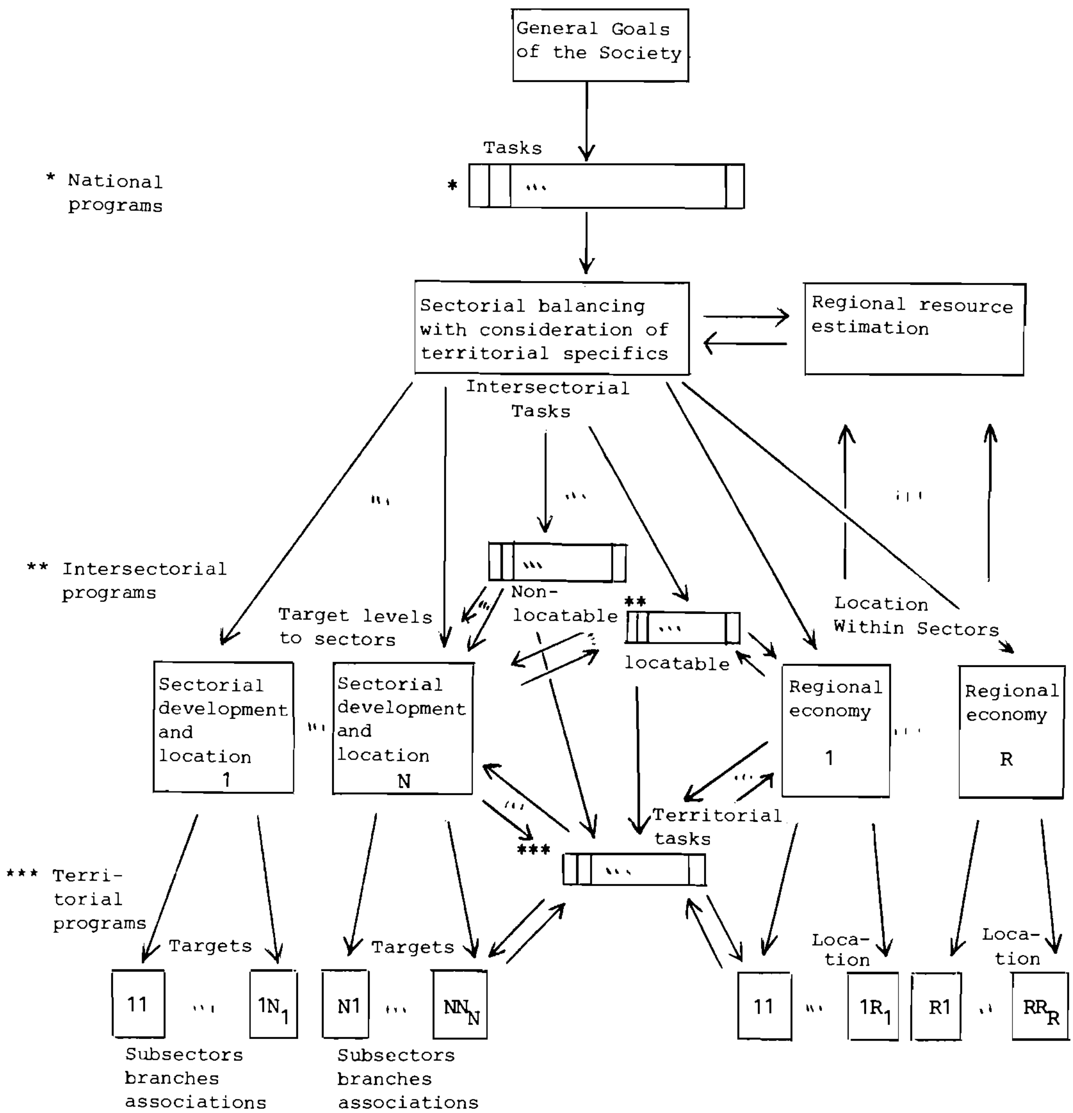


Figure 9. Tasks and programs hierarchy.

If we treat the breakdown of an economy into sectors (commodity producers) as one dimension, geographical breakdown as the second dimension, and the time horizon as the third dimension (Figure 6), we cannot fit programs and their models so as to form one more axis in this space, though they may be regarded as forming a third model hierarchy besides the sectorial and territorial one (compare Figure 5 with Figure 3). Programs refer to a more abstract, functional side of the problem, not a physically quantifiable one.

Overall Structure and Table

We have presented groups of models which constitute the primary material for the construction of "...a system of optimum territorial-production models for long-term planning..." [13, p. 13]. Figure 10 shows the interrelations between elements of the hypothetical system; Figure 11 presents a connection matrix of models listed in Tables 1 to 4.

Not only is the construction of the whole system far from being completed--unless we consider a system a set of models unified by common approach--but even its elements (the subsystems) by no means form coherent entities. This situation is not specific to the IEOIP model system. Fedorenko states that "...models do not constitute yet a unified, interlinked complex..." [14, p. 15]. They do not even constitute a complex, and the creation of a system is presented as a necessity for the future [14, p. 16]. This is a real necessity, since the individual models that can be constructed and run nowadays are incapable of encompassing all the problems, even in individual subareas (see [19, p. 55]). Obviously, modelers from IEOIP try to build a consistent system on the basis of developed and tested models. In Table 5 some

Table 5.

Sources: [1, 2, 9, 26, 27, 28, 36, 45]

Group of Models	Current			Future (Current plus Foreseen)		
	N_m	N_c	C	N_m	N_c	C
National	15	5	2.4	16	∿19	7.9
Sectorial	20	9	2.4	22	∿14	3.0
Regional	9	2	2.8	16	∿27	11.2
Program	3	0	-	3	1	not sensible
Overall	47	26	1.2	57	∿66	2.1

N_m : number of models;

N_c : number of connections;

C : connectivity index;

$$C = \frac{N_c}{N_m(N_m-1)} \cdot 100 .$$

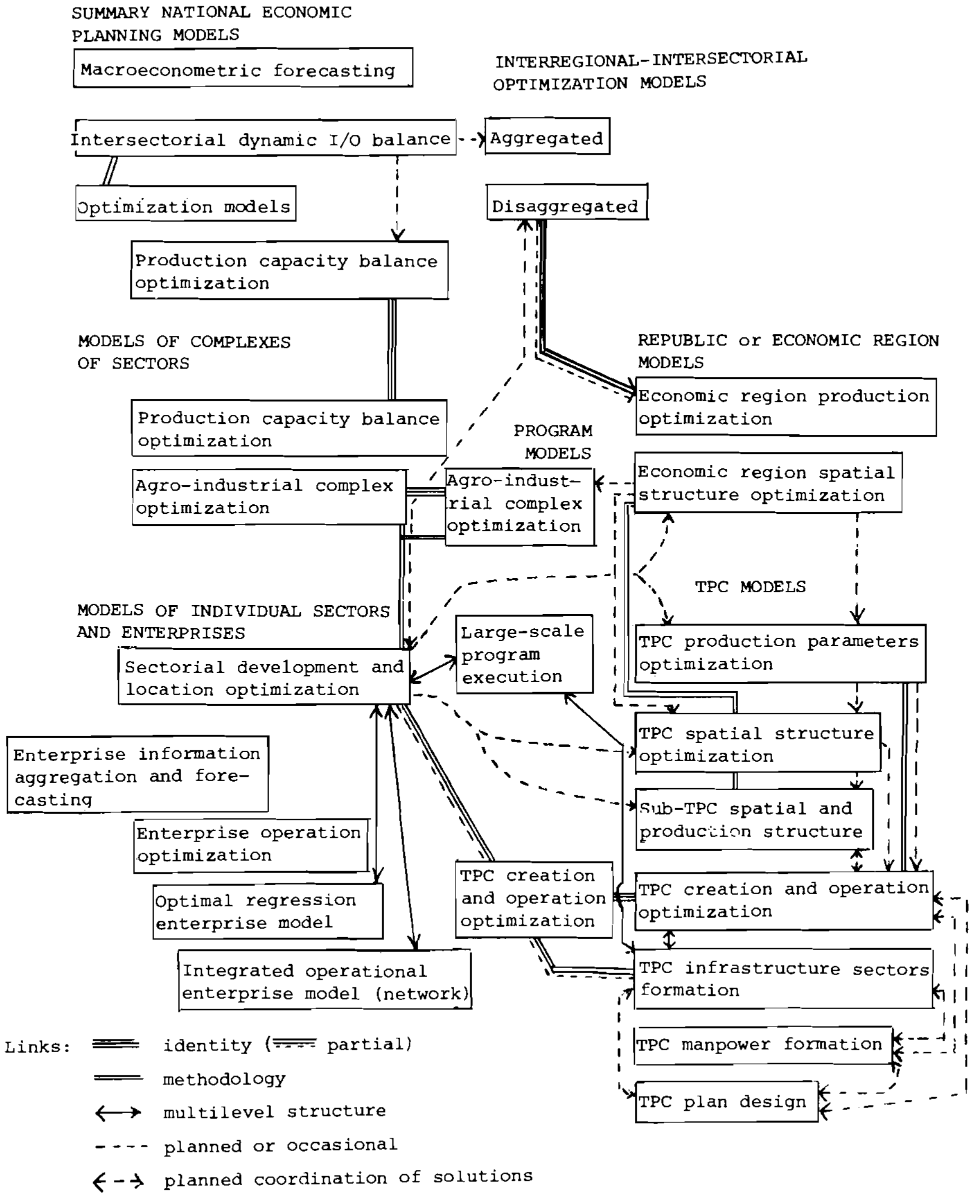


Figure 10. An overview of the IEOIP model system.

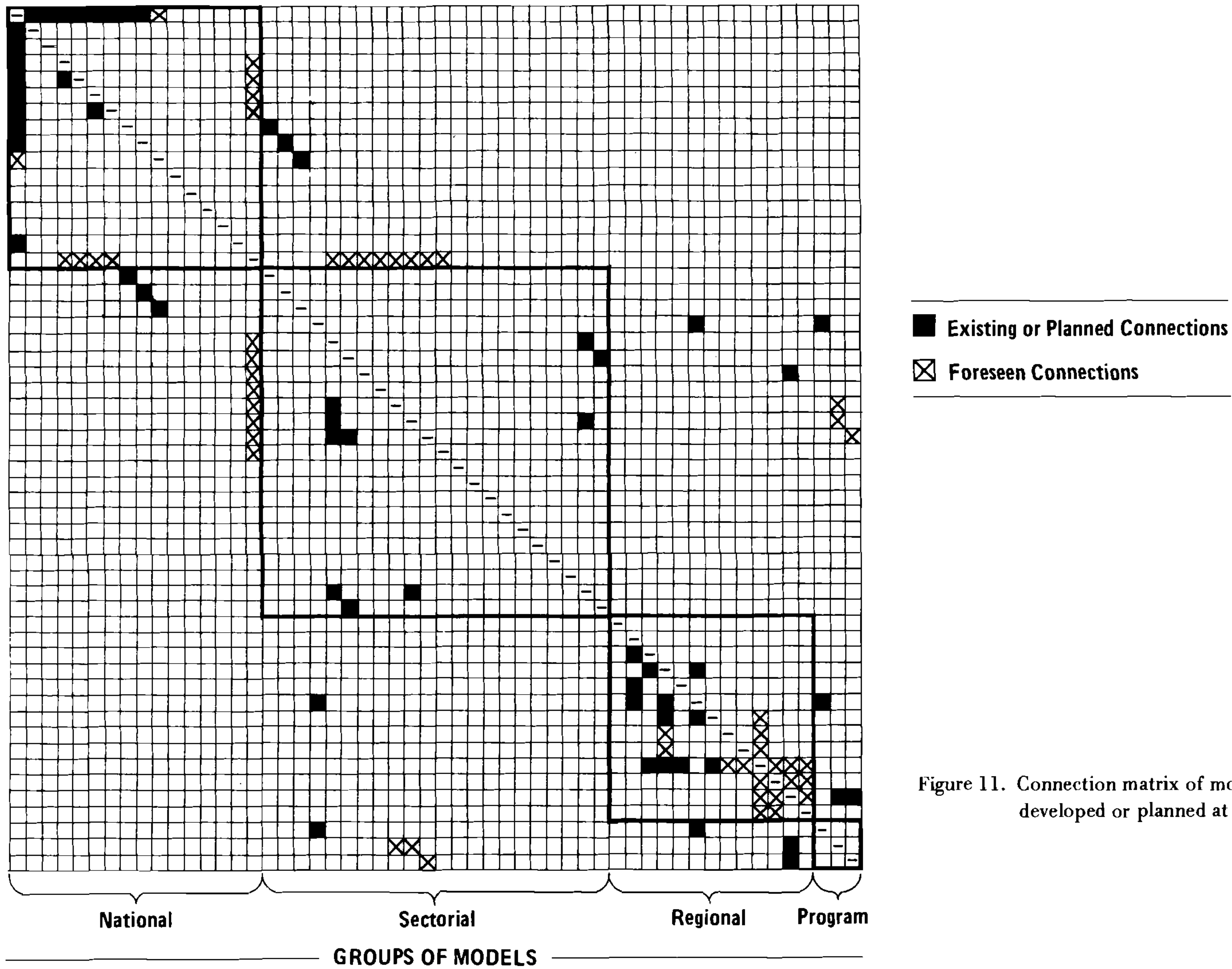


Figure 11. Connection matrix of models developed or planned at I E O I P.

simplified connectivity indices are given, showing the rough coherence of the actual and future system.

Such a simplified assessment, based on the empirical findings of Ashby and Gardner [7], and mainly on the work of Curnow, McLean and Shepherd [30], has been used by us for models in the TVA study (see [21]). We should mention here, perhaps, that a level of $C \simeq 15$ represents an important threshold beyond which additional organization is needed.

It can easily be seen that the fulfillment of the most ambitious plans pertaining to a regional subsystem will barely allow one to approach the "system" boundary by this subsystem. Others will certainly remain loosely joint entities. Not all groups should, of course, be equally internally or externally interlinked. Program models, by definition, seem to be more externally than internally connected (with sectorial and regional models of adjacent levels, while other program models are two levels higher or lower). The same applies to some extent to sectorial models which would follow vertical rather than horizontal linkage patterns. To a great extent, this is why the growth in connectivity will presumably not be very sharp.

During the Bratsk-Ilimsk Conference at IIASA we put forward the question of the efficient organization of a regional subsystem in the future, when the connectivity index of this subsystem sharply increases. It turned out, however, that the interactions between regional models were primarily seen as the utilization of results from one or several models in order to formulate input data for another model. That is, the interactions were seen in the perspective of a certain regional planning methodology and an approach to model application, rather than as software or even direct informational links. If we consider a seqment of the line leading from a point representing isolated and uncoordinated modeling efforts of differing character to another point of the software and data base supported system relying on a unified methodology of system construction and application, then with the regional subsystem of IEOIP we are somewhere in the middle. Going further on into the system's coherence (which is understood to be stronger and to have more direct information links, ultimately automatically operated) it is difficult and, at the present state of development, also not justified. In order to proceed in the direction of connectivity increase, system designers should solve the following problems:

- Provision of software for flexible and easy handling of relatively big dimensionality of tasks (ranging from a few hundred to about two thousand rows); this is connected with overcoming

- Hardware limitations. (Big tasks have currently to be run on Moscow computers to which IEOIP scientists have access.)

- Construction of an easily retrievable comprehensive and versatile data base. (A vast majority of information for individual tasks is gathered on an ad hoc basis.)

- Catching-up in realization and testing with the on-going development of the system's idea, causing an elaboration or anticipation of new models and a dropping of some old ones. (See, e.g., the number of existing and future regional models in Table 3 and Figure 11.) This problem might be solved over the longer term through the

- Elaboration of clear-cut solutions or directives as to the principles of system construction. (The subjects of objective functions, place and role of programs, goals of regional development versus sectorial and national ones, and finally differences between normativeness and projecting, optimization and simulation, deductive and inductive approaches have already been discussed.)

The latter problem does not apply perhaps that much to the regional subsystem itself as to the whole IEOIP system and to other similar attempts. Speaking about national systems we should add one more point: the limited resources and specifically oriented interests of various institutions, making them follow somewhat different methodological paths (thereby inducing the need for compromises and dovetailing in interinstitutional system considerations, e.g., as proposed in [15] the inclusion in the structure of Figure 2, of an element from the subsystem described in [3], omitting the other elements). In the Soviet Union this question is solved through the introduction of coordinative research plans on subjects which are of great national importance, among others, model systems such as ASPC construction. In the opinion of many persons, though, these plans need deeper consistency than they have now.

It can easily be noticed that almost all the above issues (perhaps with the exception of the first two) are connected, both in the causes of their emergence and in the provision of future solutions, with the interaction of the models and their designers with the planning bodies and the process. At the Bratsk-Ilimsk Conference [3], we asked for information on a feedback procedure that should generally occur between modelers and planners (Figure 12); the answers we were trying to get would enable us to analyze the more detailed issues listed. It is first of all the question of data and verification. For national level models, Aganbegyan and Valtukh [2, p. 136] propose that the planning bodies provide and analyze the data. But while it is a solvable, if not a simple question at the national level, it is certainly a very difficult, if not insolvable question at the regional subsystem level. Evidently the "lack of client" for calculation results at a proper time [8, p. 16] in the past forced IEOIP modelers to verify individual models not in the sequence prescribed by the regional subsystem structure. (There is a "client" for almost the whole of the IEOIP system in terms of the models themselves, namely the

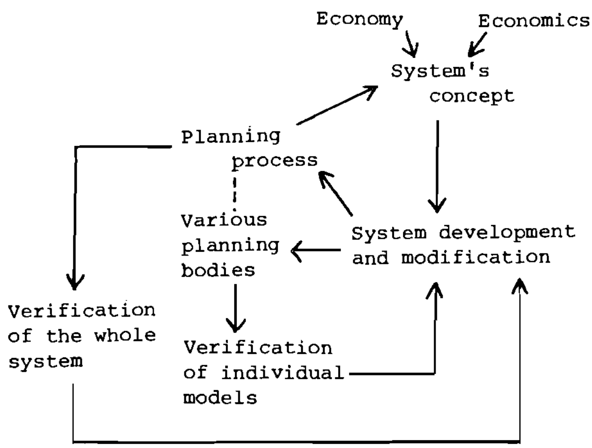
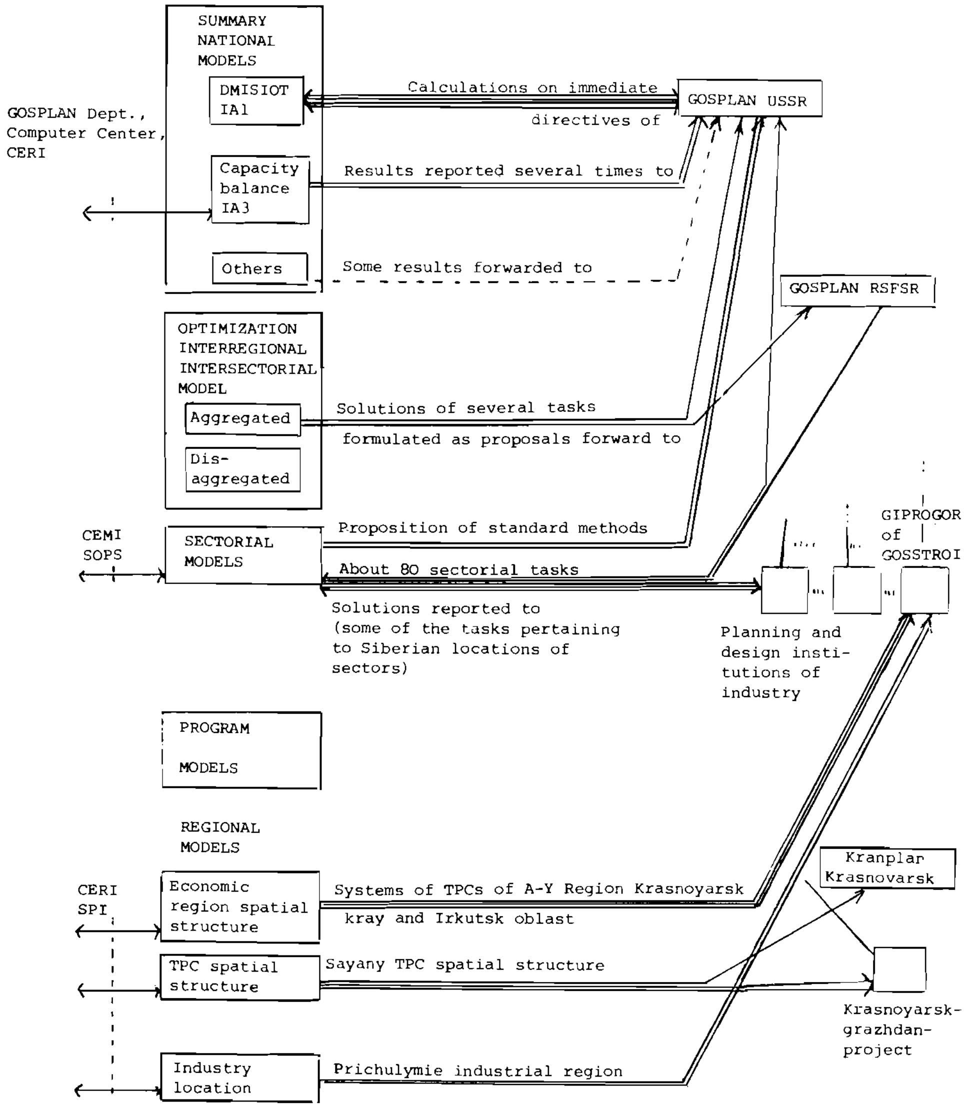


Figure 12.

ASPC design of which we have already spoken.) Now existence of a planning process oriented specifically toward the TPC approach makes it possible to activate only the inner loop of the procedure. IEOIP modelers had therefore formulated a proposition for creating such a regional planning process (see [10, pp. 153ff., especially pp. 157 and 163]), not to "support modeling" but as an objective necessity. On the other hand, if the conditions for creating a planning data base are satisfied, then the existence of such a data base would greatly enhance the coherence of the system.

Secondly, it is the question of system development tactics. Looking at the communications that occur in the procedure presented below, we can see that they are still overwhelmingly unilateral (see Figure 13), modelers planners. About the same conclusions can be drawn on the basis of the development/utilization data shown below in Table 6.

To a large degree, this situation can be explained by the stage of development of the models. The provision of bilateral communication and the matching of the planning process by the model system (also to influence it in a desired way) would, however, be greatly facilitated if an effort was made to overcome the language barrier. This question has its qualitative and quantitative aspects. The first is to bring the message to the policymaker, that is, to create an intermediary language. Conversatory, natural language oriented toward applications, simplified, easily accessible and easily modifiable models, visualizations, etc., can be a major help. This will not only provide



SUMMARY NATIONAL MODELS
DMISIOT IA1
Capacity balance IA3
Others
GOSPLAN Dept., Computer Center, CERI
Calculations on immediate directives of
GOSPLAN USSR
Results reported several times to
Some results forwarded to
GOSPLAN RSFSR
OPTIMIZATION INTERREGIONAL INTERSECTORIAL MODEL
Aggregated
Dis-aggregated
Solutions of several tasks formulated as proposals forward to
CEMI SOPS
SECTORIAL MODELS
Proposition of standard methods
About 80 sectorial tasks
Solutions reported to (some of the tasks pertaining to Siberian locations of sectors)
GIPROGOR of GOSSTROI
Planning and design institutions of industry
PROGRAM MODELS
REGIONAL MODELS
CERI SPI
Economic region spatial structure
Systems of TPCs of A-Y Region Krasnoyarsk kray and Irkutsk oblast
Kranplar Krasnovarsk
TPC spatial structure
Sayany TPC spatial structure
Krasnoyarsk-grazhdan-project
Industry location
Prichulymie industrial region

Figure 13.

Table. 6

Status / Group of Models	Theoretical or early testing	Tested	Recommendations made or occasionally run by appropriate authorities	$\sum$
National	1	9	6	16
Sectorial	2	7	13	22
Regional	7	6	3	16
Program	0	2	1	3
$\sum$	10	24	23	57

a link between formal, detailed models and natural language and intuitive understanding, but also lead to additions to the models' range--that is a broadening of the language. The set of models developed by IEOIP and available for the national system according to [13] and related publications has a fairly narrow scope of methods for viewing development. The LP with all its variations, normativeness, and optimization prevails. It has resulted from a certain perception of the economic and planning system, as we tried to present in the first sections of this paper. Not all planning functions and not all perspectives are contained in the domain thus refined. If in the space shown in Fiugre 6 we add a methodology/ perception axis or plane, then the projection of the models set on it will certainly have a very small measure.

It is more and more widely argued that simulation models should possibly be widely applied in longer-term studies, together with optimizing ones (see [14, p. 16]). A very interesting discussion of this subject can be found in [2, pp. 132-126]. A meaningful statement that may have bearing on the above question has been forwarded in [2, p. 127]: "In conditions of uncertainty primary information cannot be found strictly empirically. It should be gathered on the basis of recognition of respective qualitative and quantitative objective laws."

An increase in the variety of models not only facilitates the matching of the existing structure and tasks of the planning process, but also adds flexibility in solving ad hoc problems and insures against abrupt changes in the planning system (e.g. switch of resolution level or technical coefficients' definition)--that is, it strengthens the stability of the system.

The above comments refer to the present state of the system's development, the one we were presented with. Within IEOIP many studies are also conducted on other types of models, and on other aspects of the optimal plan formulation or data analysis, which would undoubtedly broaden the methodological scope of the system and its flexibility. Not much is known, however, on how these potential new elements of the system fit into the system's structure and on their contents and therefore on the extent to which they could play an innovative role.

Let us come back now to the phrase quoted at the beginning of this subsection, which stated in general terms the purpose of the current system: "...optimum territorial-production (...) long-term planning...". The emphasis on the *spatial* aspect of the economy and on the lack of the word *national* lets us suppose that a large portion of the future system can be regarded as being meant for regional planning purposes. This means that not only the regional subsystem (which was explicitly built for this) but also other elements (subsystems or models) can be used to determine the regional plans. Most interesting here is the problem of the position from which the regional plan is seen: Is it the top national planner or the regional community? What is the meaning of the individual subsystems? Are they "points of view" on the regional economy or are they necessary exclusively for the sake of themselves and for data provision to regional models?

IEOIP system tries to emulate with adequate fidelity the actual planning system with its output/efficiency rationale and existing information/order rules (see [2, p. 136]). It would seem, then, that it does not follow the ideas explicit or implicit in the cited works of Kossov, Volkonski, and to some extent in the research on multilevel systems in SPI, where either a certain extent of independent maneuverability of "resource complexes" or even their "bargaining power" is assumed. As has been mentioned, the latter approach could make optimal plans easier to implement through the forecasting of feedback on the behavior of the economic subjects in response to a given plan. Still, explicit application of such procedures on the national scale remains greatly limited and hence the tool for the regional plan analysis proposed by IEOIP may in the future render a great service in the coordination of top national, sectorial, and regional points of view. In itself, the proposed tool may be regarded as an emulator of different points of view which have to be coordinated on a somewhat higher level.

TPC PLANNING MODELS

The first point that must be emphasized here is that this subsystem constitutes a self-standing, complex entity meant for regional planning purposes, and not merely a device for bringing a spatial or territorial dimension into national or sectorial planning. This approach to regional planning and modeling has had an important influence on the perception of this problem by scientists from other institutions. As a comment to Figure 2, a quotation from [15, p. 246], can be given: "Concerning the outlook and terminology of the territorial structure of the economy (...) the scheme described in *Modelling of TPC Formation, Novosibirsk,* 1971 [32] is used".

In this section we will present the place of the regional, or TPC, model subsystem elaborated in the TPC Department of IEOIP and generally described in [9,12] as resulting from the "TPC approach" to the spatial dimension of the economy. Its implications as to connections with other subsystems and planning process organizations will be discussed. Then the model system structure and its hypothetical operation will be shown, along with some considerations of the system's development. As to individual models we shall shortly analyze methodological concepts underlying their construction. Other models worked out at IEOIP and concerning regional problems did not enter these considerations because they do not belong to the system and to a large extent, do not directly follow the TPC approach.

The Proposed TPC Planning Procedure

At the beginning we shall put together various observations that were made throughout this paper and which relate to the concept of the spatial organization of the economy.

Pragmatic adoption of the cost minimization objective for the regional subsystem has been carried out consequently to the ultimate, that is, all the optimization models belonging to the system are minimizing costs. In conditions where there are clear-cut national requirements formulated for the region, the adoption of the cost minimization objective makes out of a regional economy an obvious "resource complex" analogous to the sectorial ones. The main difference consists in the possibility of specifying and analyzing manpower resources and some elements of the infrastructure. All other elements can, at least theoretically, be considered as location characteristics in sectorial models. The "clear-cut national requirements" mentioned the result (hypothetically) from the solution of sectorial optimization problems, balanced and jointly optimized by national intersectorial models, with due account to the regional distribution of various resources and existing production forces. At this level big, national complex programs should be considered, generating a number of specific requirements as well (see Figure 9). Sectorial economies, as "resource complexes", are also geared toward minimizing the costs of the functioning and development for the attainment of targets by means of "routine" and "program" planning. If the locational information or sectors is as accurate and complete as that for the regions and if the national level information on regional distribution of resources is also accurate and complete (which of course they never are), then separate regional planning would not be necessary. There would be only an interregional coordination of sectorial plans based on regional resource estimates or prices. Such an approach is presented in Chapter 2 of [15].

Thus, the conceptual framework where the IEOIP regional subsystem belongs "justifies" the introduction of specific regional models for two purposes. The first is the provision of accurate data for national and sectorial models, realized through an iterative procedure for information exchange. Such a procedure could be based either on the approach proposed by M.M. Albegov, or on the use of intraregional intersectorial models, as implied by V.V. Kossov, which would be aggregated for use on the upper level and, because of their sectorial character, could be directly communicated with other models. The second purpose consists in the elaboration of detailed local plans by means of putting together final sectorial findings, local consistency conditions (e.g. interlinkages), and the elucidation of certain factors contained in sectorial or national solutions in the form of general coefficients (e.g., share of social infrastructure costs).

One aspect, however, of the spatial distribution planning could have made the above simplistic reasoning obsolete. This is the *complexity or agglomeration effect*, stemming out of the joint location of productive activities, that is, the common use of various local and imported resources, a common infrastructural base, a common settlement system providing manpower, etc., and the possibility of direct (even technological) interlinkages. The agglomeration effect can be disposed of only if certain fairly strong conditions for functions involved hold (related in the final score to the sensitivity of the intraregional intrasectorial assignment) and if adequate managerial measures for attaining additional, not explicitly calculated, benefits from the agglomeration effect can be ensured. Such a study has not however been performed, and in the IEOIP regional system, in general, the agglomeration effect has so far practically not been taken explicitly into account [9, p. 35]. It was empirically proved [20, pp. 4,5] (and partially included in some of the models) that joint location leads to specific quantitative economies, which give a justification for regional modeling in additional to the two already mentioned. But if so, then there should be a feedback to sectorial and national models on the savings obtained, which currently does not exist; though, in general, the need for this is recognized, it does not seem to be an immediate object of research.

That is to say: we are finally dealing with the simplistic procedure presented at the beginning in which regional planning models also account for some type of agglomeration effect as shown below in Figure 14.

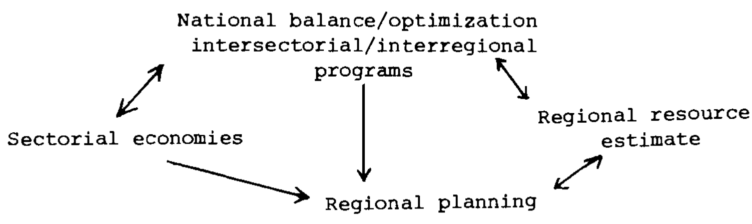


Figure 14.

We have mentioned some views according to which such a "rigid" way of proceeding is not generally advisable [23,25], and which would include specific local criteria for the regional level, involving at least the need for a coordinating procedure, if not for iterations of the complete national system. Another solution consists in adopting a kind of gaming or bargaining approach, that is, a "direct" coordination, as, e.g., proposed by Vokonski.

The clear-cut national requirements appear in the IEOIP system in the form of a production volume quota for industries of All-Union imporatnce. The industries specified for a region will be its industries of union specialization. The second set of requirements concerns infrastructure elements of interregional importance, parts of which should be executed within the region. This is the starting point; other conditions can be found in [9, p. 33]. Then the procedure, as outlined in Figure 15 follows. Two points should be mentioned about this Figure. First, the distinction of three levels of consideration is by no means obligatory, and according to [8] one level has been inserted between economic region and TPC, accounting for the fact that kray or oblast (computations for Krasnoyarsk, kray and Irkutsk Oblast) are methodologically treated in the same way as economic region. We shall refer to this level as the subregional level. Secondly, there is a difference between the ways in which two upper levels and (or three, if we take these together with the subregional one) and the IC are viewed. The two upper levels are, or according to IEOIP proposition should be, seen from the national level, while the IC is totally a local entity. It is, therefore, really the level of detail into which neither sectorial nor national models cannot have an insight.

As for these levels, we should come back to the question raised in the introduction to this paper: What spatial organization do they represent in the given concept of regional planning and modeling? Obviously, certain territorial partitioning exists prior to any solution of economic models, if only to provide adequate data to various types of models. It is easy to assume a current administrative breakdown. Once this occurs, when the data are fed and locations, intensities, etc., are found, we can obtain any kind of compositions of plants, infrastructure, settlements, etc. They may have *any* shape and magnitude (especially when there are no bounds on the magnitude, e.g., environmental costing). Certainly, the development will tend to gravitate to existing centers or to cluster to form new ones. It will proceed along certain channels or corridors, but we cannot a priori say with any accuracy what will be their structure, magnitude and intensity of interconnections. There exists, potentially, a multidimensional continuum of such entities.

When we think of development of virgin territories for the benefit of the whole nation, it becomes at least intuitively clear that both the scale of national demand and the "threshold"

Sectors

Intersectorial/interregional optimization

Production volume quota of industries of specialization

Interregional infrastructure construction tasks

Technological variants of production

Limits on scarce resources utilization

Site requirements of sectors

EXAMPLES OF DIMENSIONS		PLANNING DOCUMENTS THAT MIGHT POSSIBLY USE THE RESULTS
	Economic region	
11 areals** 21 basic industries	*Development and structure of industries of specialization and interregional infrastructure (others as aggregate); their location *Choice and location of TPCs *Specialization of TPCs	General Schemes for the country and for the region
	Territorial Production Complex	
~20 sites*** ~20 industries (types of plants)	*Development of production structure (priorities, rates and sequencing) *Location of activities (plants, infrastructure units) *Location and specialization of intra-TPC industrial centers	Technico-economic justifications of regional layout General Schemes of sectors General Schemes for the region and for TPCs
	Industrial Center	
	*Location and development of activities (plants and their parts, infrastructure, services) *Layout for the settlement system *Zoning of the area	Schemes of regional layout Scheme of regional settlement system Scheme of environment and resource maintenance
	Design of the Plan of TPC Formation	
		Schemes of TPC sectors development Schemes of ICs general plans

*Sequencing of development of TPC elements.
**Areals are high territorial units including sites.
***Sites are territorial units corresponding to the location of individual industrial industrial plants or complexes.

Figure 15.

conditions for investing development from scratch (lack of infrastructure, manpower, need for self-sufficiency, etc.) make the basic, primitive solution to location appear in urban dimensions. Such a settlement would contain a few units of specialization industries, auxiliary, and servicing activities. This is the basis for the IC, which can in general encompass an urban agglomeration and, with progressing development, a "zone".

On the other hand, it is obvious that neither the magnitude of close locations grouping, nor the intensity of technological or other interconnections can make the agglomeration effect spread over an entity of the regional or subregional size in the Soviet Union.

How does one treat TP combinations that result from optimization tasks and fall between the two above territorial categories? (There is no difficulty in obtaining them in an artificial way through the "partitioning of the region into TPCs", but that is not the point, and the location concept virtually excludes exhaustion of territory by locations.) It seems that the answer is not easy (see [9, pp. 15-16]). The distinction between TPC and other TP combinations is fairly unclear, even for distinguished economists. (At SOPS and in [28, p. 25], Bratsk, Ust'-Ilimsk, and Bogouchany have been referred to as "complexes", and according to [14, pp. 14-15], the main problem of TPC management establishment involves the "determination of large TP units, containing oblasts and krays with similar production conditions".) To define precisely various combinations, post solution procedures are proposed [33]. The question arises: To what extent are the TPC-type combinations objectively defined? This question has not so far been answered. Such entities may appear as a technically necessary step in hierarchical aggregation and disaggregation within regional modeling. If their existence is not sufficiently enough objectively based, then the critique pronounced by Kossov [25, p. 957], about too much effort being put on TPC studies instead of on more implementation-oriented ones may be justified.

If, however, the TPCs are objectively defined as intercenter or interurban structures, then not only is it justified to study the principles of their formation, but also necessary to include them in the planning and management structure, as it has to some extent happened with ICs (e.g., the proposition of General Schemes for TPCs see Figure 15).

And that is where the importance of the work on the TPC planning model system appears. It already provides a powerful, though obviously limited, tool for the preparation of bases for regional planning. Ultimately it does not necessitate the endogenous specification of any distinct regional "level", but that respect mainly relies on exogeneous information, and therefore may be subject to "softer" human analysis. The advanced stage of implementation studies fully allows treatment of this subsystem as a handy information source.

The Model System

In Figure 8 we have presented a somewhat simplified view of the principles governing the construction of the regional model system in accordance with the staging or level distinction previously shown. In practice, these principles are not fully realized, or are not realized in the same way or extent in all models. The real structure of the system is shown in Figure 16. If this structure does not strictly follow the iterative procedure from Figure 8, at least explicitly (both spatial and temporal features can be contained in one model, sequence may be reversed, etc.), it certainly follows the general line of the planning approach conceived at the TPC department of IEOIP and presented in Figure 15.

Computations of the system and of the individual models therein are conditioned by the following information (see Figure 14):

- Production quotas of specialization industries;
- Segments of interregional infrastructure;
- Specification of industries, their requirements as to sites, capital/output ratios, technological coefficients, etc;
- Resource specifications and limits on utilization;
- Site specifications.

This information is disaggregated on lower levels according to the need for accuracy in existing or proposed planning and design documents (Figure 15), and to model capacities. Because of the latter and also because of limitations of other links of the planning and data preparation process, a certain level of predetermination is inevitable. This concerns first of all technologies, possible interconnections between various production activities, and site specifications. The situation here is worse than in sectorial problems because of such an additional dimension as territory and the necessary inclusion of population problems. A decrease in the range of possible alternatives is therefore necessary. It is not seen as a very constraining factor, especially in the case of virgin areas such as East Siberia, because the choice of specialization industries is already economically limited there to the ones which, for the given investment input, would yield an outstandingly large output. The situation might be very different in developed areas where the all pervading presence of an infrastructure of all kinds levels out the ite potential and initial investment magnitudes, and usuall} there are no more unused or undiscovered resources yielding easy and voluminous gains.

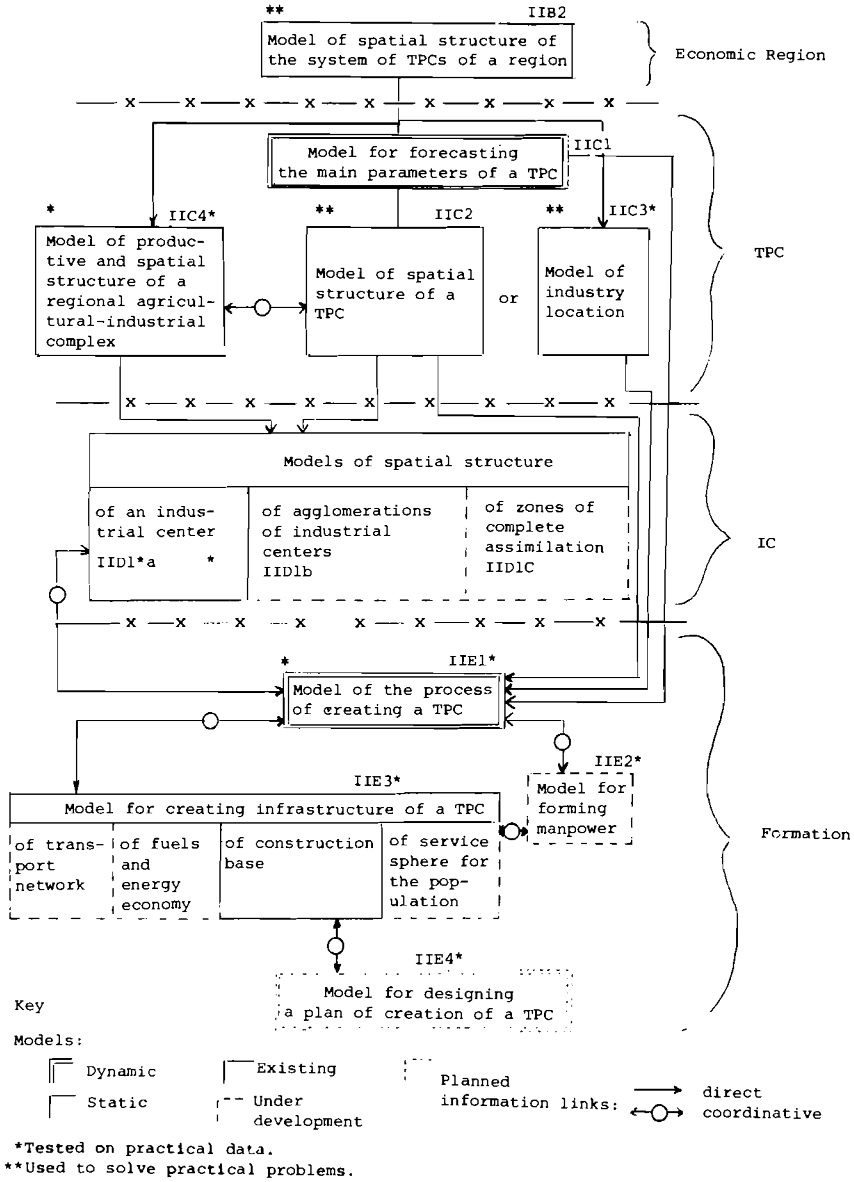


Figure 16. Structure of the regional model subsystem.

For the subsequent stages of execution of the planning procedure implemented with the help of models, the following results are obtained.

- *Economic region:* Activities of specialization industries (in aggregate form or as large plants) are allocated throughout the region among various *areals*, their development rates are specified; the same for interregional infrastructure segments; on the basis of these locations TPCs are identified together with their specialization.

- *TPCs:* Development rates and sequencing of resource utilization over time are determined for each TPC for units of specialization industries and for interregional infrastructure segments; then allocation among various *sites* and intensities of various activities (plants of specialization and auxiliary industries, transport and communication linkages, infrastructure plants and aggregate intensities) is determined, providing the basis for the definition of ICs within the TPC.

- *ICs:* Allocation among various *grounds* and intensities of activities (plants or bigger shops of specialization industries, plants and aggregate activities of auxiliary and servicing industries, intercenter communication and transport elements) is determined, together with resource utilization; the scheme of IC zoning is therefore defined and the basis for the settlement system is designed.

- *Formation:* Rates, priorities, and sequence of construction and development of the main elements of the whole TPC are determined.

Thus by proceeding, possibly with the inclusion of an intermediate, subregional level of resolution, one should obtain a sequence of solutions which finally determine the productive and spatial structure of the region, down to the general shaping of settlements. The results of previous stages are more or less directly utilized in the formation of data for the next ones. Coordination is performed by analyzing the consistency of the results of different models and by economic evaluation. The overall system is not meant to be a black box into which one feeds prescribed data and gets final, incomprehensible (as to the rationale underlying them) results. A continuous communication and analysis process occurs around the model system. Outputs of individual models are intuitively analyzable so that the basis for choices can be seen. On the other hand, running the models requires much information preparation work. There exists, then, a basis for considering the tradeoff between the data preparation effort and the magnitude of improvement of solutions achieved in the traditional way, in conditions of high uncertainty and fairly limited choice, as we shall see in the examples of application.

The model system's concept includes an elaborated initial stage of regional considerations, which are more production structured than spatial distribution oriented (see Charts 3 and 7 in [9]). As the model subsystem corresponding to this stage has no clear shape yet, we are not considering it here. The only evident element of this production structure subsystem is the IB1 model, methodologically related to the OIIM.

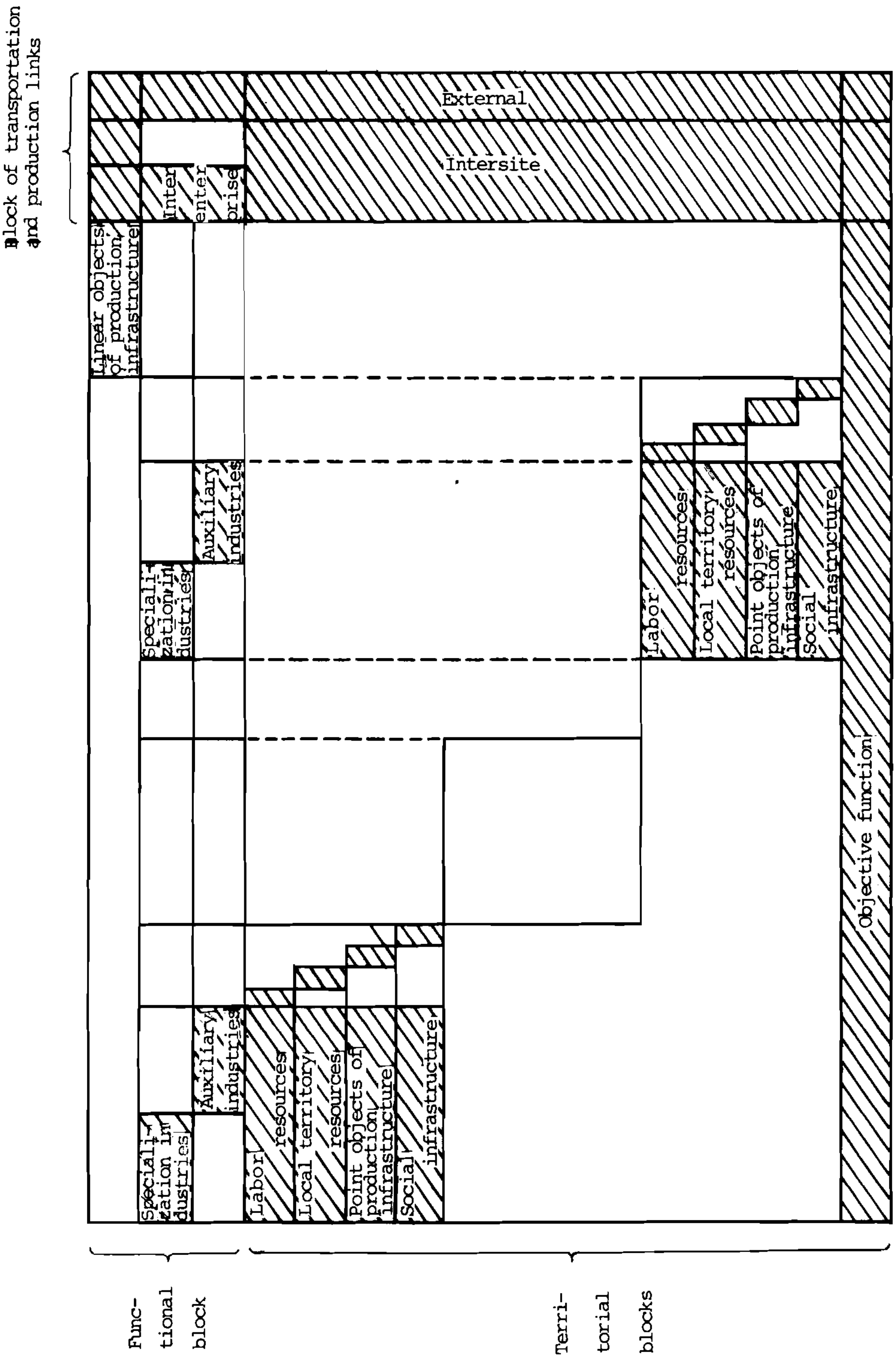
The "ideal" run throughout the existing portion of the system has not been realized for reasons already mentioned. It is not possible, then, to assess the characteristics of the coordinated system's operations. Only the existence of an appropriate planning process may enable verification of the system's operation, with so much depending on socioeconomic planning concepts and human input. Strict execution of such a formal process should also reveal very important characteristics of the system related to interconnections with outer subsystems, i.e., national, sectorial and program (see Figures 9 and 10). Especially the connections with the latter two are of interest, because according to the actual state of the work they should either be closely linked to or even partially entered in the regional subsystem. The last statement particularly concerns the sectorial formulations which may enter as lower level models of infrastructure sectors' formation, while the upper level, program-like model sets the conditions for regional project construction. (At present this is not done for the whole of a TPC, but for its elements, e.g., big railway line.)

Certainly, even if the desired planning system existed, the model system run will not currently end up with a definition of a TPC creation plan, as foreseen, because it is by no means finished. It is interesting, in general, to look at the development of the system's concept in time. As indicated in [9, p. 55], the first efforts were directed at elaborating one comprehensive model for TPC planning. This proved to be impossible, and therefore an outline of a group of models was elaborated and presented in [32], a most important work in this domain until quite recently. Further development consisted mainly of additions of alternatives or different aspects of the models, and in the extension of further stages. An intermediate state of work can be seen in [42, p. 773]. At this moment it was evidently not certain how to divide considerations of production and spatial structure of the region, so that a number of models, which are now out of a regional spatial structure model, were still considered part of it. The formation phase of the system operation was far from complete, even in concept, in relation to what is currently foreseen. Right now the manpower model, plan formulation model, and most of the infrastructure formation models are still missing, hindering execution of the"ideal" run. Also the IC spatial structure models should be completed in the near future (with the two models for more advanced development period). According to what has already been said, IEOIP modelers believe, and this is certainly true, that further development and practical implementation of regional planning models can take place only if a core for the appropriate planning process is created, if only in the form of an approved approach and methodology (see [10, pp. 149-151]) and a steady informational basis. The first function of the closed loop interaction between modelers and this hypothetical process ought to be through verification of coordinated operation, flexibility, etc., of the model system.

Individual Models

The study began with an effort to produce one comprehensive model which would incorporate all necessary aspects of regional economy, and whose outcome would contain all information needed for formulating regional plans. This attempt failed but its results are still being utilized. It took the form of the LP model for the optimization of a spatial structure of various TP combinations and other territorial entities. This typical form is used at three places of the structure (Figure 16): as an economic region spatial structure model (IIB2), a TPC spatial structure model (IIC2), and a IC spatial structure model (IID1*a, perhaps also IID1b and IID1c). Models that are complementary or alternative to these (agro-industrial complex, IIC4* and industry location, IIC3*) also take on a similar form. The outlook of the matrix for these kind of models is shown in Figure 17 ([31, p. 22]). Such a form can therefore be regarded as basic, especially for the first stages of the model system operation. It is static, though some very limited temporal considerations can be introduced through technological coefficients of production alternatives. Dynamic, or rather in reality semidynamic optimization, is performed for the TPCs after they have been defined (EEC1) and after their complete spatial structure has been defined (IIE1*). In these two models all categories of economic activities distinguished in the IEOIP regional approach (specialization, auxiliary, servicing, etc.) are jointly considered. The third group of models, not elaborated yet (IIE2*, IIE3*), differs at this point, because in them individual sectors of the economy are to be treated separately.

Simple linear formulations cannot reflect all kinds of causal relations taking place in a regional economy, and there is a great deal of uncertainty inherent in the enormous amount of initial data often set as a result of relatively arbitrary procedures. That is why there has been an effort to include the implications of the above in the models already constructed. Firstly, piece-wise linear objective functions were introduced, approximating certain non-linear cost relations. This approach, though quite straightforward and simple, could have only a limited scope of applicability. Recently, certain procedures and algorithms are being tried out to account directly for nonlinearities. The most important progress (both from the point of view of advances in methodology and because of its significance for regional modeling in general) has been made in calculating the agglomeration effect magnitude. Efforts have been made to deal with the problem through indirect and special approaches (see [9, pp. 88-90]) that



Block of transportation and production links
External
Intersite
Inter enter prise
Linear objects of production infrastructure
Speciali- zation industries
Auxiliary industries
Labor resources
Local territory resources
Point objects of production infrastructure
Social infrastructure
Objective function
Func- tional block
Terri- torial blocks

Figure 17.

allow the addition of effects from joint location of facilities and common resource utilization; such approaches, however, had an important number of shortcomings and seemingly had to be abandoned. Recently (1976) an algorithm was tested (see [6]) which was developed originally at CEMI, and is based on the statistical game-theoretical approach that ensures incorporation of nonlinear consolidation effects in the spatial structure type model. (We recall at this point that an intraregional model containing a heuristic procedure for calculating the agglomeration effect has been elaborated at SOPS.) A very important source of nonlinearities is absent or almost absent in Siberian conditions, which makes the task simpler. It is connected with saturation: land-utilization, environmental, resource utilization and similar limits that affect to a far greater extent more developed regions.

As far as uncertainty is concerned, we have noticed that IEOIP modelers often utilize the method introduced at SPI for evaluating ranges of solutions and their probabilities. These do not enter as yet into developed models belonging to the regional system, but are currently subject to investigation. Such a situation may serve to corroborate the previous statement that input data for regional models possess a high degree of arbitrariness (defined out of routine planning and information flow process) and therefore uncertainty. Probabilities and probability functions can be estimated only for quantities of which we have fairly good knowledge, measurements, tests, etc., while for regional problems these are very often first efforts to establish any quantatitive characteristics (see [24]).

To account for the dynamics of a LP, one simply introduces an additional breakdown in variables, generating an additional block-diagonal structure in the matrix. This is also the case with the two semidynamic models mentioned (IIC1 and IIE1*). The third dynamic model to be introduced to the system (IIE4*) should have a network formulation [9, p. 71]. In general, however, network formulation can lead directly to the LP model as is evidently the case with the TPC creation process model (IIE1*). Progress has also been made on the "borderline" of regional models where they interact with sectorial and program models. Direct connections were created through the introduction of multilevel structures. Because of a loose connection in other parts of the regional subsystem, it would be advantageous to internalize such multilevel structures, e.g., by connecting the TPC creation process model (IIE1*) with infrastructure formation models (IIE3*).

We are, therefore, dealing with a very clear line of development--from one LP model, to a group of LP models representing a consistent approach, to some less rigid, "softer" approaches, facilitating consideration of additional effects within the same conceptual framework.

It is not unlikely that both faster convergence to some point where only greater accuracy in data will decide a model's improvement, and better communication with the end-user (as has been pointed out) could be achieved if the model development proceeded from two (opposite) directions. Besides modifications, breakdowns and a "softening" of a group of LP models, simple simulation or managerial gaming techniques were also introduced earlier and served for learning, education, data collection, and notion definition purposes. They could be modified and updated in accordance with the increase of knowledge of the problem, and would prepare the intellectual basis for the application of more sound techniques.

APPLICATION OF TPC PLANNING MODELS

Tasks that were solved with the help of models belonging to a regional subsystem can be grouped so as to form categories corresponding to the levels distinguished within the proposed planning procedure. Thus, the TPC Department of IEOIP has been involved in solving the following problems:

- *Economic regions or subregions:* Angara-Yenisei Region (1973), Irkutsk Oblast' (1971), and Krasnoyarsk Kray (1972);
- *TPCs:* Sayany TPC (1964, 1970, and 1973), Prichulymie Industrial Region (1969), and Middle-Ob TPC; and
- *IC:* Abakan IC (1971), and Abakan-Minusinsk Agglomeration (1974).

For solving these problems various models from the system were utilized separately. Only after the data on the whole of the sequence of hierarchically structured problems have been gathered as a result of separate problem solving can the run of the whole subsystem be performed (though for a somewhat abstract example with (outdated information, and no real customer for such results). This sequence might be formed for example, by problems of: A-Y Region (solved in 1973), Krasnoyarsk Kray (1972), Sayany TPC (1970, 1973) and Abakan IC (1971) or Abakan-Minusinsk Agglomeration (1974).

When we look at the types of studies needed to define the information for activating the models and at the effort to present this information quantitatively in model conform values (e.g., see [8]), we can observe the progress made in the *structurization and rationalization of analysis through the introduction of models,* as compared to traditional methods. The advance has not been that evident on the solution-seeking phase as it has been for analysis and information definition. This was caused by a relatively narrow scope of input data and the character of solution-seeking method (LP with its limitations) which does not differ qualitatively from traditional methods. We shall illustrate below some of the problems of application to be found in the present approach, but the conclusions derived can be given here. Further progress can be, and to some extent is, achieved in two ways: by broadening the scope of input data (e.g., more alternatives) and by introducing real-world relations (e.g., nonlinear) which add to the reality of the models and to the counter-intuitive character of the solutions. Both methods involve as much modeling effort in themselves as they concern the modeling/decisonmaking interface (e.g., planning process of TPC → informational basis).

Table 7 gives the predetermined feasible locations of 21 specialization industries in 11 areals of the Angara-Yenisei Region in order to illustrate the level of detail of various models. Such predetermined locations would enter into the optimization model. In addition there are amounts and locations of resources, interregional infrastructure construction obligations, auxiliary industries and social infrastructure coefficients, etc. Each of these groups of data multiplies the dimensions of the problem and, at the same time, introduces its own level of predetermination*.

Now, if we go one step down to the subregional level (Irkutsk Oblast, Table 8) where some new areals appear, and note the changes in the composition of industries, we also see that feasible locations change in an important way**.

Are these changes--resulting from different tasks on different levels or from individual notion definitions--comparable with marginal changes in optimal results? This is not only a question of sensitivity and uncertainty analysis, but first of all of the input to models provided by the planning process. On the other hand we can see that the relative rigidity of assumptions causes each industry to appear in only one location (see Table 8). (This may not be the rule, but certainly it is a tendency.) If, then, the output of the optimization procedure is heavily input-dependent, and if this relation is intuitively retraceable, the question might have arisen: what additional benefit, as compared with traditional analysis, is brought about by this optimization procedure? We are making a clear distinction here between data analysis and the structurization phase, and optimization itself. It is conceivable that at present the first phase of modeling yields such progress that "reasonable" vertices can also be analyzed--once constructed--by a human planner.

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*There are two industries (nonferrous metallurgy 8 and 9) which do not have any feasible location in the Region; Nonferrous metallurgy 4--has only one location. There is also an areal (Markovo) which is feasible only for one industry (chemical 3).

**See for example the Markovo areal which has 4 feasible industries to locate, of which at least one was not mentioned for Table 7. If Markovo is eliminated on the Angara-Yenesei regional level for nonferrous metallurgical industries, how can it reappear there for the Irkutsk Oblast?

Table 7. Feasible variants of allocating individual types of production of specialization industries in the Angara-Yenisei Region.

Source: [8]

Areal	Ferrous metallurgy		Nonferrous metallurgy									Chemical Industry					Machine Industry				
	1	2	1	2	3	4	5	6	7	8	9	1	2	3	4	5	1	2	3	4	5
(1) Taishet	X	X			X													X	X		X
2 Bratsk	X	X			X				X			X	X	X				X	X		X
3 Ust'-Ilimsk		X			X		X		X			X	X	X							
4 Markovo														X							
(5) Zima-Tulun									X			X	X		X	X			X		X
(6) Irkutsk-Cher-emkhovo													X		X				X		X
(7) Achinsk		X	X		X			X					X			X	X		X	X	X
8 Abalakovo		X			X		X	X				X	X			X				X	
(9) Kansk				X	X	X	X					X	X				X	X		X	X
10 Bogouchany				X	X																
(11) Sayany		X	X		X			X								X	X	X	X	X	

( ) Areals entering optimal solution

...ible variants of allocating new production in the Irkutsk Oblast.

Source: [8]

Areal	Ferrous metallurgy		Nonferrous metallurgy		Machine Industry				Chemical Industry				
	1	2	1	2	1	2	3	4	1	2	3	4	5
1 Taishet (1)	⊗	⊗	⊗		X	X	X	X					
2 Bratsk (2)	X	X	X	⊗		X			X	⊗			
3 Rudnogorsk	X	X			X								
4 Ust'-Ilimsk(3)	X	X	X		X			X		X			
5 Nizhneudinsk (1)					X	X	X	X					
6 Tulun (5)				X	X	X	X	⊗	⊗		X	X	X
7 Zima (5)												X	⊗
8 Cheremkhovo (6)					⊗	X	X					⊗	
9 Irkutsk (6)						⊗	⊗						
10 Balagan					X	X	X	X			⊗	X	X
11 Tanguy					X	X	X	X			X	X	
12 Markovo (4)				X						X	X	X	

(N) Number in table for A-Y Region

⊗ Choices of optimal solution

Thus, we may repeat our conclusion: an important qualitative advance in optimization will be made in the next generation of models, where broader choice and counterintuitive phenomena will be accounted for. We want to add now that, as it can be seen from the above, the utility of results greatly depends on the type of links with adequate planning process.

As far as the Bratsk-Ilimsk TPC is concerned, we present its relative place in the Angara-Yenisei region in Figure 18, where the actual size of production is shown for operating ICs and the production size planned for the immediate future is shown for constructed ICs. The structure of the TPC system resulting from the solution to the problem of spatial allocation within Irkutsk Oblast is shown in Figure 19. (It is interesting to note that neither the Bratsk nor the Ust'-Ilimst areals entered optimal solution for the whole of the Angara-Yenisei Region (see [11, p. 25]). According to these results which were obtained in 1972, the possible future development of the BITPC was far from being decided, and this situation evidently persisted in 1973 when the spatial structure of the region was analyzed with the help of a model.

Model calculations were utilized in district plan designs for the Prichulymie Industrial Region, Irkutsk Oblast and the Krasnoyarsk Kray, for the preparation of preplan materials on East Siberia as a whole, and for Krasnoyarsk Kray in particular. The customers and, at the same time, the collaborators in the studies were design institutes, Krasnoyarskgrazhdanproyekt and GIPROGO (Moscow), respectively, as shown in Figure 13. The efficiency of utilization of calculation results can, however, only be assessed together with an evaluation of the efficiency of town and district planning for new centers in Siberia, that is, the implementation and influence of plans and designs on real district and town structures.

In general, model calculations gave results that were in accordance with those obtained through the use of traditional methods. Sometimes more precise formulation was obtained, or a need for more accurate information was stated. Less frequ
as in the case of the Sayany TPC, some modifications/recomm
tions were forwarded. In this case an aluminum plant (and
sumably other energy-intensive and less labor- and materia
sive production units) was advised to be located somewhere
because electric power conditions in Sayany proved to be
satisfactory than anticipated [10, pp. 141-142]. Anothe
osition concerned the change of location of an electric
lurgy mill between the sites within the Sayany TPC. Th
example of a result differing from decisions already m
pared concerns the Bogouchany Center.

Construction of the Bogouchany hydroelectric pov
(HEPS) (now underway) can be justified only by the p
highly energy-intensive production within this IC,
minium plant that was planned there. Even so, the
areal does not prove to be the optimal one for thi

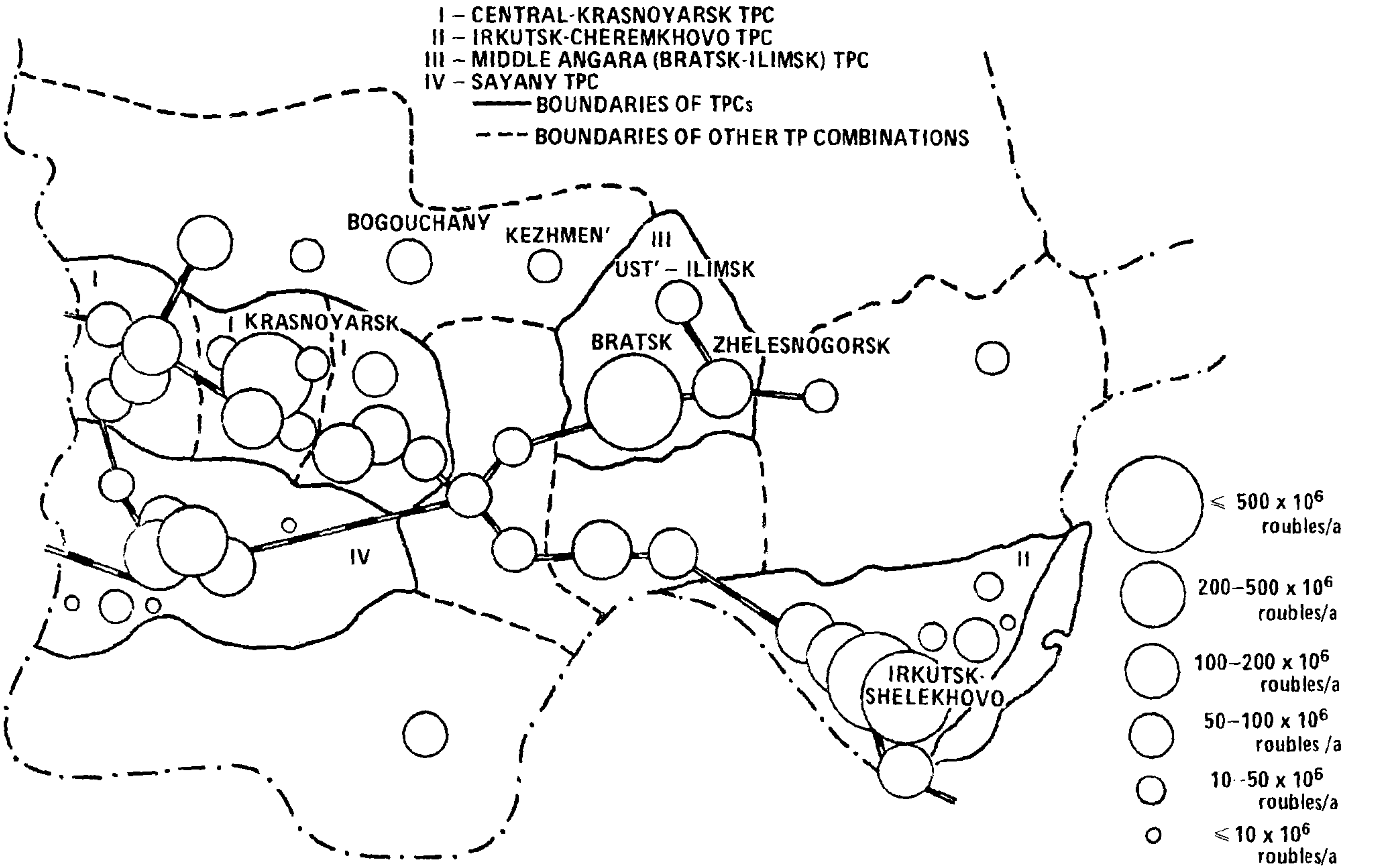

Figure 18. Development of industrial centers and TP combinations of Angara-Yenisei Region.
Source: [8].

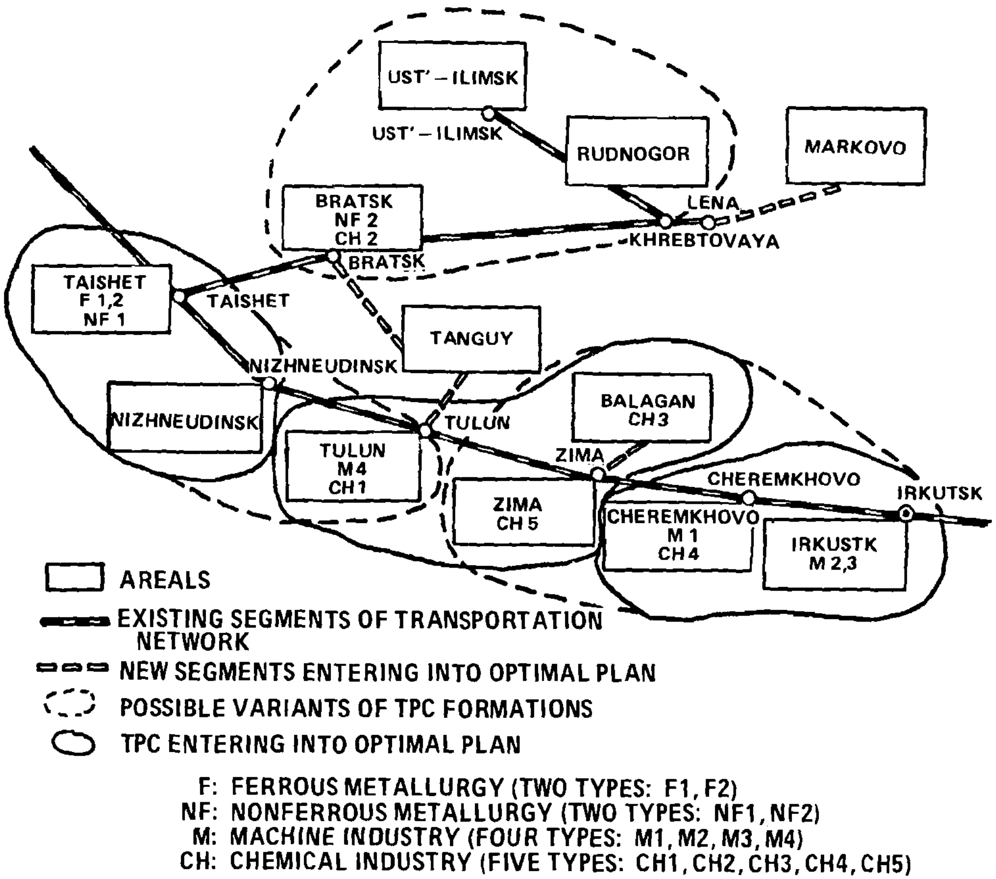

Figure 19. Distribution of specialization industries and formation of TPCs within Irkutsk Oblast'.

Source: [8].

Undoubtedly, the most thorough analyses were performed for the Sayany TPC and for its elements (determination of spatial structure, optimal plan of agro-industrial complex, studies of individual ICs). It seems it is at these levels of regional analysis that the following question arises: what is the limit of applicability of linear or quasi-nonlinear models, based on a great number of coefficients which in principle should reflect cetain averages over time or space, thus representing stable relations or their trends? For very detailed future-oriented analyses, where much uncertainty and one-at-a-time occurrences enter, the weight of accuracy may not be on the model itself but more on the precision of the coefficient definitions formulated outside the modeling group (e.g., the "complex estimate of grounds taken under industrial use in ICs" determined for various sites, grounds and utilizations by Krasnoyarskgrazhdanproyekt--see [8]). It is possible that more design or project-oriented computer applications would be of great help here, allowing for greater flexibility and adaptation. A step in this direction has certainly been made with the introduction of network formulations.

One matter of great conceptual importance, which has already been discussed, is worth coming back to at this point. After the areals are chosen and industries are assigned to them by optimal solution of economic regional level task, the definitions of TPCs are not disposed right away. They must be defined either beforehand by certain out-of-model considerations, or through additional procedures for "TPC pattern recognition". There is presumably no basis for model definition of any kind of specific TP "level" between economic regions (data definition level) and ICs (final location level) since there may exist a continuum of TP combinations between the two levels. The only evident cause pertaining to the current state of modeling art is connected with the need for a two-step disaggregation of data, which is by no means invariant with respect to software, hardware, and information system development. The situation may change in the future, when the complexity/agglomeration effect is accounted for on a scale greater than that of the IC, but we cannot tell what impact it would have on TPC determination. For the time being, then, we can change the boundaries of TPCs according to changes in qualitative beforehand assumptions, and hypothetical measures thereof introduced into "TPC pattern recognition" algorithms. Examples of this can be found in Figure 19 and through comparison of the results of algorithms mentioned in [24] with the actual status in [8].

As shown in Figure 20, if the boundaries can be changed, even in a limited range, then all further considerations of the model system must account for this. In other words, all calculations for ICs and formation stages must be carried out for alternative TPCs definitions. This poses serious computational problems; on the conceptual level these problems could, in the future, be solved together with agglomeration effect considerations and the provision of adequate feedback links.

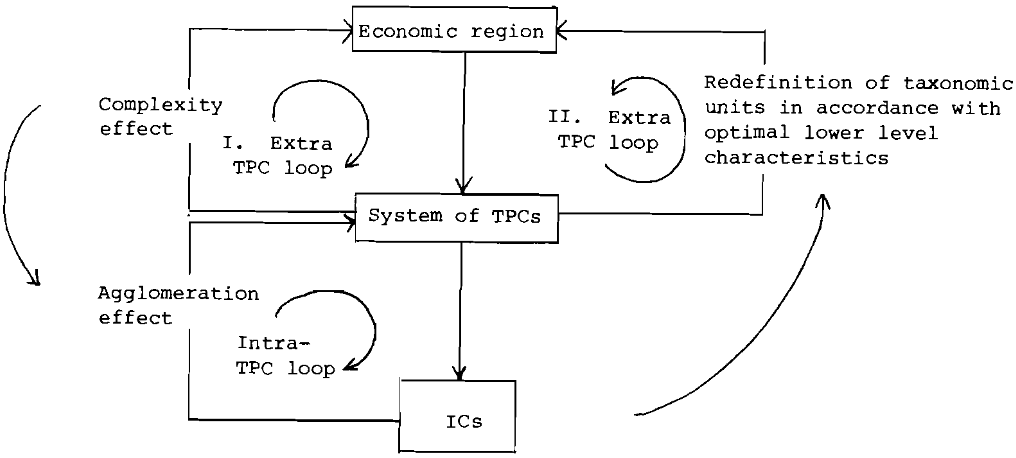

Figure 20.

That is one of the most important subjects: the definition of individual TPCs will be made through the introduction of a new generation of models comprising nonlinearity and feedback effects, whose creation has just recently begun in the TPC Department of IEOIP with studies on the nonlinear objective function optimization [6,9].

COMMENTS, CONCLUSIONS AND RECOMMENDATIONS

Having presented the outlook of the model system elaborated at IEOIP, and specifically its regional subsystem together with some of its results, we shall come back to the more general issues. We shall devote a paragraph to the assessment of the status and methodology of the system's development--that is, not the approach to the formulation of individual models which constitute the system but rather the way in which the whole structure is conceived and developed. On the other hand, we are interested in measures which are, or could be, taken to ensure the efficient utilization of models in real-life decisionmaking--planning and management. The manner in which the model system is or will be imbedded in the planning process is to a high degree connected with the system creation principles.

In general, regional model applications are somewhat delayed in relation to national and sectorial ones, and this situation is by no means specific to the Soviet Union. A survey on model applications in respect of town and county planning, recently made by Kenneth L. Kraemer for the United States, has shown a lack of clear-cut model solutions. The reasons for this are many: they result from both complexity of regional modeling, and the historical development in economic planning and therefore modeling. On the other hand, the need is more and more strongly articulated for the construction of models and of systems of models for regional development purposes by scientists, computer people, and, most important, decision-makers. Certainly the advanced computer applications in regions, both for continuous regional policy elaboration and for regional development programs, are hindered by the lack of modeling solutions.

Experience gained in the Soviet Union, especially in imbedding models in the regional economic concept of a TPC, has played and will probably continue to play an important role in promoting models for regional development. The concept of a TPC and models thereof were primarily elaborated and tested for very specific types of regional development which took place in Siberia. The results obtained can be verified for their transferability and elaborated further, and will ultimately constitute an essential element of general understanding of model application to regional development. We should emphasize here the possible role of IIASA: After a study of the experience of many national groups and schools from the USA, the USSR, France, the UK, the Netherlands, Poland, etc., the Institute should elaborate guidelines for future research in this field.

Increasing penetration of information technology, especially over the next decade, and changes in information technology itself will creat new situations on a local scale, and therefore in regional development. This information challenge may also provide opportunities for many regions, especially those lacking in resources. A good example of an effort to handle the development with this perspective in mind is provided by Japanese national and regional development projects and the related scientific programs. In general, experience from many countries shows that regional development, particularly models serving it, is still the subject of fundamental scientific research, carried out with the help of scientific communities. Practically the whole of IEOIP with its branches in all of Siberia could be said to be oriented toward regional modeling and economic development. At present, this scientific effort cannot, of course, aim at the elaboration of one unique solution, but rather at a set of approaches and resulting solutions. (One such approach to regional planning in the national economic perspective is the TPC approach.) The phenomenon of a variety of theories and models can be seen even within a single institution.

Soviet economists and modelers seem to have become convinced that the system creation is much less of a stepwise design operation followed by a longer or shorter period of execution of the design than it is an evolutionary process [14, p. 16]: "Considering the extraordinary complexity of model systems for forecasting and planning (...), its elaboration will inevitably have an evolutionary character." A good overview of some problems in this evolution is given in the introduction to [3]. Actually conducted works, both on individual subsystems and models and on the whole of the system, cannot be treated as only preliminary steps toward a system creation. Alexeev [3, p. 7] states that the "ideology" of such a model design, which would allow its inclusion in the system, is currently gaining popularity. Fedorenko [3, p. 15] estimates that existing models do not form a unified, interlinked complex (let alone a system). Also for more developed subsystems, such as the national (see [2]) or the sectorial ones, the above evaluations hold fully.

We have tried to look at the beginnings of the evolutionary process within the regional system of IEOIP and to trace its direction. Certainly the development of the whole set of national economic-mathematical models cannot have the same "linear" character as one locally developed subsystem. Still, certain features seem to be preserved within this broader perspective. Great methodological strength, from the mathematical side and in economic analysis, leads to an approach "from little to comprehensive" with observance of initial assumptions as to the methods of modeling and the nature of the object of modeling. It would speed up the development of national model systems and, as has been mentioned, of local ones and enhance their flexibility if more diversified methods were utilized. Further points of communication with decision-makers would be established, and the sensitivity of the system operation to external changes would be decreased--that is, if through the evolutionary process more resilient structures are retained. The above aspects of model development can be summarized as a view of a multifacet model as presented in Figure 21.

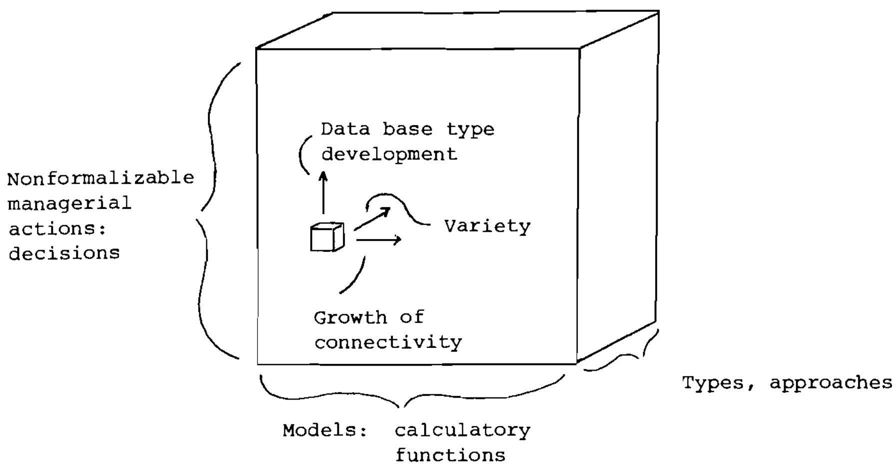

Figure 21.

Managerial functions cannot be reflected through a one-dimensional methodology as used at present in most developed models, even though it may be expandable to various circumstances. Studies undertaken on other modeling techniques or on other aspects of the analyzed systems must have an important influence on the future of the model systems.

The development of studies on model systems has matured to the point where there appears to be a problem of redefining the elements in practical terms. That is, models have been sufficiently mastered both in intersectorial and interregional dimensions to seriously consider the problem of optimal sectorization and regionalization (see [3, pp. 27-34] and [9, pp. 33-34]). This problem, however, is certainly very closely related to existing classifications and, therefore, to real planning systems.

Scientific work on planning approaches has played a very important role in the promotion of regional considerations. However, we should not over estimate it, especially now, when after the elaboration of a first generation of regional models, the time has come for their thorough verification through implementation in the planning process. Decision-makers and planners must bring in their criticism and experience. The building of further models is not an essential task nowadays; more important is the assessment of how existing models are and should be utilized. The most important questions are: who are the models used for and why (or for what purpose) are they being used? And so on. The TPC case study gave us a possibility of finding some answers for this particular case (see Table 9).

Let us look at the interaction between modelers and models on the one hand, and that of the decision-makers and the decision process on the other. From the viewpoint of problems that must be solved in order to facilitate and accelerate imbedding of models in a decision process, the following can be seen:

- There must be a general coreespondence between the model system structure, the approach to its formation and utilization, and the decision process to which it is geared. This does not necessarily mean that the models or the model system should always imitate in some way the real process. IEOIP gives an example of the inverse situation where, besides the imitatory effort, there is a tendency to influence real planning process structure. Nevertheless, a degree of correspondence should be established enabling two-way communication.

- An important aspect of this communication is the transmission of data which should on both sides be defined in a compatible way. It is not possible during the development stage of the complex model system to create autonomous data collection and processing facilities.

Table 9. Questions regarding model uses.

WHO?

Institutions	GOSPLAN USSR	GOSPLAN RSFSR	GOSPLAN Kray or Autonom. Republic	Oblast Authorities Obplan	Town Council	Sectorial Ministries	Ministerial Design Institutions	Ministry of Construction Design Institutions
Models and Computers Utilization	Running national balance and optimization models	National balance and optimization models: occasional runs	?	Limited interaction with regional models	Very limited interaction with town planning models	Sectorial development and allocation models: occasional runs	Participant in works on sectorial model	Participant in works on regional and town-planning models

WHAT FOR? OR WHY?

Phases of Regional Development	Preplanning	Planning	Formation	Operation	Monitoring and Control	Post Development
Models and Computers Utilization	Extensive use of models for scientific studies (forcasting optimization)	Initial stage of implementation: feasibility (inclusion in ASPC)	Single models originating from sectorial organizations creating TPC (Bratsk gesstroi)	Sectorial models ?	?	?

Cont.../

Table 9. (Continued)

WHAT POSSIBLE USE OF?

Purpose of Activity	Source of Additional Information			Source of Planning Information			Persuasive Argument for Other Participants of Process
	Forecasting	Goal Structure Analyses	Balancing	Forecasting	Scenario Writing and Balancing	Optimization	
Models and Computers Utilization	Macroeconomic forecasts on national level	?	Intraregional production balances	Population forecasts demand forecasts technological forecasts	National macromodels and balances: production and capacity interregional	Sectorial development and allocation models	Regional resource efficiency coefficients calculations

TIME HORIZON?

Regional Development Time Horizon	Long Term	Medium Term	Short Term	Immediate
Models and Computers Utilization	Many of national and regional level models (macro directional)	Some national, sectorial and regional models, models of programs (knowledge of coefficients allowing to optimize development path)	Subsectorial models detailed subnational balances, if any	Operational subsectorial models

> If such do not exist in the real system or if they provide data incompatible with that needed for models, it is up to the modelers to exert the influence for introducing the necessary measures (e.g., into national accounting methods, see [18, p. 73]).

If the above-mentioned interaction (Figure 22) does not occur, or if the transmission of data and verification of results are not sufficient, then justified doubts can arise as to the quality of the results obtained. The problem concerning the data has been emphasized several times during meetings with CEMI representatives (see also [9, p. 46]); the existence, and reliability of the data is a crucial factor, and, as we have suggested for long-term subregional studies, may ultimately be even more important than the question of the choice of the modeling methodology.

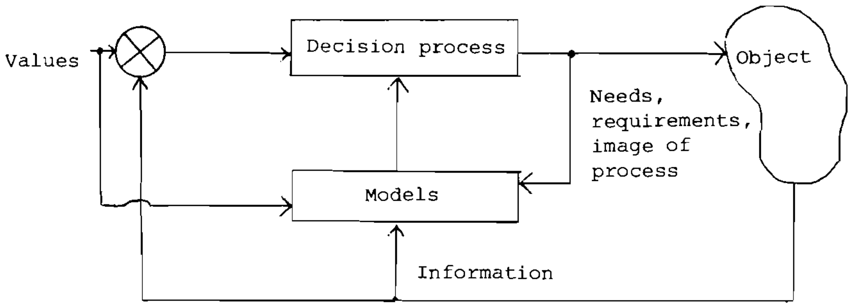

Figure 22.

In addition, there is still the problem of the fairly limited capacities of software and hardware. It is partially reflected (together with shortage of information) in relative "rigidity" [26, pp. 4,5] of models and their contents, i.e., their inflexibility and high uncertainty which, again, becomes specially acute with greater breakdowns and longer time horizons.

Certainly it would be advantageous for systems flexibility to have continuously updated, and an easily retrievable data base for regional purposes containing location and economic information. For example, the IBM Scientific Centre in the UK is working on the use of relational data base for these purposes. This is, as we can see, not only the question of models and hardware available, but also, to a large extent, that of the interaction between the planning/decision process and modeling. This is just an example to show what influence this interaction can have on the shape of the model system and the planning process.

The construction of the model system for regional development planning cannot be done by one group. Even development and utilization of individual models is very often a collaborative venture (see Figure 13). The increasing number of institutions working in the field makes this aspect increasingly important. In our study we have been able to gather general information on just a sample of the Soviet groups--even so the most important ones working in economic modeling. For an example of information on model-builders in the Soviet Union, see Table 10. As far as the inter-institutional cooperation in this field is concerned, we also see an important role to be played by IIASA, especially in conditions of growing international preoccupation with regional economies and their development. (For example, the Workshop on Industrial Geography held in Novosibirsk within the framework of the Twenty-Third International Geographical Congress concentrated on the optimization of territorial production systems.) The Bratsk-Ilimsk Conference held at IIASA in March 1976, with participants from more than a dozen countries, proved that there exists strong interests in some aspects of the TPC approach, and among them in model development and utilization. Soviet modelers who have been involved in the Bratsk Conference and in the Bratsk Field Study have expressed their wish to maintain and broaden the exchange which has begun, especially in view of the necessary further development of models of which we have spoken. In planning this development one must be aware of options available and of experiences which others have had with those options.

We do not mean only the choices in the types of models describing the same phenomenon for the same purpose. We mean the encroachment of new functions which models can and should perform; that is not only *preplanning*, which to some degree has already reached "model-saturation" point, but also *planning, operations* and *monitoring and control* (especially important in environmental management) in the future (see Figure 23). This would in turn involve the broadening of the scope of model types and application; for example, a balance between optimization and imitation (simulation) must be maintained. The experience of other countries (e.g. the USA, Japan) shows that the future set of models must incorporate both normative and retrospective considerations, forward and feedback loops.

Let us look once again at the models/decisions and planning interaction, but at a higher level: the level of organizations on both sides. The methods of development and incorporation of regional planning models in the national system were of special interest to us. The first question we met concerned the structure of the system and the place of the regional models in it. Should regional models only play the coordinating role, or should they be treated as self-standing entities whose solution provides explicitation of additional benefits? When speaking of additional benefits we refer, first of all, to the agglomeration effect. This effect is at the moment primarily accounted for on the lowest location analysis level, and only in a quite limited scope. If the sectorial models

Table 10. Model builders for economic planning: types of questions.

WHY? WHAT? / WHO?	ORGANIZATIONAL OBLIGATIONS: PARTICIPATION IN SCIENTIFIC PROGRAMS	ORGANIZATIONAL OBLIGATIONS: INTERACTION WITH PLANNING PROCESS	ORGANIZATIONAL OBLIGATIONS: DESIGN TASKS	TYPE OF OUTPUT: GENERAL METHODOLOGY	TYPE OF OUTPUT: ALGORITHMS, TECHNIQUES	TYPE OF OUTPUT: SOLUTIONS OF SPECIFIC PROBLEMS
CEMI KEY INSTITUTE	NATIONAL MODEL SYSTEM	INDIRECT		+++	+++	+
SOPS WITH GOSPLAN		DIRECT		++	++	+++
IEOIP	DEVELOPMENT OF MODELS, PROBLEMS OF SIBERIA	INDIRECT		++	++	+++
CERI, RSFSR	GENERAL ECONOMIC RESEARCH	INDIRECT		++		+
INSTITUTE OF MANAGEMENT AND CONTROL	MOSTLY FUNDAMENTAL RESEARCH			+	+	
INSTITUTE OF CYBERNETICS, KIEV	MOSTLY FUNDAMENTAL RESEARCH			+	+	
INSTITUTE OF MATHEMATICS, SIBERIA	FUNDAMENTAL RESEARCH			++	+	
SPI, SIBERIA	SECTORIAL MODELS	INDIRECT	?	+	+	++

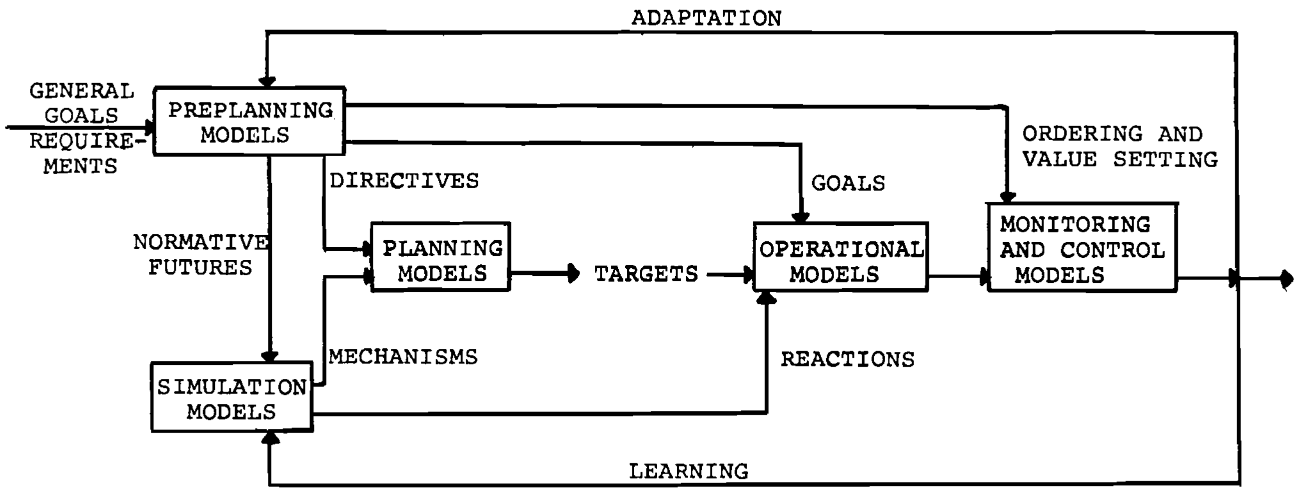
ADAPTATION
GENERAL GOALS REQUIREMENTS
PREPLANNING MODELS
ORDERING AND VALUE SETTING
DIRECTIVES
GOALS
NORMATIVE FUTURES
PLANNING MODELS
TARGETS
OPERATIONAL MODELS
MONITORING AND CONTROL MODELS
MECHANISMS
REACTIONS
SIMULATION MODELS
LEARNING

Figure 23.

intervene at this point, coordination can also be performed on this level. Coordination on a local level appears to be necessary not only because of various sectorial interests, but also because these interests originate at various levels (see Figure 24) adding up to regional managerial entropy.

Closely connected with the question of *system structure* is the question of *objective functions*. A region can either be treated as a production unit, namely as a resource complex (as it is currently treated--see e.g. [23, p. 36]), and therefore regional planning can easily be reduced to a sophisticated location problem (V.V. Kossov is also of the same opinion), or it can be treated as an acting subject. A certain "loosening" of the production unit approach can already be seen in a proposition elaborated in the System Science and Cybernetics Department of SPI, in which a large degree of decentralization is introduced especially with regard to coordination. Kossov [25] proposes to look at the region as a certain "controllable" unit over which we must define optimal controls while maximizing benefit. In the gaming approach of Volkonski, the region is a "partner" in a game seeking its benefit together with other players (e.g., representing sectors).

The last two positions are certainly justified by the existence of the regional community with its needs and requirements. In our opinion, progress can be accelerated in the creation of model systems through the introduction of diversity as previously mentioned. Local (nondual) objectives exist in reality; on the other hand, we do not have (and we will not have in the near future) any methodological or instrumental capacity for putting everything into a neat, formal framework. If we know the rules governing a particular subsystem, we can model it and its relations with other elements, which may be expressed in a less formal way--through the introduction of a unified approach, language of description, etc., by imbedding the models in a certain loosely defined system. Full formalization may or may not come at all.

As we have seen, the IEOIP regional system was not directly utilized. It seems to be more "intraprocess" oriented, that is, to play the role defined by the proposal of Kossov and the model of Volkonski: to determine the (locally) optimal trajectory of "controllable" unit, or to determine the behavior of one of the players. Such a role is especially important in a situation where there is no managerial structure responsible for a TPC and no planning process geared toward it. Modeling therefore becomes one of the leading forces with a significant persuasive role in the overall decision process. In practice, models are virtually the exclusive domain in which a TPC appears as a certain reality (though, as we said, somewhat unclearly defined). Their role as intraprocess arguments of development in the case of Siberia can be estimated still higher if we consider that the TPC models are specially fitted for virgin territory conditions, where reluctance to invest is higher than anywhere else (see [23, p. 42]).

It should be easy to understand then why we are not seeing this case as one for a strict, unified modeling methodology. The

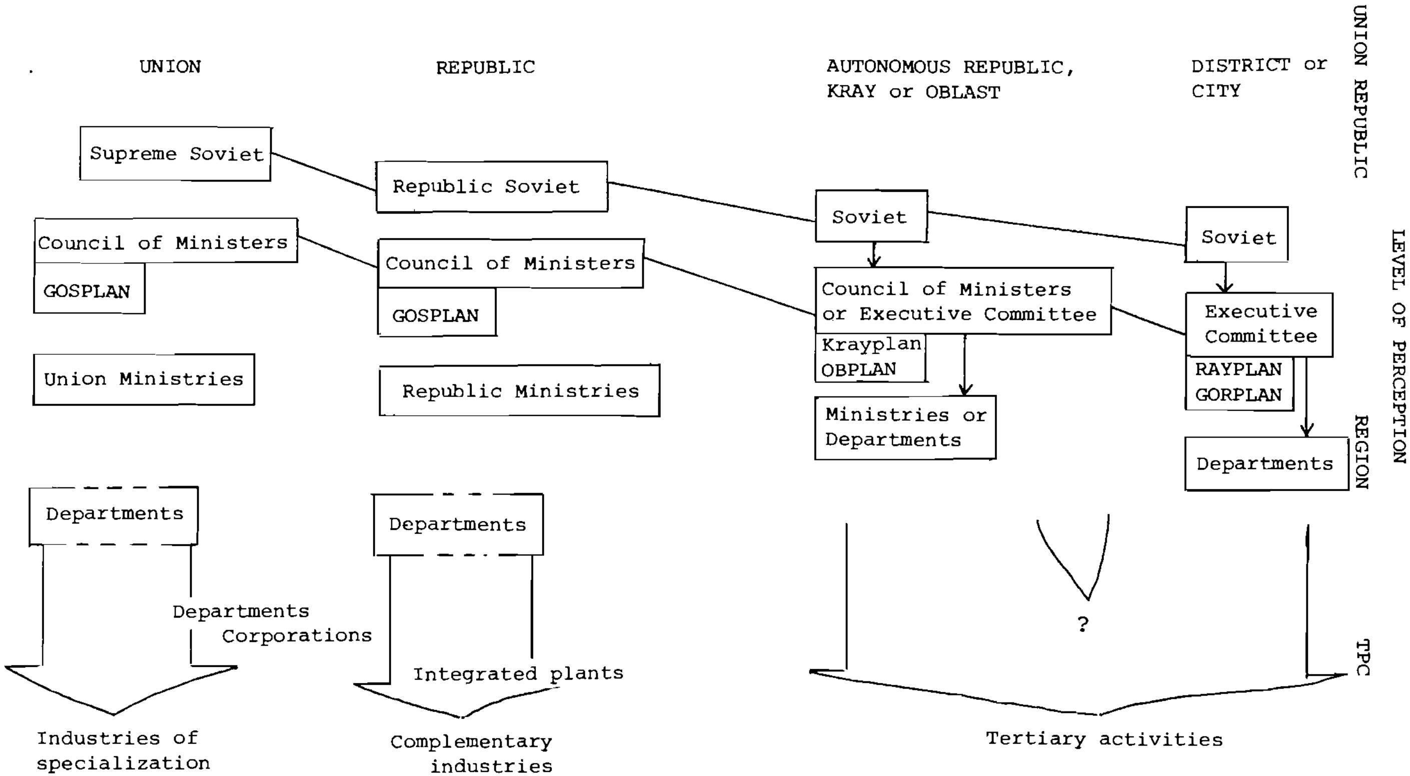

Figure 24. Projection of authorities of various levels into the region (planning relations not accounted for).

system's development cannot go this way because of its own structural-organizational requirements, and because of the organizational environment. As the organizational evolution goes on, various solutions may be adopted for planning and management as well as for the model system structure. The functions of models in the TPCs may also change. It is of great importance at present to bring about adequate coordination and to visualize, or represent, the TPC itself, i.e., to decrease the entropy. Such functions can in the present institutional environment be performed by a *TPC computerized information center*. Its role would certainly change in the future, but in a future greatly influenced by its existence.

Regional development is founded on material and human resources. We must see, however, the growing role of information resources--that is, the latter ensuring higher efficiency of the previous ones. It is with better utilization of this specific land of resource that much of the success of integrated regional development programs is connected--that is, better utilization of models and of computing hardware.

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Automated Management Systems in the BITPC

INTRODUCTION

The investigation of management information systems or automated management systems (ASU)* at the factory level was originally not intended to be a part of the field study on planning, management, and organization of the Bratsk-Ilimsk Territorial Production Complex (BITPC). However, the study revealed so many interesting facts with regard to ASU in the three factories visited that we have summarized them here together with a brief description of the concept of computer application in the economy of the USSR. A detailed examination of ASU in the USSR would certainly provide many new aspects for application of systems analysis in economic planning and decisionmaking.

BACKGROUND OF ASU IN THE USSR

At the 24th Congress of the Communist Party of the Soviet Union (CPSU) it was decided that, beginning in 1971, computers and integrated management systems were to be used in the development of the national economy. Substantial funds were reserved for investment in hardware, and for encouraging new efforts in research and application areas. The present Five-Year Plan (1976-1980) provides resources for upgrading and extending existing systems and for producing the hardware and communications equipment necessary to implement new systems; and directives were given to many sectors of the economy, and particularly to the industrial sector, to develop and implement ASU within the period 1976-1980. Eventually, a long-range plan for the development of ASU evolved. Four levels were identified for the functioning of ASU as individual systems and as units of an integrated system for the basic functions of planning, management, and control of all sectors of the national economy. The integrated system, OGAS**, is shown in Figure 1.

The *first (top) level* of OGAS comprises the ASU for GOSPLAN, GOSSNAB, GOSSTROI, the State Committee for Science and Technology (SCST), and the All-Union Ministries--some 100 units in all.

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*The Russian designation for computer use in improving management is ASU: Aytomatitsoheskaa Systiema Upravlenia.
**Obschegosudarstovenaja Avtomatizerovanaja Systiema.

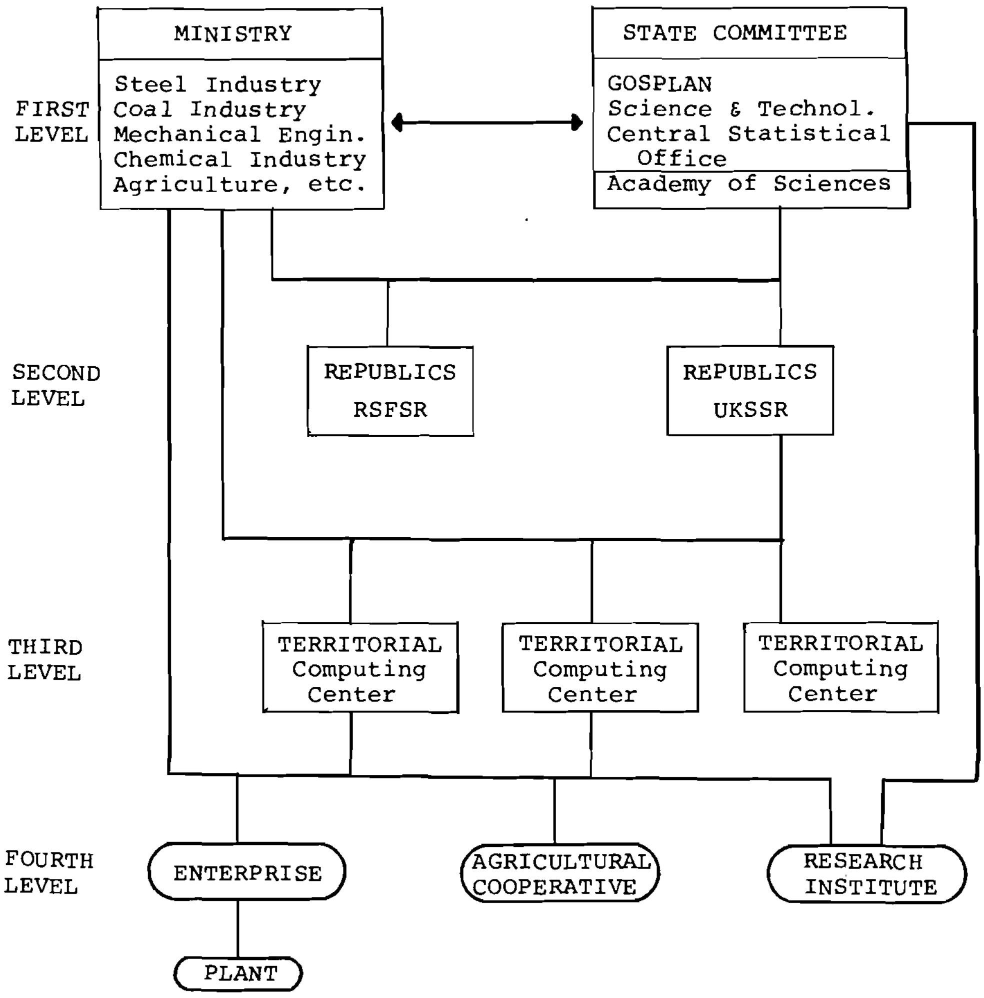

Figure 1. Integrated system OGAS in the USSR.

The *second level* embodies the ASU for individual Soviet Republics and Republic organizations and for individual Ministries and major industrial and commercial sectors. In the period 1971-1980, new planning and management systems are to be implemented to cover integrated ASUs for the 15 Soviet Republics and some 30 Republic Ministries.

The *third level* of OGAS is to be organized in territorial computing centers covering the demands of ASU in local organizations and enterprises through the use of computer services by remote entry. The computing centers are also intended to interlink the fourth and the second levels of OGAS. Two hundred centers are planned for the period 1971-1980, increasing to 3000 to cover present and potential economic regions and industrial and administrative centers.

The *fourth level* of OGAS will be the so-called ASU for production associations (ASUP), enterprises, plants, agricultural cooperatives, etc. In the long-term plan 25,000 ASUs are comtemplated, each with its own computing center and hardware.

The planned integration of all levels of OGAS through a centralized data base and decentralized regional and Republic computing centers is illustrated in Figure 2.

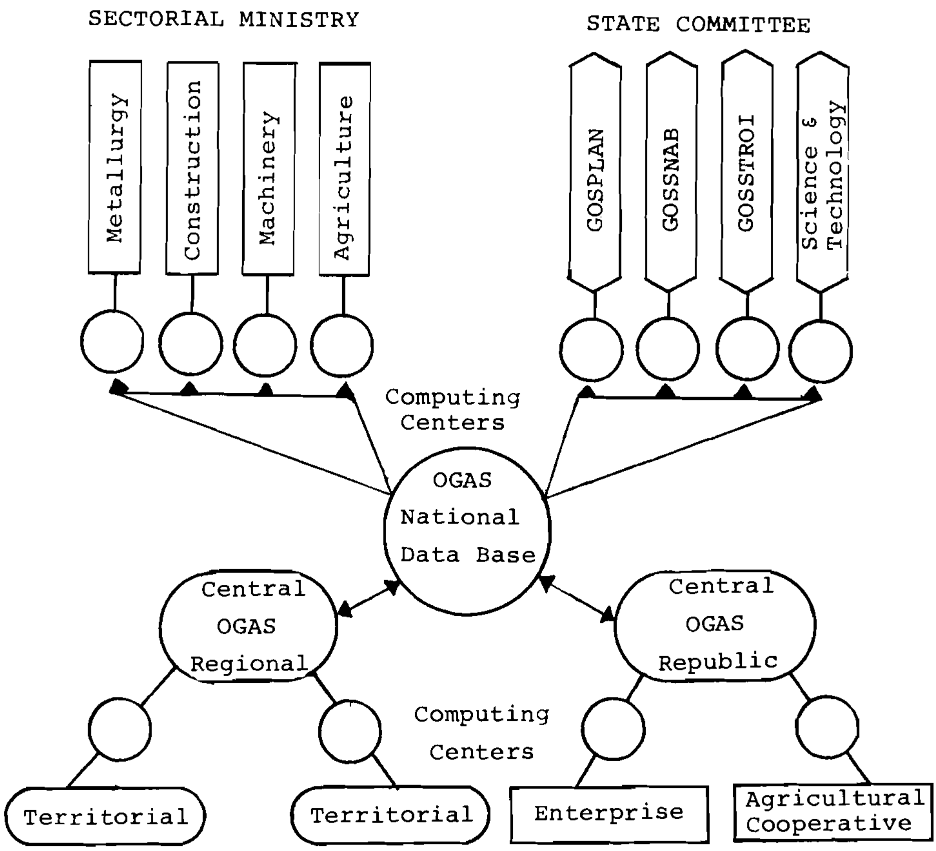

Figure 2. Prospective integration of OGAS with centralized data base and decentralized computing centers.

The functional structure of OGAS reflects the combination of sectorial and regional management principles. Sectorial development planning based on intersectorial input-output models, takes into consideration the interests of both sectors and regions.

Sectors represent general economy units in planned-economy countries. The development of sectorial management and the corresponding ASU is one of the more important tasks of a plan-oriented country.

The optimal management of sectors--the planning of development, allocation, etc., based on economics, mathematics, management and administrative methods, and computer implementation--is the main aim of ASU for the production areas of the national economy. To achieve this aim, it is essential that data processing, transmission, and control be designed at the sectorial level and coordinated with the activities of individual plants, enterprises and institutions, and regional authorities.

The following typical subsystems are included in sectorial ASU:

- Prospective location and development of sectors;
- Techno-economic planning and analysis;
- Operating control;
- Material-technical supply;
- Data management;
- Sales management;
- Finance;
- Bookkeeping and accounting;
- Planning and analyzing the labor force and wages;
- Planning and accounting for labor force and key personnel.

Typical problems solved in ASU at the sectorial level include:

- Calculating prospective demand (including export) in sector production;
- Identifying and analyzing different alternatives for development and allocation in sector enterprises and plants, and choosing the optimal scheme;
- Recommending means for improving the economics and techniques of production sectors.

There is no constant flow of information from sector, enterprises, or plant to or from the Ministries. Information flows in one of two ways:

- The large enterprise sends information directly to the main sector computer;

- Medium-sized and small enterprises and individual plants send information to the regional computer center.

The regional ASU deal with the management and control of the national economy. A regional computer center typically has the following functions:

- To gather and process information from all enterprises and other organizations in the region; in this sense the center plays a major role as a collective computer center;

- To provide the linkage between the fourth (lowest) level of ASU and the second level of the Republics;

- To be able to take over for the highest-level computer.

The regional computer center has the task of preliminary processing of information that is sent to the sector's main computer center. It is responsible for fulfilling operating management tasks, and for processing information for local authorities who make decisions on the basis of the best of several variants.

The organizational structure of ASU in the USSR is based on three State systems:

- State computer network;

- Standard State communication system;

- Standard State data transmission system.

At present the State computer network is based on the RIAD system that was developed by the socialist countries. The second system secures communications among computers, and the third has two functions: data collection multiplexing and information transmission to other managerial levels.

Figure 3 shows the hierarchy of computer systems in the USSR and the development of these systems. There are currently about 3000 computer centers. During the period 1970-1975, 700 computer-based systems for the technological unit or process level, and 1800 ASU for the enterprise level, were put into operation. Twenty-six ASU for all State Committees and Ministries and 57 for the Republics are partly in operation and should be completed by 1980. The 22 large regional computer centers will also be organized in the five-year period (1975-1980). By 1990, the number of regional computer centers should be 200. Fifteen ASU at the Republic level are partly in operation and should be ready by 1980. The integration of most of these systems in OGAS should be completed by about 1990.

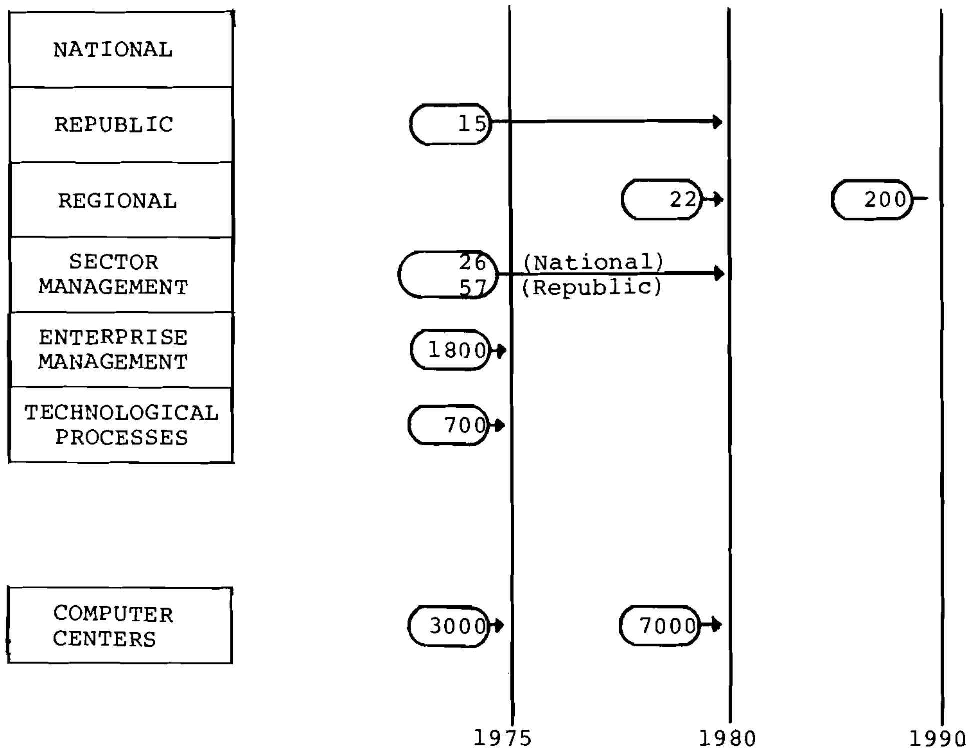

Figure 3. Hierarchy of computer systems, and number of computing centers planned in the USSR.

HARDWARE AND COMPUTER FACILITIES

The USSR produces a broad spectrum of electronic equipment and computers. Extensive efforts have been made over the past ten years to intensify research, and to establish laboratories and plants to produce computers domestically.

Initially, computer production of the BESM series was oriented primarily toward speedy processing for technical and engineering computations. Computers constructed at a later stage, representing the second generation of hardware logic and architecture (URAL, MINSK), are intended to accelerate the development of ASU and to make available more sophisticated computers for management and control of the national economy.

About five years ago, it was decided to establish a program for producing a new family of computers, in cooperation with other countries of the Council for Mutual Economic Assistance (CMEA) which is to be similar in structure to the IBM 360 series. Three series labeled RIAD, ASVT and EC form a family consisting of small (1010, 1020), medium-sized (1030, 1040), and large computers (1050, 1060) respectively. Further technological improvements were made to these systems, and the basic line was modified. The newer versions of hardware are identified by the number 5 instead of zero in the last digit (1025, 1035, etc.). The new models are planned for application of ASUP for organizations and enterprises, as well as for territorial computing centers.

In addition to the RIAD series, there is also a heterogeneous group of computers with specific uses or functions. These include the computer series M4000 (4010, 4020, 4040) and M6000, which are particularly applicable to process control, and have been initiated by the Ministry for Instrumentation and Equipment (Ministerstro Priborostroenia).

The larger, more advanced units are oriented toward the centralized needs of the Government and the State Committees, and link the sectorial Ministries and enterprises. The connection between enterprises and Ministries is to be supported by telephone lines and telex, for mutual and consistant understanding of planning and statistical information. The State Plan outlined for the next ten years contemplates a sophisticated network system with extensive integration of all units through direct data transmission and communication at all basic levels of OGAS.

The following sections deal with the individual enterprises and institutions which the Study Team had occasion to visit.

ASU IN BRATSKGESSTROI

One of the early decisions (in the 1950s) in the development of the Angara River basin was to place responsibility for all regional hydroelectric power and industrial construction in a single organization, the Bratsk Hydropower Construction Enterprise (Bratskgesstroi). This organization has a specific function in the development of the territorial production complex (TPC). Its structure provides for heterogeneous functions relative to specific activities: construction of towns, communications, hydroelectricpower sites, industrial complexes, net of services and infrastructure, etc. Bratskgesstroi is in charge of planning, managing, controlling, arranging, and supplying everything necessary--manpower, materials, equipment, money. It now has over 80,000 people on its payroll, and is the dominant organization in the central Angara Valley area.

The Bratskgesstroi computing center was organized in 1967 and began operating in 1970, using a second-generation URAL 14 computer with two processors. A second unit was later added. The staff of the computing center now numbers some 250 people with the following tasks:

Task	No. of People
Technical, maintenance	30
Programmers, mathematicians	20
Systems analysts	10
Controllers of standards	15
Data preparation	30
Files, dispatching	12
Tabulators, data acquisition	120
Others	15

The personnel qualifications are adequate for the present hardware, but intensive courses are planned to upgrade the profile of the computing center in preparation for the integrated ASUP now under development. This new system is the so-called *ASU - Second Level* and will include "the main functions of subsystems important for the complex management and control of the enterprise". The Ministry of Power has allocated 25 million rubles for the new system for the period 1976-1980, including the purchase of two EC1030 or 1035 third-generation computers.

An agreement was signed with the Centrprogramsystem organization in Kalinin to supply Bratskgesstroi with the basic packages of programs for organizing I/O data.

Another major upgrading of the Bratskgesstroi computing center is foreseen for the end of 1980, when a large-scale EC1050 computer is to be installed. Terminals are to connect all major

Bratskgesstroi and Ust-Ilimsk operations. A teletype paper-tape system is now used to connect all participating units, which are located in an area roughly 500 km in diameter. Here again, no information on how these expansions are justified could be obtained.

At present, the computer center serves 70 clients (organizational units), handling some 2000 projects of construction. The major applications are described in the following.

Payroll is prepared monthly for 17,000 construction personnel. Intermediate pay disbursements are made on an estimated basis, and all adjustments, bonuses, etc. are done at month's end. The upkeep of the detailed files on all personnel and all changes is vital for planning, accounting, payroll, and statistics. Statistical summaries are prepared quarterly.

Materials planning is done quarterly, using standard bills of material and unit costs supplied by the Ministry and modified locally. Material requirements for 10,000 subprojects or tasks are prepared annually and updated quarterly. The outputs of this system are listings of material requirements for the quarter, by contractor, subcontractor, trade or type of work, "investor" (Ministry or administrative unit supplying funds for the project), and supplier. These listings go to the planning department where they are compared with manual availability records. Files are twofold: to control the production, transport, stock and warehouse, and to control the volume of used material for new buildings and plants for cost calculations, etc. The system is called *ASU- First Level* because of the basic features which include prescribing the general methodological standard obligatory in ASUP. This system is very similar to the BOM (bill of materials) used in other countries and has no internal link to other subsystems (the exception is payroll and budgeting), i.e. to inventory and total production control.

Daily dispatching of concrete trucks is based on information on daily requirements, by location. These are telexed in via paper tape, and a least-cost allocation of trucks is made. The resulting schedule is given to the concrete-producing units, the using locations, and the truck dispatcher and drivers. This system is the single largest user of computer time, and is said to have resulted in a 20 percent reduction in the number of trucks.

Material delivery truck expense allocation uses daily trip tickets. They are allocated for all deliveries and costed according to standard per-kilometer and per-stop charges, and costs allocated to the receiving unit.

Network scheduling for all major construction projects is done annually, but requires the use of a larger computer in Novosibirsk. Job status information and manpower utilization data are collected continually, and analyzed in relation to schedules quarterly. Day-to-day analysis is done manually at the work site.

ASU IN THE BRATSK ALUMINIUM PLANT

This plant is the largest in the Soviet Union, and is said to produce more aluminium than ALCOA. The technology is up to date and cost effectiveness is viewed as a key factor in the planning and management system. The plant is "obliged" to yield 18.6 million rubles profit, and the ASU is considered an important tool for reaching this objective.

The computing center is equipped with two MINSK 32 (second-generation) computers and a M4030 is being installed to handle production and technological process control problems.

The ASU is to include 12 subsystems, of which 4 are in operation. Eventually the system will cover economic planning, accounting, material supply, and manpower control, as well as a number of process control applications. The software is characterized as a system of models to integrate the levels of production scheduling and process control. Because of the complicated technology and sensitivity of production to a number of process variables, several research laboratories and institutes participate in the preparation of the software and the ASUP. The Institute of Automation in Kiev was mentioned as a pilot for this project. A branch of this Institute in Irkutsk is also involved in the development of the system.

At present, the major applications are a daily evaluation of the composition of the electrolytic bath in each of some 2000 cells (possibly to be converted to on-line operation) and the calculation of optimal blending of molten batches of aluminum depending on required end-product specifications. The upgrading of these systems is expected to produce savings on the order of 100,000 rubles per year through electric energy conservation, anode life extension, and end-product quality improvement.

The group of specialists in the computing center concentrate their attention on fulfulling all tasks of the ASU First Level to be ready in 1976 and to prepare the ASUP by 1980 when it will be fully operational. Besides the standardized structure of ASUP common to other plants in this sector, the aluminium plant in Bratsk will establish a special group for mathematical modeling of the process so as to be independent of the research institutes outside. The local systems group feels strongly that it should play a greater role in systems development vis a vis the research and design institutes located 5000 km away. No details about this new activity were related.

ASU IN THE BRATSK TIMBER COMPLEX

The timber complex produces 1 million tons of wood products per year, including cellulose pulp, liner board pulp, bleached pulp, and viscose cellulose. (A second unit of comparable size is under construction at Ust-Ilimsk, 250 km to the north.) It draws on an area of 30,000 km^2 of timber resources--enough for 100 years' supply, corresponding roughly to the Siberian growing cycle. It uses a sulfate liquor process which has been discussed elsewhere in this Report.

The computing center was founded two years ago and is characterized by a significant development tendency for the near future. At present they use a single second-generation MINSK 32 computer, with limited capacity and data throughput. A third-generation computer--EC1030 (or 1035)--is planned for next year.

Present applications of the ASU cover 22 tasks which may be categorized into four groups:

Annual planning is based on a limited number of key output objectives, by major product category, which are issued by GOSPLAN. The system calculates weekly production and maintenance-time requirements by production center. The system is fully functional and includes all information about the plan indicators and normatives (standards). Outputs include approximately 50 indicators to schedule production flow by using normatives for all products.

Personnel records and payroll are kept for 14,000 employees. The computing center maintains all the personnel information. Payroll is processed monthly, except that of some seasonal workers which is processed weekly. Basic statistics are prepared quarterly.

Accounting and inventory cover recording of production, shipment, receipts, and inventories for all warehouses and shops, processed monthly or quarterly.

Production planning (automated system of standards) produces management reports, by production center, on cost performance, personnel utilization (professional structure, level of skills, etc.) and quality performance in comparison with objectives or plans; this is generally done on a monthly basis. This system is similar to production planning and control using EDP in other branches of industry. The system is able to analyze the situation in all parts of the enterprise and evaluate the effectiveness of the production in detail and as a whole.

CONCLUSION

ASU are prepared in all enterprises and institutions visited by the Study Team, and are pursued with great empahsis. The Team noted two positive factors for acceleration and implementation of new aspects of planning and management in the national economy:

- Standardized methodology for preparation, construction, and implementation of ASU for all levels with detailed characteristics;

- Production and determination of different-sized computers and equipment to cover all the needs of the new computing center within a relatively short period of time.

Research institutions taking part in the process affect the system and enforce progressive tendencies to increase the effectiveness of the decisionmaking system. Their help and positive intervention in the planning system, namely by ASU development, can be considered a very important factor. We found a very progressive tendency and a decided interest by many qualified and skilled people in the BITPC factories to influence the level of management and control in a modern way with a high level of efficiency.

Integration of Environmental Factors in the Development of a Territorial Production Complex*

INTRODUCTION

The environmental factors associated with economic development programs have received widespread attention in recent years. Because the environment has not been a major component in the formulation of such programs, the ensuing environmental impacts have assumed major importance, as is shown by the recent literature and the creation of a number of environmental institutions.

Such an extensive and complex economic development program as that of a territorial production complex (TPC) generates a variety of environmental impacts. Thus, part of the research effort concerned the integration of these factors in TPC development.

This paper describes the Soviet Government's current approach to environmental factors in TPC development as it was presented to us.

Approach to the Study

The concept of *environment* as accepted by the Study Team is very broad, embracing the whole array of surroundings in which people perceive, experience, and react to things and events. The changes brought about by some intervention, such as the activities associated with the management of water resources, not only alter the related ecological system, but also affect the perceptions of those living in the area concerned. People may respond more to the aesthetics of changes in their surroundings than to the potentially measurable but less visible changes in an ecological system.

System changes may induce other changes which can have both immediate and long-term impacts. An immediate impact of a project, for example, might be the inundation of a valley; long-term impacts may include changes in soil salinity, drainage patterns, climate, and habitat, which in turn affect the fish and wildlife of the region. Such changes can create new interrelationships,

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*The authors appreciate the comments and general helpfulness of their Soviet colleagues, G.M. Filshin and K.P. Kosmachov during the Field Study. The final draft was edited in collaboration with G.M. Filshin.

new values, new uses, new users, and eventually new institutions. The direct environmental impacts of a project may be compounded by people's perceptions of these impacts and by further, development-induced impacts, thus causing major environmental disruptions that may in turn disrupt the intended benefits of the development scheme.

An understanding of environment as related to development goes well beyond the areas of engineering and economics. The more subtle and longer-range consequences of development decisions warrant that a broader range of considerations be built into the planning and decision process. Environmental impacts must be recognized before they occur in order to alleviate them altogether or to constrain their effects through proper project selection, design, and location.

Given this broad definition of environment, it follows that environmental policies are also seen to be quite far-ranging. Such policies are more than mere pollution control standards. The lack of far-reaching environmental planning policies in a planning system means that the development process sets the stage for whatever environmental quality is present in a region, relegating the environment to a residual set of factors and values.

Two criteria were used to evaluate the descriptions given to us by Soviet scientists. The first was *comprehensiveness*: that is, inclusion of all the environmental processes comprising an environmental management system. These processes, which comprise an environmental management system, are:

- Environmental goal setting;
- Environmental research programs (e.g. ecological, environmental, and socio-psychological);
- Environmental planning precepts;
- Information gathering regarding public preferences;
- Environmental impact assessment and management;
- Environmental institutional advocates.

In a strongly development-oriented system, the environmental management system should be organized and operated separately from the development planning system. This separation allows for a counter-balance to the developers as well as provides for a strong source of environmentally sound ideas and information to support, bolster, and integrate the development planning system. These strengths derived from a comprehensive set of separate environmental processes can be of great utility to development planners.

The second criterion used to evaluate Soviet descriptions of their planning efforts is that of total *integration* of the environmental processes in the development planning system. By integration is meant the complete set of processes and procedures for giving environmental factors consideration, or even precedence, over development aims where major environmental disruptions are likely. Integration, which should exist at every planning level where decisions affect the environment, requires the following:

- Placement of environment on an equal level with development;
- Consideration of environmental alternatives (including elimination of planned development);
- Consideration of the environment from the beginning of the planning period;
- Strong linkages of environment to development at each development stage;
- Building of environmental incentives into development planning and operation stages;
- Recognition and integration of environmental limits and potentials at each development stage.

These factors comprise an initial set of environmental planning principles that are necessary for an environmentally sound development planning system.

These two criteria--comprehensiveness and integration--comprise the approach taken by the IIASA environmental team in evaluating the information obtained from Soviet scientists, planners, and practitioners.

Two other considerations are important. They involve process *theory* and performance *practice*. Process deals with what is said to be done for the environment and includes the description of an array of activities--forecasting, assessing, planning, and monitoring aspects of TPCs. Performance includes what is actually done to and for the environment. The Study Team tried to evaluate the *process* of incorporating environmental factors in TPCs. The team did not attempt to assess the actual *performance* of this process, only where it could be verified by observation (as with the waste treatment facility in the timber complex at Bratsk). Thus, the evaluative observations made by the Study Team apply only to the process as it was described to us. An actual performance evaluation would require a longer study period and additional team members.

Because environmental factors have recently increased in interest relative to the original development of the Bratsk-Ilimsk Territorial Production Complex (BITPC) which began in the

1950s, it would be surprising if they had been successfully integrated. Discussions with the organizations contacted in the USSR emphasized their present environmental concerns rather than their experiences, and little information was therefore gathered that dealt with experiences in the BITPC. Thus, this part of the Report deals mainly with current programs for integrating environmental factors in TPC development.

The organization of the study largely determined both the approach and the results. Five scientists with no previous Soviet experience and representing the following areas of specialization were recruited for the study:

- Environmental economics and impact assessment;
- Environmental and energy modeling and planning;
- Science and environmental policy analysis;
- Environmental modeling and pollution control;
- Public health.

Organizations to be studied were selected by the head of the IIASA project in conjunction with the Soviet scientists. The only environmental organizations that were seen were geography institutes, a limnological institute, and the Hydrometeorological Service (HMS).

Bias plagues any study, and this one is no exception. The environmental group's lack of Soviet experience or the fact that no member was from a socialist country meant a reliance on written material in English, much of which is highly critical of the Soviet situation. (See for example [10,18,39].)

The greatest problem is that the individuals and organizations interviewed are not representative of the overall environmental situation. The lack of flexibility in the schedule made it difficult to follow up leads resulting from interviews.

The universality of environmental problems is such that all nations, regardless of political orientation or stage of development are affected. This universality creates a situation where little criticism can be made on a political basis; the complex and cumulative physical interdependencies associated with the environment know no boundaries. Any development program such as a TPC creates new requirements on the existing environment. All nations suffer from the environmental impact of development programs, especially as the technological capability to alter the environment increases. Thus, experience in dealing with environmental impact is transferable among countries, whatever the scope of the impact.

Major Findings

Two major findings were made by the Study Team: that *environmental factors appeared to be integrated in the development of the TPC,* and that *they played a limited role in a development orientation; e.g., were less comprehensive.*

Environmental concerns appear to have a role in the forecasting, planning, and operation of a TPC. Organizations interviewed discussed their environmental tasks and the process for including environmental factors. Even given the limitations of the study, there was no doubt among the group that from what was described there is a concerted attempt to integrate environmental considerations in the development process.

Once this position was perceived, the question became one of quality and comprehensiveness of the integration process. The group agreed that environmental factors were influenced by a development emphasis. Thus, while environmental factors are considered, evaluated, and integrated in the TPC program, the environment is not treated in a fully comprehensive manner with respect to the above criteria.

Outline

The organizations interviewed represented various aspects of the environmental spectrum of activities that can be integrated in an economic development program. These organizations can be grouped as follows: research, modeling, planning, operations, and monitoring and control. While closely related, they can be seen to constitute essential features of an environmental management system linked to a development program, and will therefore be major section headings in this paper. Each section contains the organizations interviewed within that appropriate classification and briefly describes their approach to the environment as described to us. Key observations are made by the group about the information received. Organizations not interviewed are, of course, excluded from the study so that the representativeness of these observations may not be complete. Nevertheless, these observations form the findings of the study. While many of these observations can be interpreted as criticisms, they are intended solely as aids to a fuller integration of environmental factors in the development planning process. As the Soviet environmental management system improves, so does the environment.

Two environmental decrees of the USSR Council of Ministers were approved during our stay in the USSR in June 1976 [22]. These decrees, while centered around the use of water resources, show the continuing progress being made in the area of environmental protection within the USSR.

Introduction to the Soviet Approach to the Environment

The Soviet approach to the environment is generally construed to be comprehensive, and an integral part of the well-being of Soviet society, particularly with regard to health and recreational aspects. From this point of view the preservation and protection of the landscape is seen to be part of the totality of Soviet living conditions. Economic development is another integral aspect of Soviet well-being. Both environment and economic development are seen to be compatible in their mutual contributions to the Soviet quality of life. For example, any regional economic development scheme would come as a package with waste treatment facilities and urban infrastructure, including outdoor recreational areas and urban green zones for open space. Thus, the rational use of natural resources is interpreted as contributing to both environmental protection and economic development. Thus, Soviet planners do not see a contradiction between protection and production.

In a recent formal statement on this general approach, the planning apparatus relies on guidelines from the Supreme Soviet. At the 25th Congress of the Communist Party of the Soviet Union (CPSU) in March 1976, it was noted that the scale and growth of economic activities was such that "special measures to protect the environment" were necessary. Such measures included changes in production and waste treatment technologies which comprise the "comprehensive and rational use and protection of aquatic and forest resources". Also, "all industries are to be switched to the utilization of recycled water" [25, pp. 58-59]. From this perspective, protecting the quality of the environment is seen as an important goal for enhancing industrial production.

The TPC concept is one means for attempting to operationalize this more general set of guidelines. For example,

> ...neither arbitrary nor maximum exploitation of all resources determine the goal and character of a TPC. Appropriate kinds of resources, extent and directions of their utilization should pay and be efficient not only and not so much from the viewpoint of a given area as of the national economy as a whole.... Thus, a TPC, as we consider it, is a territorial production system within which elements of three larger systems (economic, demographic, natural) interact. Functioning of each of them is subject to their objective laws and studied by respective sciences.... Thus, a TPC is considered as a spatial form of organization which makes use of advantages of specialization, cooperation, combining all elements of the economy, rational utilization of all resources, and environment protection, arrangement of life of the population, and management organization [5, pp. 17-19].

Within the TPC concept a definite and integral role is seen for the set of *local natural resources* comprising the environment.

> It is characteristic of local natural resources that they constitute a necessary condition for locating and operating any productive activity over some area.... These are first of all water and land resources, climatic and other conditions....
>
> The natural environment elements are considered at present in the models, first, from the viewpoint of the efficiency of utilizing them for creating and operating production and for the population, second, in relation to the conditions of their use, with the environment protection measures being planned at the same time. Let us indicate the ways of representing natural resources in the TPC models and examine the possibility to introduce some additional conditions relating to natural environment protection and reproduction into the models.
>
> The TPC models usually take direct and indirect account of the effect of natural conditions and resources on production location. In the former case it is specific conditions reflecting the effect of natural resources that are considered. These are constraints on resources and conditions of their utilization. Such conditions are constructed for all areals into which the area of a complex is divided. Special consideration given the particular conditions relating to natural resources permits their influence on the process of creating the TPC economy to be studied more thoroughly. Regional differences in allocation of productive forces are affected also by many natural conditions, for example, climatic, soil composition, relief structure, and so forth. These conditions are examined in the TPC models indirectly through the coefficients of the functional.
>
> In general, natural resources and conditions are represented in the models by constraints on the possible amount of particular kinds of resources allowed to be utilized as well as of particular sources of one kind of resources (maximally possible scale of exploiting the deposits of raw materials and fuels, water sources, land areas, etc.); by technological coefficients (indicators of raw material expenditure, demand of productive activities, infrastructure units and of the population for land and water resources, and the like), and by coefficients of the objective function (expenditure on producing raw materials, area exploitation, water supply organization, etc.) [8, pp. 6-7].

The above comments on the environment as a constraint in the TPC modeling program raise an important point reflected in this Report. Each organization has a goal that it attempts to maximize and promote. For example, the chemical production Ministry promotes chemical production while the HMS promotes environmental protection. In putting these various goals together into a unified planning framework, Soviet officials such as the State Planning Committee of the Soviet Council of Ministers (GOSPLAN), must contend with a whole range of independent goals. These may include production goals, economic efficiency goals and environmental goals. From the interviews undertaken for this Report, it is clear that production goals (or targets) remain sacrosanct or fixed. Goals that remain negotiable or variable via trade-offs are economic and environmental goals. For example, at the Central Economics and Mathematics Institute (CEMI), the environmental protection function is defined as a compromise function resulting from a cost minimization approach to production costs, protection costs, and damages from such production. Although at this point waste treatment technology is stressed, it is recognized that over the long term a change in production technology, while retaining the fixed production targets, is the most efficient approach to reducing pollution.

One approach to the environment proposed by a scientist at CEMI is as follows:

> A socialist society, with its humanitarian aims, cannot reduce its output. Furthermore, it cannot reduce the rates of growth of this output either, since this would automatically lead to a decline in the growth rates of welfare. Nor can society reduce the economic efficiency of production.
>
> On the other hand, society cannot allow the growth of output and of its economic efficiency to be achieved by exhausting natural resources and polluting the environment because it is on their condition that depend not only the development of industry but also the very existence of life on earth.
>
> Under these circumstances, only one approach remains open--that of the joint optimization of the economic and ecological subsystems; or more specifically, this means ensuring the growth of public production and increasing its efficiency under strict ecological constraints which do not permit environmental destruction and degradation....
>
> ...No projected method (alternative) of using natural resources, however high the level of economic growth it promises, should be included in a plan if its economic impact is accompanied by the degradation, destruction or collapse of natural ecological systems or important components thereof. Nor should a plan include a method

(alternative) of natural resource use which, while ensuring the conservation or even the development of natural ecological systems, entails a reduction of output or of its economic efficiency.

Public ownership of the means of production in the USSR, the concern of the socialist State for the welfare of all members of society, a highly developed public industry and the planned nature of its development make it possible to organize appropriate control of economic development, taking into account ecological factors [25, p. 149].

This same approach of fixing production goals while varying economic and environmental goals is carried over to the TPC via the location decision. The TPC is formed via economic indices but is constrained from a very large negative impact on the environment via relocation, as a proper match is sought between the enterprise in the TPC and its impact zone on the TPC environment. While production targets are not foregone, the protection of the environment is not foregone either. Thus, while both production and protection goals exist and are promoted via their respective adherents, production goals are taken as given parameters, subject to the constraints imposed by the protection goals.

One significant exception to this process is Lake Baikal where the environmental protection goal took precedence over both production and economic goals. In the Lake Baikal case, Soviet scientists took the lead in promoting the protection goal for this unique natural resource. The role of scientists is particularly important because in the Soviet Union the burden of proof is placed on those who take the environmental viewpoint. For example, unless they can produce scientific evidence of harm to the environment and man, the planned production will occur.

This discussion of the planning apparatus where a production goal is constrained by an environmental protection standard (which is a goal in itself) does not preclude scientists from using the criterion of reciprocity for trading-off production and protection in their mathematical programming models. One of the many advantages of such modeling is the ability to exchange goals and constraints to understand the difference in impacts. One approach that was discussed with us is examined in detail elsewhere in this Report. In this approach, production is maximized with environment treated as a constraint, the cost of which is minimized in the overall programming model. Another approach used, but not shown to us, is to maximize an environmental goal and then use it as a constraint for which costs are also minimized for some production goals. Either of these approaches requires the environmental aspects to be founded upon some scientific and hence rational basis.

In conclusion, environmental protection occurs within an industrial planning context. The environment is linked to a planning system where the burden of proof of environmental damage rests with the environmental scientists so that any changes proposed for planned production for environmental reasons must be convincingly supported by strong scientific evidence and support. Where such evidence is forthcoming, Soviet leaders seem to support changes in technology, infrastructure, waste treatment, and location in order to protect the environment. Production goals, however, remain the same.

ENVIRONMENTAL RESEARCH PROGRAMS

Division of Research Effort

There appear to be two types of environmental research in the USSR economic development program. One research effort provides continuous and direct integrated support to the economic planning system while the other is based upon contracts and is therefore less integrated in nature. The research groups interviewed are all economically-oriented institutes with the exception of the Limnological Institute at Lake Baikal. The two geography institutes and the geography faculty visited were all interested in economic geography. Thus, this section discusses only the research done by these groups. These groups may not represent the entire environmental research program in the USSR but they are the only ones with whom interviews were arranged.

Three institutions were interviewed that provide continuous research support:

- the CEMI,
- the Council for the Study of Production Forces (SOPS),
- the Institute of Economics and Industrial Engineering (IEOIP).

CEMI established an environmental arm in 1973 called the Department of Nature Utilization with a staff of ten out of total institute staff of 1000. This unit has two basic tasks: to develop methods for economic assessment of natural resources, and to develop methods for economic assessment of environmental protection. The latter methods are to be oriented toward providing damage estimates capable of being linked to production decisions for minimizing environmental damages for given production targets. The primary focus of CEMI is on facilitating production targets, their linkages and their economic costs. Through the addition of environment, CEMI attempts to account for the social costs of such production. Research problems are suggested to CEMI by GOSPLAN.

To meet the task of minimizing environmental damages associated with production, CEMI is attempting to identify changes in production technology that are linked with environmental changes, and to define such changes quantitatively. On a long-range basis there is to be some attempt to model the bio-economic system for the development of environmental normatives. No changes in production targets would be considered, only changes in inputs and processing of the same commensurate with the given output targets.

The second research organization providing continuous support is SOPS. This unit is involved in planning for productive forces on a national scale. Much of its environmental work is involved in locating TPCs to reduce pollution impact. The environmental factor is perceived as the base for the development of the Soviet society and economy. Environmental evaluations are made from the following points of view: the natural environment as inputs to industry, industrial impacts on human environment, and the environment as the territorial base for resource allocation of productive forces (location of industry). The environmental unit within SOPS perceives its main task as attempting to account for environmental factors before forming TPCs. This a priori accountability considers from a scientific point of view the environmental base, the negative impacts from all parts of the TPC, and an evaluation of alternative TPCs.

Because SOPS is an economic organization, it must take an economic view of environmental factors. Thus, environmental protection is only one out of many aspects to be considered from the viewpoint of economic efficiency as regards the complex itself, and intraregional and interregional efficiencies. The potential total pollution associated with the total TPC is compared to the regional standards for locating that TPC. SOPS deals only with TPCs and not with individual enterprises in such efficiency calculations.

The environmental unit within SOPS is attempting to emphasize environment at the beginning of the project planning period. This unit takes a rather complete analytical view of the environmental impact process by incorporating base studies, impact evaluation, and consideration of alternatives. Alternatives are limited, however, to relocation rather than elimination or modification of the TPC production targets by proposing alternative arrangements for meeting national planning goals. The assimilative capacity of the regional environment is seen as a natural resource to be used to its fullest extent.

IEOIP outside of Novosibirsk is a major economic institute in Siberia. Indeed, it appears to have had a significant role in the formation and implementation of the TPC as a concept [10, pp. 51-52]. Even though this Institute plays a major economic role, its environmental research program is mostly sustained via contracts granted by Moscow agencies. Therefore, its environmental involvement in the planning process appears more discretionary.

The posture that IEOIP has adopted for environmental research is that of integrating the environment in its regional economic models, which is discussed in the next section. Its main environmental task is the specification of waste treatment alternatives in the modeling of the regional development process. Such environmental factors include the efficiency of natural resource use, the conditions of natural resource use, and regional environmental protection. Production targets serve as the given objective with environmental standards acting as a constraint on production. Given production goals, a set of tentative locations are selected and a specific site is chosen via the research and modeling process which includes the use of pollution control standards and environmental impacts.

Environmental factors are integrated through the use of linear programming models for optimizing both type and location of TPCs by including the cost impacts of considering the environment. The model aids in the selection of an industrial complex compatible with the regional environment based on industrial emissions, efficiency of purification, assimilative capacity of environment, and existing pollutants in the environment.

The manpower resources in environmental research of IEOIP are small, with about seven scientists out of a total staff of 500. The research program is venturesome, given these resources, and includes theoretical work on the bio-economic system as well as applied work in economic modeling with environmental constraints.

From interviews with representatives of these three economic research institutes it was indicated that economic considerations were predominant in defining and integrating environmental factors. Environment at these institutes is seen as a constraint on production rather than as an inherent goal in itself. Again, it should be noted that these were the only research institutes shown to us that are directly linked to the development planning process. The study group was informed that environmental research institutes with environmental planning goals existed, but no arrangements had been made to visit such institutes.

Contract Research Support

Contract research is necessary to supplement the research capability that is directly and continuously available to economic planners. Such contract research is also seen as continuous, but the distinction is made on a more discretionary basis. Contracts are let at the discretion of, say, GOSPLAN or SOPS, and presumably any applicable institute could fulfill the prescribed role, or the role could be reduced to that of expert ad hoc advice without specific research tasks. Certainly, the institutes described here play less of an integrated role than those previously discussed.

Two kinds of institutes of this contract nature were visited: geography and limnology. The role of economic geography in planning for TPCs seems to be relatively strong and growing. Three separate geography organizations were interviewed, including the Geography Institutes of Moscow and Irkutsk and the Geography Faculty at Moscow State University.

The contract research of geographers appears dominated by economic geographical considerations since the use of natural resources is emphasized. Research on man-environment linkages is, however, increasing. Geography's research role vis-a-vis TPCs is geared to showing the natural resource potential and cost for regional development and to performing environmental impact studies as requested.

The Geography Institute at Moscow currently has a coherent and well-planned research program based on a systems approach. The program consists of seven phases: natural systems, natural-technical systems, natural-economic resources, medical-biological linkages, recreation systems, urban systems, and international systems. Each area has a research team.

Communicating the results of this research program has received attention. The Institute is involved in four key channels of information dissemination on an ad hoc basis: participating in setting regulations and guidelines for regional development; publishing theoretical and practical publications on man-environment linkages; teaching engineers about the environmental impacts of engineering projects; and participating as experts in special problem areas as requested.

The Geography Institute at Irkutsk specializes in Siberian geographical research, and is involved in both economic development and environmental protection studies. Many of their studies are done with a river basin as the unit of investigation. These studies include natural resource development, population living conditions, and location of industrial enterprises. The Institute operates six field stations in regions of economic importance, including TPCs, by doing base studies of natural conditions. Thus, monitoring of the environment begins before development occurs in the region.

The Geography Institute at Irkutsk works in cooperation with IEOIP by providing IEOIP with medical-geographical information as an input to their economic models. In addition, the Institute plays a central, though ad hoc, role in regional layout planning for TPCs, enterprises, and cities. Planning bodies now go through this Institute even though there is no requirement for them to do so. The Institute provides environmental assessments for the layout of the various planned activities.

The Geography Faculty at Moscow State University is also involved in environmental studies to support planning endeavors on a contract basis. For example, an environmental impact contract for a water diversion scheme included the following phases: identification of regional problems associated with the area; estimate of environmental base; determination of degree of present environmental change; analysis of long-term changes in area; forecast of possible disturbances due to proposed economic change; identification of environmental protection measures needed; and identification of problems in local economy.

Because environment is seen by the planners as only one of many factors to be considered and because environmental research is difficult to document, not all recommendations of the geographers have been accepted by planners, though such adoptions are increasing. One problem is that scientific opinion will not be considered unless specific research studies bear out such opinion as being based on fact. This procedure, however, is difficult in these early stages of environmental assessments. Geographic representation on ad hoc expert committees is increasing, and one can expect their influence will be increasing as well.

It is clear from the interviews of these three geography groups that geography is carrying a major role in defining and evaluating environmental factors in regional development schemes. The geographers appear to have well-defined environmental study programs as well as approaches to such programs. The actual integration of environmental factors depends on the quality of their studies, the place of such studies in the planning process, and the willingness to place a high priority on environmental factors. Certainly, geographers are giving a more wide-ranging definition to environment rather than perceiving environment as mere pollution control as economists have tended to do.

The geographic approach to environmental research, with its close link to economic considerations in the planning of TPCs, appears to be weighted in the direction of development from their extensive work in natural resource appraisals and environmental studies associated with development projects. With the exception of the Geography Institute at Moscow, pure environmental research seems more limited, given the discussions with these geographers. One concern with geographic research is its ad hoc and purely advisory role in the planning process. Its role should be both direct and continuous in order to better counteract the economic bias of the existing planning system. Contract research roles have been expanded for geographers because of the growing importance of their data to development and planning.

The Limnological Institute at Lake Baikal does applied as well as basic research. Its applied work comes through contracts to support Siberian economic development. Indeed, the Director of the Institute defines science in relation to economic development. The natural water regime is studied as the basis for aiding in the rational use of water resources. Given its twelve laboratories, the Institute is capable of carrying on a large water research program. Basic taxonomic work is still being carried out.

In relation to TPC development the Institute has done reservoir studies on the hydrological regimes associated with large dams, but their recommendations are not always readily followed by planners. One area of contention is the rate of filling reservoirs. Limnologists prefer to see a slower fill-rate to allow desirable fish species to develop, whereas planners prefer a rapid fill-rate regardless of fishery development. The Institute played just such a role in the filling of the Bratsk Reservoir. Planners wanted an accelerated filling schedule to get the power station operating, but the Institute successfully stopped this acceleration program from occurring.

In the design phase of a water resource-based TPC, the Institute can have a role via contracts from an ad hoc project council formed by the hydroelectric construction organization (GESSTROI) or by GOSPLAN to oversee its planning. Their consultant status means that only an advisory role is possible and that environmental recommendations do not have to be followed by the planners although they may choose to do so. Even in the monitoring phase of environmental studies the Institute has no responsibility for continuous monitoring as its monitoring effort is done only through contracts from other Ministries. Also, the monitoring services that do have responsibility for monitoring do not regularly send pollution information to the Institute. Only on request are such data forwarded.

The Institute is playing a major environmental role in the regional development north and west of Lake Baikal. This role, however, is on a cooperative basis at the discretion of the planning authorities. The Institute sees its role as attempting to keep science ahead of the demands of the developers so that they are in a position to give the right recommendations to them. As future development proceeds, adverse environmental impacts may be heightened, unless a continuous and direct planning role exists for the Institute.

Observations on Research Role

Environmental research has a major role in planning for regional economic development. The statements here are based on the study group's observations of this role as described to us at the institutions visited. These observations, while stemming from Soviet descriptions, are subjective in nature because of the group's interpretation of Soviet remarks. The following observations can only apply to the organizations visited:

- *Environmental research is integrated into regional development;*

- *Some of the environmental research is at the discretion of the planners;*

- *Economic research institutes also conduct environmental research, defining environment in economic terms;*

- *The role of pure ecological and environmental research is unclear to us as only applied research was emphasized.*

Certainly, environmental research appears well integrated in the development process. In particular, geographic research has been readily adapted to performing environmental impact assessments on a regular basis when requested to do so. The assessments as described have appeared to be both complete and timely.

The key problem in this research role is the very nature of the role itself as perceived by the development planners. Such assessments appear ad hoc in nature so that they occur at the discretion of the planners who decide which institute is to be involved and at what stage and state of involvement. Even if the planning system now regularly employs environmental research via contracts, a more formal integration system would seem preferable. A formal environmental planning system would ensure continuity and direct environmental inputs regardless of the strength of development interests or changes in planning personnel. Timeliness of environmental research is also of great importance, and a formal process would ensure that environmental research is done without development timing constraints.

The USSR Academy of Sciences provided for the establishment of a Siberian Branch to do in-depth studies of particularistic aspects of the Siberian economy. The next stage in this process is to broaden its environmental research and to ensure that the results of such Siberian research have a regular role in Moscow [19].

Each large economic research institute visited had an environmental component recently formed within it, thus ensuring that environment is accorded some role in the economic research program of these institutes. Each unit of these institutes is involved in commenting on the work of the other respective units within that same institute. Such wide coordination procedures allow for environmental aspects to be considered at various points in the modeling process and for various kinds of economic models. This coordination effort is in addition to the work carried out within the environmental component of the respective institute.

The results of such work, of course, are the casting of environmental factors in an economic mould or definition. Such an economic cast can constrain the view accorded to the environment. Thus, the environmental research efforts of these economic research institutes must be supplemented with environmental work elsewhere. No information was available on the coordination of environmental research work among the institutes visited. The only links noted among these institutes were that from the Geography Institute at Irkutsk to the environmental modeling group at IEOIP, and IEOIP's link to the City Planning Institute in Moscow.

While research is directly geared to the planning system, little research effort seemed directed toward the operational and monitoring aspects of development. These important areas provide the long-term assurance of whatever environmental objectives were perceived by planners so that large research resources are necessary to support the operations of enterprises and TPCs, and the monitoring functions designed to check these operations.

The role of pure ecological and environmental research remains unclear. Only development oriented research was described so that no comments can be directed toward pure research. It is important for planners to see the distinctions between pure ecological and environmental research. Research programs can be shifted over time with adverse results if an applied orientation remains the norm.

Even given the above comments, it is important to stress that environmental research is growing in importance and impact. Over time this research effort can be expected to improve even further. A great advantage of research programs in the USSR is their close links with the planning system. A solid link exists between planners and researchers. From the point of view of many western countries this link is enviable. Most of the above observations on the Soviet research program are also applicable to western research programs.

MODELING OF ENVIRONMENTAL FACTORS

While modeling is clearly a basic aspect of environmental research, it is a separate section in this paper because of its importance in economic planning for development programs. Modeling that was described to the Study Team fell into two broad categories: *geographic models* and *economic models*. No ecological nor environmental models were described. No environmental impact models were described, although geographic and economic models have some application in such an effort.

Geographical modeling included mapping, scenario construction and forecasting, information models, and potential models. Economic modeling was concentrated on input-output, linear and integer programming, and cost estimation models. Geographic models seem to be used as inputs to economic models rather than being used directly by development planners. Therefore, this section will emphasize the economic approach to environmental modeling. No detailed descriptions of modeling efforts will be made here since this is discussed elsewhere in this Report.

To describe dozens of models used and to understand their role in the environmental management process was beyond the time and resources available. Therefore, it was necessary to be selective. Preplanning models were chosen as the basic focus because they seem to best match long-term environmental management considerations and policy questions, in contrast to more narrow questions of operations. This type of model seemed best exemplified by the optimization (linear programming) models used in IEOIP. In particular, the approach used by the Sector of Territorial Production Complexes within IEOIP was of interest.

There are several groups of models that are used by IEOIP for forming TPCs. These include:

- Models for optimizing the spatial structure of a system of TPCs in an economic region;
- Models for forecasting the main parameters of a TPC;
- Models of spatial structure of an industrial site within a TPC.

There is great emphasis placed on the use of models in the preplanning process. However, the builders of these models emphasize that any modeling effort, however extensive, is not able to guarantee a comprehensive representation of all processes of creating and operating a TPC. They view a variant obtained from a TPC model as an approximation to the national economic optimum, given a certain combination of fixed parameters and permissible uncertainty range.

Environment and Optimization of a TPC

An excellent description of a TPC optimization model that takes into account environmental factors is given by O.P. Burmatova [8]. From this description it is possible to see the role that this type of model plays in answering locational questions, in providing insight into the degree of waste treatment that might be needed to prevent the exceeding of absorptive capacity of a region, and to examine various technological (industrial) mixes in a given region or complex. This model could be useful in producing a regional layout and in answering general questions, before going into more detailed locational and engineering design phases.

The group of models used is one of the large systems of economic-mathematical models used in the territorial production planning; the system of models has been described elsewhere many times [1,2]. The inclusion of the environmental considerations in this general type of model appears to be increasing in importance [8,28]. It seems that the environment enters the model through various types of constraints which then allocate resource use.

The local natural resources clearly have a great effect on the choice of production units, their location and the character of the city and recreational areas. The group of models can be applied to the problem in a hierarchical manner, i.e., they can be applied to one group of TPCs or to an economic region, to a particular TPC, or to an industrial center within a TPC.

The TPC models can take into account only the effect of natural conditions and local natural resources on production location. Regional differences in allocation of productive forces, as affected by natural conditions of climate, soil, etc., are examined in the model through its objective function.

In general, the natural resources and the environmental conditions are represented in the models by the following:

- Constraints on the possible amount of particular kinds of resources allowed to be used;
- Technological coefficients which may be indicators of raw material expenditures, demand of productive activities, infrastructure units, etc.;
- Coefficients of the objective function such as expenditure on producing raw materials, water supply organization.

The general solution to the above problem, using the linear models at IEOIP, makes it possible to determine the amounts and uses of land, water resources, etc., to satisfy the needs of the various TPC economy elements and the various environmental standards. It is assumed that industrial plants, infrastructure, and population located within a TPC are the origins of various kinds of pollutants. Three ways to prevent pollution are technology improvement, purification of harmful waste, and restrictions on the location of facilities generating pollutants in accordance with the requirements of environment standards. The limits of the carrying capacity of the region are then used to specify certain constraints on pollutants. Generally,these appear to be expressed in terms of quantities such as emissions, and land area used. Limits on emissions are then put as additional constraints in the model [4]. These conditions provide the basic constraints on the output of harmful substances within each area of a TPC resulting from production and economic-communal activities.

This preplanning modeling activity has been done by Bandman's group at IEOIP in collaboration with The State Institute for City

Planning (GIPROGOR) and The State Institute for Industrial Design (PROMSTROI). These two organizations produce the regional layout in collaboration with groups such as Bandman's. In particular, GIPROGOR apparently coordinates the environmental studies. For example, in the Ust-Ilimsk Complex the main problem was fog which concentrates pollutants. One result of the model is a general picture of some of the necessary pollutant purification processes and their costs.

Thus the optimization models provide input to the planning process. These models, however, were only applicable for the preplanning phase of territorial studies and not for comprehensive planning that includes detailed environmental considerations. In the models developed environmental issues were taken into account via outside constraints [4,28].

Bandman's Model to Introduce Environmental Factors in TPC Modeling

From the viewpoint of environmental protection at the level of the TPC, Bandman's group in IEOIP has been developing a model dealing with the optimal layout of polluting industries [8,33]. The model was used in the preplanning stage for the formation of a timber complex and for the formation of recreation zones associated with the layout of the appointed set of enterprises within a TPC. In this model the natural environment is considered as one of the important elements in the system of TPCs. The interrelationships of production, infrastructure, population, and the environment is shown in Figure 1.

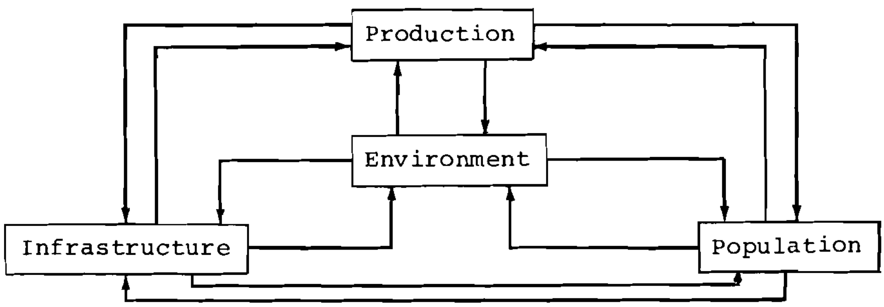

Figure 1.

The natural environment consists of raw materials which specialize the production system of a TPC, and local natural resources which are used within a regional complex and constitute the necessary conditions for locating each industry such as water, land, air and climatic conditions. Raw materials determine both the production structure in the whole system of the TPC economy and the gross potential pollutants generated within the TPC. Local natural resources are concerned with actual environmental protection, including the layout scheme of enterprises and the location of human settlements.

These factors are evaluated in TPC models from the points of view of efficiency of natural resource use, conditions of using natural resources, and environmental protection measures.

Environmental protection measures were recently introduced as additional conditions of the TPC optimization model. The following elements are developed to explore optimal solutions:

- Sources of pollutants in TPC: industrial plants, infrastructure units, and population.
- Policy to prevent pollution: technological improvements, purification of harmful wastes, and restriction of location of units generating pollutants.
- Protection measure: regional maximal permissible pollution; e.g., if the discharges due to the production process exceed the allowed limits of the carrying capacity of the natural environment, purification facilities should be installed.

The environmental aspects of the LP model used by Bandman's group is briefly shown below:

- Alternatives of the purification process:

  F^p_{gik} : operation intensity of purification facility in a plant:

  p - variant of pollution technology,
  g - pollutant,
  i - industrial plant,
  k - areal number.

  $\bar{F}^p_{sgk}$: operation intensity of purification facility in the community:

  s - sth purification process for the community,
  g - pollution generated by population.

- Additional equation for environmental protection:

$\sum_i \sum_r a_{gi} A_i \cdot X^r_{ik}$ $+$	$\sum_{\ell} \bar{a}_{g\ell} Y_{g\ell}$ $+$	ξ_{gk}
Pollutant generated by plants	Raw material pollutants	Pollutant by infrastructure (power, transport)
$+ \sum_i \sum_p \sum_{\rho} \hat{a}_{g\rho} F^p_{\rho ik}$ $+$	$\tilde{a}_{gk} \cdot \varepsilon(X_k + \bar{X}_k)$	
Pollutant by utilizing pollutant ρ	Population pollution	
$- \sum_i \sum_p b_{gi} F^p_{gik}$ $+$	$\sum_s \sum_p \tilde{b}_{sgk} \bar{F}^p_{sgk}$ $\leq$	G_{gk}
Abatement by purification plant in enterprise	Abatement by communal purification plant	Maximum permitted pollution in Kth region

where X^r_{ik} : the operation intensity of plant i according to variant r;

$Y_{g\ell}$:: the raw material ℓ to be produced;

$a, \bar{a}, \hat{a}, \tilde{a}, b, \tilde{b}$: parameters;

G_{gk} : given level of environmental quality for pollutant g in Kth region.

- Selecting conditions for purification technology:

$$\sum_k \sum_p F^p_{gih} \leq 1 \qquad , \text{ for all g and i}$$

$$\sum_k \sum_p \tilde{F}^p_{skg} \leq 1 \qquad , \text{ for all g and i} \quad .$$

Thus, under the conditions above, the "best" policy will be explored among the group of alternatives, such as purification technologies and allocation of each enterprise and population area. By adding the total expenditures dealing with the installation of purification facilities to the entire optimization criteria, environmental "costs" can be determined.

Remarks on Bandman's Model

The model was the only "environmental" model described to us. The comments included stem from the group's experiences with model building and application.

From the viewpoint of mathematical programming, Bandman's environment model is an environmental condition for the entire optimization approach to creating a TPC layout. This model is an additional constraint for the overall LP model. The integration process is illustrated in Figure 2.

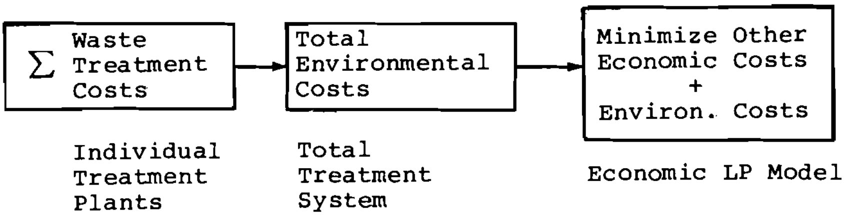

Figure 2.

Only the total expenditures of purification facilities are taken into consideration directly. Other environmental costs seem to be involved implicitly through environmental standards which presumably come from other environmental research groups.

However, the constraint can exert an important effect on the final result of the solution, if the environmental condition G_{gk} is properly chosen to protect the natural environment. It sometimes happens that if the environmental constraint is a key one, it plays a more fundamental role to the optimal solution than even the type of objective function to be minimized. Strict constraints do not permit any trade-offs to be made among objectives.

In spite of the large open area available and the abundance of natural resources in Siberia, the concentration of high energy consumption industries in limited areas may lead to serious local environmental problems and to the destruction of the surrounding ecosystems, without comprehensive environmental management within a TPC. In this respect the principal measure of environmental protection--G_{gk}--in each area has great significance in Bandman's model. Therefore, the context of G_{gk} should be enriched to include the analysis of environmental issues, both qualitative and quantitative. For example, regulation is important not only of the pollution level but also of the total amount of pollutants in any given subregion as each of these aspects affects the self-purification capacity of the region. In such a case the allocation of pollutants to each area within the region (the determination of G_{gk}) plays a key role. No information was given to indicate who determines G_{gk} and how it is determined with what information or research base. Thus it appears that the process of determining G_{gk} itself involves a decisionmaking process.

In order to evaluate the parameters and constraints in each TPC relating environmental impacts to natural ecosystems, it is essential to establish standard or compatible regional statistics in the sense of environmental and ecological indices. The limits on emissions have to be determined by auxiliary models which relate emissions to ambient concentrations, and even to damages. The lack of such types of information makes an analysis of the model simulation incomplete, sometimes resulting in serious misunderstandings [3]. In this respect the complexity of the model should be matched with the contents of the required information. It appears that the Bandman modeling effort may have gone beyond the information resources to support it, given the problem of information on forming environmental indices, the state of the art and the information inputs listed [13, pp. 101-118; 14].

The certification of the validity of the Bandman model is not described. This problem is closely connected with the coordination of the research and operational processes. It is unknown by our group what feedback mechanism, if any, exists between these two processes. If this model is to receive wide acceptance and application, linkages are needed to establish the validity of the results of its use when actually applied to TPCs.

It would be interesting to have the model consider trade-offs between local heavy pollution and pollution levels over the entire TPC region. The average pollution level may be the same even though the situated industries are concentrated or spread over the entire region. Each TPC contains an extensive area which seems too wide a space with too much natural variety to force a specified uniform environmental measure (G_{gk}) over the entire region. In addition, the pollution problem is often perceived and exposed in an extremely localized area [15]. Therefore, a more detailed breakdown of the context of the protection measure is important as it involves trade-off considerations at the local and regional levels within the TPC [20].

Finally, perceiving and reducing all environmental information to that of money costs can overlook important environmental factors that are themselves "costs" [14]. The money cost of waste treatment may not even be the relevant environmental cost for a given area, as in the displacement of a unique species through siting an enterprise near its habitat. Therefore, the

Bandman model should be used in conjunction with other types of models and information for a more complete "optimization" of environmental factors for the development of a TPC. This model does not now appear to be used with complementary environmental models.

General Observations on the Use of Models

Because of the very extensive set of linear optimization models being used for planning TPCs, it is natural that environmental questions should be included in these studies. The opportunity to use these formal mathematical tools for studying environmental questions is an envious one from a methodologist's point of view. In many countries and regions of the world, such an extensive set of models and data bases does not exist so that the use of such techniques for environmental management would be out of the question. For example, in the studies at IIASA on the State of Wisconsin and the Rhône-Alpes Region, the fragmentation of the decisionmaking and data collections does not permit such an approach [6]. It is extremely interesting to see this work being conducted and considered in the planning process of the USSR.

On the other hand, certain overall limitations to economic optimization models are important to keep in mind. Such limitations can include the role of ecological and environmental information, the creation of ecologic and environmental models and integration of these with economic models, and the role of pure modeling.

One problem of great concern is the matter of getting adequate ecological and environmental information into the models through the use of simple constraints such as emissions or costs. It was very difficult to determine what sorts of data and external models (and/or value judgments) were used to determine these linear constraints. Much of this information came from other institutes or other sources outside the group that did the optimization modeling. Until a better picture of the adequacy of this information is obtained, it is not possible to comment on the adequacy of these optimization techniques as a tool for environmental management.

Although asked about other models, no ecological or regional environmental models were discussed by any of the research groups visited. If such models do not exist or are rudimentary then, by definition, more sophisticated economic models are of lesser utility in the planning process as they contain incomplete indicators of environmental quality. Certainly, it is of interest to economic modelers to support other modeling that can extend the validity of their own results. Pure environmental modeling on a regional or a TPC basis is important for ascertaining the interplay and role of environmental factors within a region.

Trade-offs between using various types of constraints and objective functions which place collectively greater and smaller emphasis on environmental protection would be desirable. (An example of a systematic approach to assessing these trade-offs through the use of a multiattribute objective function is shown in [7].) Given the strength of the planning system, this display of results would appear of great interest to planners. The modeling being done, however, is going in the direction of integrating environmental factors in economic models.

PLANNING FOR THE ENVIRONMENT

This section does not attempt to explain the planning system of the Soviet Union; it presents the current efforts of certain planning bodies to integrate environmental factors in the hierarchical levels of the planning process. Naturally, the description as presented was somewhat idealized, and the information was specifically related to development in the Siberian Region of the USSR [11]. The following information should be examined along with the more detailed discussion of the entire process of planning contained elsewhere in this Report.

Planning in the Soviet Union is a continuous process that does not end with the publication of a five-year plan. Certification of a five-year plan by the Supreme Soviet merely signifies the affirmation of preceding efforts and gives the authority of law to the development plan for the next five years.

Basically, the planning cycle consists of four major phases and may cover a time span as much as six years. It appears that planning for the next Five-Year Plan and implementation of the present Five-Year Plan overlap. The four phases of planning can be summarized as follows:

- *Preplanning activities.* This phase appears to be most important in relation to the inclusion of environmental considerations in the planning process because it involves the organization of research and scientific work for detailed studies.

- *Formalized planning.* Formation of goals for the national economy, enterprises, delineation of target figures, etc.

- *Detailed draft preparation of the planning document.*

- *Review of the planning draft and final approval by the Supreme Soviet.*

Each of these phases will be briefly discussed in relation to the integration of environmental considerations.

Preplanning Activities: Phase 1

Three major planning bodies are important at the State or national level. The descriptions below are simplified and emphasize only environmental function [24, pp. 198, 212-213].

- *GOSPLAN.* Since 1968, its environmental function is to plan measures necessary for the protection of the environment while planning economic development. These measures become part of the USSR plans. An environmental section was added in 1975 since this planning aspect has grown.

- *State Committee for Science and Technology (SCST).* Together with the interested Ministries it develops plans for scientific research on environmental protection and supervises and controls their fulfillment. It also coordinates activities of scientific institutions in this field. In 1973, a special Scientific Technological Council was established within SCST; the Council is mostly of an advisory nature, but it can influence activities of different Ministries through representatives. Another important council within SCST is the Scientific Council for Problems of the Biosphere.

- *State Construction Committee (GOSSTROI).* Since 1972, it is responsible for establishing, coordinating, and maintaining environmental protection standards for the construction of new towns and industrial project design and layout.

In addition, there are different national Ministries which advise on the bulk of the planning for environmental protection. The most important ones are: the Ministries of Agriculture, of Melioration and Water Resources, of Geology, of Fishing, and of Health. Each has a special department to coordinate activities for environmental protection of corresponding Republic Ministries.

The Republics have different systems of organizations responsible for the protection of the environment. These bodies sometimes vary in structure and in competence from different Republics so that the problem is to achieve proper coordination of their activities.

Figure 3 presents an outline of the preplanning process. During the initial part of this first planning phase, the types of forecasts for scientific and technological progress are determined. From the delineation of these items research institutions and scientific bodies are designated or formed ad hoc to develop specific programs and forecasts which would furnish the needed data. Research tasks are organized on the basis of the following five territorial divisions: Soviet Union nationwide, Republics of the Soviet Union, economic regions, administrative districts, and TPCs.

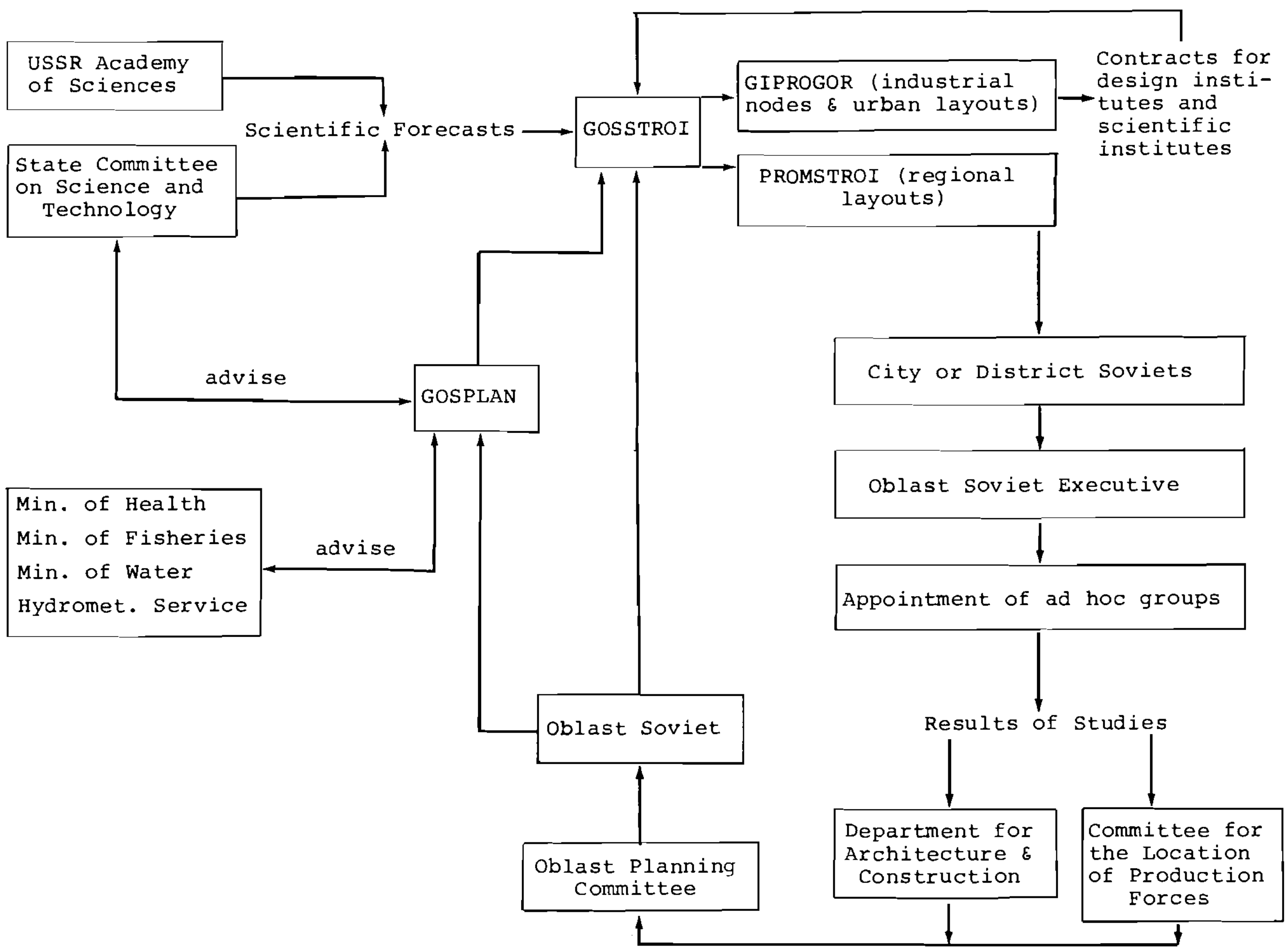

Figure 3. Overview of the preplanning process.

Source: [11]

Research funds for studies of environmental aspects of development are provided through several sources. The SCST and the USSR Academy of Sciences are the main organizations for determining the need and extent of scientific contributions during this period. The environment is studied from the points of view of establishing the rational use of natural resources, and establishing standards for environmental protection. These initial studies are sent through the SCST and the USSR Academy of Sciences. After initial review by these two bodies, the study results are passed on to GOSPLAN and GOSSTROI. The latter defines more concrete studies based on initial information received from the scientific forecasts. These more detailed study proposals are distributed through two major planning bodies in GOSSTROI: GIPROGOR which identifies and coordinates urban design and layouts, and PROMSTROI which deals with industrial design and layouts. These two organizations are special bodies under the control of GOSSTROI. GIPROGOR concentrates on city planning problems of a health nature by ensuring that the designs from specialized design units meet with health standards. The planning of cities also includes certain special requirements which are in addition to achieving health standards. Examples of such requirements are as follows [11]:

- New cities should be located near a source of water both for sufficient water supply to the residents and industries and also as a source of recreation for the populace.

- A forest or "green zone" is required as a sanitary protection area and is not considered a recreation zone.

- Cities must be located on a higher geographical point than an industrial site.

- The landscape of a city has to be taken into account, including aesthetic criteria. For example, the preservation of forest areas is to be an integral part of the city environment.

- Cities are designed for walking to places of interest and shopping. Major transportation systems connecting other urban nodes and industries should be located outside the city proper.

PROMSTROI deals mainly with industrial design and location in regional layout schemes. While GIPROGOR concentrates on human environment based on where and how the workers are to live in the selected region, PROMSTROI is involved with impacts on the natural environment. Since it is assumed that industries will have the greatest impacts on the natural and human environments, PROMSTROI coordinates the design of production and waste treatment technologies for meeting whatever environmental standards for effluent that have been set from previous scientific efforts. One trade-off problem that must be solved by this organization is the location of the industrial node. It must be far enough from the nearest city area to reduce pollution exposure and yet near enough to allow convenient commuting. Wind patterns are important for determining the location. At two of the Bratsk communities there appeared to be less of a commuting problem and more potential exposure from the aluminium and timber plants.

Planning models are used for determining locations of the city, industries, infrastructure, recreation areas, and green zones as separation areas between industries and cities. For example, the Bandman cost minimization models with environmental constraints are used as an input to this process. After the initial planning for design and location, specialized design units in production Ministries and elsewhere develop the detailed designs necessary for a specific location.

Both of the above bodies act as major coordinating units for designing and locating industries and living areas. Their activities include the distribution of funds to research groups, ad hoc expert committees, and special design units. The results of these research activities are then reviewed by GOSSTROI, GIPROGOR, and PROMSTROI. Specific areas are then designated for development. The designation of areas includes provisional plans dealing with designs for production technology, types of industries, architectural designs, and pollution control requirements and equipment. The design of pollution devices should include the following considerations:

- Improvements in pollution control technology which may also include foreign equipment;

- Improvement in purification installations using a systems approach to pollution control, one facility for many industries.

The end result of activities at this stage include recommendations and preliminary designs for urban areas and industrial nodes as well as their regional layout. These plans are then sent to regional Soviets and to all district controlling organs, including district and city planning commissions.

This phase of the preplanning process at the local and regional levels is the most important for integrating environmental criteria in the formation of the plan. Although environmental considerations have been made at the State level, they have been abstracted from the actual context of the area. It is here that local and regional commissions, Soviets, and scientific institutes who are familiar with the problems and needs of their specific areas play a definite role in ensuring that all criteria considered important are effectively treated.

Environmental protection is included among the criteria to be examined by these local and regional groups. In fact, the

Soviet is responsible for the quality of the environment, both social and natural, for their inhabitants. Whatever the Soviet decides on environmental factors then becomes immutable at other levels in the planning system. Thus the Soviet is used as the basic coordinating mechanism for environment at each jurisdictional level except the State level.

Regional and local Soviets examine the preliminary schemes developed for their territory. These Soviets can then recommend specific duties to research groups and committees. The committees are basically of an ad hoc nature, and in the case of the environment may include experts from the following disciplines: geography, geology, biology, climatology, agriculture, sociology, etc. Their recommendations are then sent to the Executive Committee of the Oblast which acts as a coordinating body for the use of experts on the district and city planning levels. Deputy commissions organized by the Oblast Executive Committee on specific problems perform the actual review. In the specific case of developing plans for the Ust-Ilimsk industrial node, a special committee on the environment was formed which evaluated the environmental impacts of the proposed industries. Ad hoc experts were employed in the examination and a total of 500,000 rubles was spent on the environmental part. The deputy commissions are assigned special funds for the formation of these expert groups.

Environmental criteria are directly associated with the Soviet system of environmental standards for the protection of health associated with industrial pollution control. The inclusion of strictly environmental preservation criteria in the planning and study process was not noted in interviews. The main environmental criteria followed are the established standards of the Soviet Union. Deviations from these standards to account for higher environmental quality would have to be backed by rigorous scientific data showing greater impacts if the recommended standards were followed.

The expert groups not only examine regional layout plans but also concern themselves with individual industries. The expert groups also contain representatives from the monitoring and enforcement organizations that review industrial plans. They ensure that the minimum amount of pollution treatment equipment is present, and that public health will not be affected by the operation of the recommended industries. Participation of the monitoring and enforcement agencies is not strictly required at this stage. However, it was stated that their approval of the design is necessary before an individual unit is placed in operation. Experience in the Soviet Union has indicated the need for active participation by these units in the design stage.*

*The major example explained was the case of development along the shores of Lake Baikal in the early 1960s. Two large paper plants were constructed without sufficient pollution control devices. Additional facilities had to be installed which increased the cost of pollution control to 50 percent of the cost of the plants themselves.

The design plans and the opinions of the expert groups are then reviewed by two major bodies of the Oblast Executive: the Department of Architecture and Construction, and the Commission for the Location of Productive Forces. These two bodies review the design plans for regional layout and for individual industries. Designing bodies of individual Ministries may also be involved if their designs are not sufficient for adequate pollution control. Recommendations may be formed for the design of better pollution control equipment, increase in pollution control facilities, new standards based on the peculiarity of environmental conditions and zoning regulations of territories. Each of these bodies has its own staff plus a budget to invite external experts to aid them in their review.

Finally, the Oblast Planning Committee of the Oblast Executive approves the regional layout and individual enterprise designs and locations. This approved set of plans is sent back to GOSSTROI in Moscow where it is approved at the State level. Any differences of major importance must be resolved at this stage of the planning process. Conflicting opinions that cannot be resolved are sent to GOSPLAN where Siberian representatives can make direct appeals. If no agreement can be made the case can go to the Council of Ministers or even as high as the Supreme Soviet for final resolution of the conflict.

The completion of new enterprise designs and new regional layouts signifies the end of the preplanning stage. The formal process of planning begins with established operating industries as well as the actual construction of new enterprises.

Formalized Planning

Planning projections are based on recommendations received from each individual enterprise and from that derived by GOSPLAN. In this sense it is a bottom-oriented approach to production targets based on the experience of individual enterprises.

The Oblast reviews their individual enterprises' recommendations and submits them to GOSPLAN for review. The process of preplanning and planning up to this point takes about three to four years.

During the same span of time GOSPLAN also prepares a production prognosis through regional GOSPLANS and production Ministries at the Republic level. The prognoses are usually based on economic regions of the USSR, but in the case of regions of national importance (for example Siberia), recommendations can be sent directly to GOSPLAN, bypassing the Ministries. The two separate prognoses from the Oblast Soviets and the Republic GOSPLANS and production Ministries are then compared, and the two are aggregated in the formulation of draft goals. These goals include the amounts of production and capital expenditures as well as standards and budgets for environmental protection. In the current Five-Year Plan, over 11×10^9 rubles are budgeted for environmental protection. It was stated that this figure is only a portion of the funds available for environmental protection. If supplementary ministerial programs are taken into account, the actual expenditures for environmental considerations are much higher [12].

The next phase represents the process of compromise and adjustment and usually involves approximately one year. The control figures prepared by GOSPLAN are sent to the Oblasts and individual enterprises through the Ministries. The Oblasts and industries revise their first stage estimates according to detailed estimates developed by GOSPLAN. If there is disagreement, counter proposals are prepared and negotiations undertaken with the appropriate Ministry. Major arguments may be taken to the highest body for resolution, the USSR Council of Ministers. In the case of environmental questions, the Supreme Soviet of the USSR has a special commission on environmental protection which considers all suggestions and makes final recommendations. Environmental commissions also exist at lower levels of government for resolution of conflict.

Because of the special nature of certain economic regions in the Soviet Union (such as Siberia), conflicts may be resolved directly by the highest level of the Supreme Soviet, thus avoiding the tedious process of advancing along the chain of command. This ability to bypass interim bodies resulted in some major decisions affecting the state of environmental protection in the Soviet Union. For example, in the case of developing plans for the BITPC, it was determined that production Ministries must share in the cost of environmental protection systems for cities and their industrial complexes.

The final planning document, including the resolution of conflicts, is prepared in time for the Congress of the CPSU where it is discussed and finally approved by the Supreme Soviet. The approval of the plan gives it the force of law. The plan is then sent to the proper bodies for enactment. On the basis of the plan the individual enterprises formulate their one-year plans for operation.

Observations on the Planning Process

Integration of environmental factors in the preplanning system is important as it sets the stage for both the more formalized planning process and the actual development. This integration occurs at various levels in the process.

Generally, the process of environmental integration at the *State level* begins with the scientific forecasts provided as the data base for the design and location studies which follow. Then environmental factors are considered at both the technological design stage and the enterprise location in the regional layout.

At the *local and regional levels* environmental experts are used to advise on the suggested designs and locations from Moscow. Any differences in points of view are then negotiated between the State and these lower levels.

Organizations interviewed were of a large variety which included such functions as research, planning, academic, construction, political, monitoring, and operational. Only two environmental organizations were visited at three separate planning levels: the Limnological Institute, and the HMS. Each organization noted its main environmental task and perceived means for approaching this task in the planning process. In many of the organizations interviewed environmental factors are generally cast within an economic framework to which they are viewed as constraints. No organization interviewed perceives its task to maximize environmental considerations subject to certain production constraints. While these organizations may not completely represent the total environmental planning picture in the USSR, these groups were the only ones interviewed. No centralized environmental planning organization exists to promote environment as a separate planning objective to be maximized. Rather GOSPLAN, SCST, and GOSSTROI play the key roles in coordinating and allocating planning and research effort for environment.

The following observations have been made on the bases of information received, field observations and evaluation of interviews by the study team.

In the BITPC, the preplanning process was not totally effective in alleviating many of the environmental problems encountered. This implementation problem is easily understood when it is recalled that the BITPC was established in the early 1950s after a devastating war and under severe climatic and frontier conditions. Added to this set of constraints is the recent emergence of the general awareness of the extent of the environmental problem and its inherent complexities. Thus the BITPC is not the best case study example of how environmental factors are currently defined and incorporated in the planning process. Given many of the problems listed here it is surprising that the general environment of Bratsk is of such high quality. For example, many outdoor recreational facilities have been provided and a network of trails in forested areas was created. Green spaces exist in Bratsk and between the urban nodes and the enterprises. The central thrust was to create a "wilderness" environment in Bratsk rather than an artificial, isolated park copied from other areas of the USSR. However, during its development stage the Bratsk environment suffered from splintered planning among production Ministries, and a lack of a general plan for the entire TPC, of effective planning controls, and of urban and regional planning criteria coupled with an urgent need to have the TPC become operational.

In addition, locations of the timber complex, aluminium plant, and town center were also not well situated with respect to potential air pollution distance to the adjacent worker populations. In spite of these problems, Bratsk has emerged as an important development center in Siberia, and some of the lessons learned have been translated into better planning for the water resources at Ust-Ilimsk, including the construction of the city center and the timber complex. However, while some of these learning costs have been translated into an improved preplanning process via new design standards, there still remains a problem in implementation. Many of the above coordination and planning problems at Bratsk have also occurred at Ust-Ilimsk [5, p. 7]. An overall coordinated planning capability for either development or environment is still not operative in the BITPC, but some of these lessons have been translated into design standards for other large-scale projects.

Other more general observations on the planning process are as follows:

- While environmental considerations are integrated at selected phases of the planning process, the preplanning process is used as the major vehicle for environmental interpretation.

- The integration of environmental factors in the planning process has political support from the ministerial level, active participation by scientific professionals, and includes input from local and regional bodies, mainly the Soviets.

- Environmental considerations are related to proposed enterprises.

- The environmental assessment process is not systematically initiated and well coordinated since there are many splintered functions and no central environmental agency.

- No environmental coordination capability is available at the TPC level.

The planning process attempts to integrate environment in the planning for productive forces. Environment is integrated in the planning process via environmental standards for design for development projects and the location of such projects. There seems to be no doubt that environmental protection is considered a legitimate cost of production; however, the actual process of who pays for how much protection for whom was not made clear in the interviews. For example, a production Ministry may concur that environmental standards must be met by its enterprises but may at the same time balk at paying for such protection from its production funds. In this case, GOSPLAN would have either to find additional funds to be transferred to this Ministry or to request the Ministry to pay directly out of its own funds. In this latter case, the Ministry may delay such implementation, as has seemingly occurred in the USSR [23, pp. 176-177].

Because of the orientation of the planning process, the planning system generally considers environmental factors in the context of proposed developments. At the national level, a perception of environment as a constraint on production is legitimate, given its stage of economic development and social goals. On a regional basis, environment can become the overall goal subject to certain production constraints, or even no production if it is desired to preserve the region as a wilderness area. Regional development can progress to the point where the goal for the region must shift to an environmental one to retain the habitability of the area. Certainly, depending upon how environmental factors are defined and implemented in a region, a different array of productive activities will evolve.

Even though environmental standards can be set prior to development, such standards do not constitute goals in the widest sense. Environmental standards are designed to create minimum acceptable pollution levels given the production capacity in place and producing as well as the planned production. Questions of not having that production and hence pollution in the first instance were not discussed by the Soviet scientists and planners in their statements on the planning process. Little information was obtained on the process of setting environmental standards. (For a general statement on standards see [26].)

Siberia is currently being divided into economic regions based on economic assessments of the inherent natural resources. This same area could be divided into environmental regions based on environmental quality assessments of the inherent environmental qualities without having to subordinate these same resources to an a priori economic development program. (This suggestion was also raised independently by a Soviet author; see [38].) If both economic and environmental assessments were made of the same area according to different goals and criteria, e.g. without a project context, then trade-offs could be viewed in the light of losses to these goals and hence to Soviet society.

The integration of environmental factors in the planning process is an important step in establishing a system of environmental management. In the case of the Soviet Union, they are only beginning to establish such a system. Because of the Second World War, the severe climate and the rough frontier conditions, their planning process tended to emphasize production, with environmental considerations only beginning to emerge from being overlooked or disregarded in the past. The history of the BITPC demonstrates that environment did not play a large role in influencing decisions in its regional development, but given what was learned there it appears that scientific institutes and people in Siberia are more aware of the need for environmental protection. For this reason, they now press for more thorough and complete environmental studies to ensure that decisions are not made without environmental consideration.

There is a basic ad hoc nature to environmental assessment procedures in the planning process which stems from ad hoc committees being formed on regional and local bases. This process does not allow for the systematic integration of environmental factors unless environmental coordination is done on a more regular and ongoing basis. However, a role for knowledgeable and interested citizens and journalists who are not certified experts would seem of benefit, especially since these individuals played such an important role in getting the pollution at Lake Baikal raised to higher levels of public and scientific visibility [23, pp. 174-175].

Obviously the Soviet Union has learned from mistakes made in the past, and has established changes in its planning system which are designed to allow for the consideration of environmental effects. These changes in policy are examples for other nations to watch since planning occupies such a central role in the USSR, and since they have made an attempt at integrating environmental factors.

It was also mentioned repeatedly during the course of the study that there is serious consideration being given to the establishment of a central environmental planning ministry or committee. (See for example [38].) It is our opinion that such an advocate with regional representation would be an advantage to the Soviet Union and would allow for more advocacy and coordination on an all-union basis.

INTEGRATING ENVIRONMENT IN OPERATIONS OF THE BITPC

The TPC consists of three main pollution sources: the individual enterprises, the infrastructure (power dam, transportation), and the city itself. Each has a level, composition, and distribution of a potential spectrum of pollutants that can endanger the operation of the TPC, its occupants, and the surrounding natural environment. This wide range of pollutants calls for a vast system of integrating environmental factors in the operational programs of each part of the TPC.

The Role of the Local Soviet

One key body in all matters affecting the TPC is the local Soviet. This body, which consists of elected representatives from many different walks of life at the local level, has the main responsibility for the social and natural environments in and around the urban nodes of the TPC. The local Soviet is charged with particularizing national environmental standards and implementing them as local environmental policies applicable to all industries and urban nodes within the TPC. In order to carry out this task, the local Soviet creates an environmental commission from among its members who specialize in making environmental policies. This commission has wide powers to implement its decisions and to generate knowledge to support its decisions via research contracts.

Figure 4 shows some of the many inputs to such a commission of the local Soviet. The organizations interacting with this commission include research institutes, pollution monitoring organizations, production Ministries and their local enterprises and other environmentally related bodies. In cases of disagreements or disputes, the commission can call on the aid of the Management Institute, the Department of Arbitration, and the Department of Justice at the Oblast level. In the case of a special large-scale environmental problem, the local Soviet will appoint a deputy chairman with an ad hoc commission to develop a management solution to the problem. Thus the local Soviet is organized to accomplish the coordinating and implementing roles for environmental aspects of TPC operations.

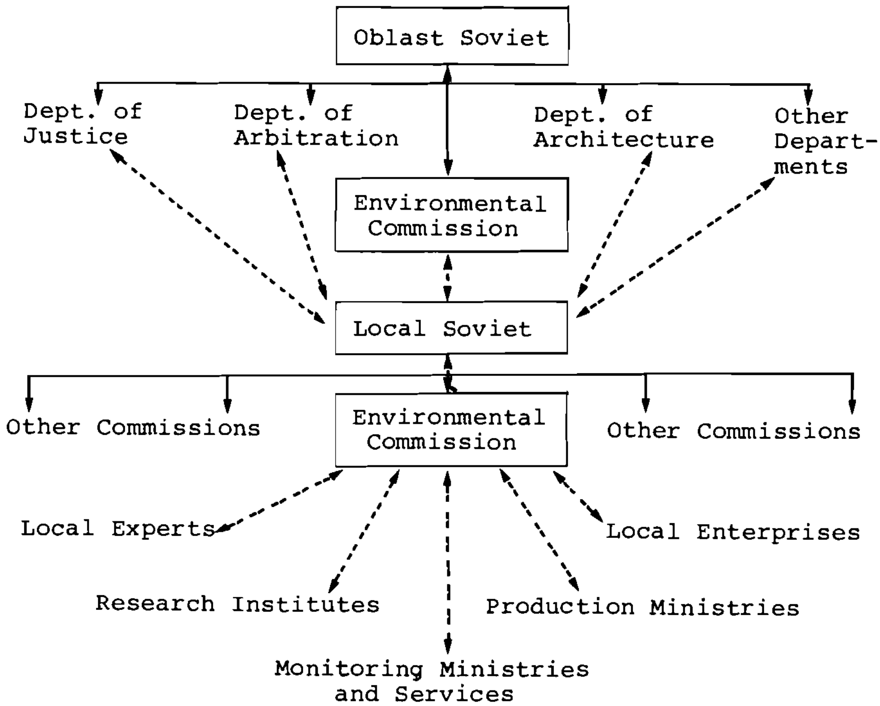

Figure 4. The central role of the local Soviet in environmental planning and operating decisions.

Of particular interest is the local Soviet role in the pre-planning process for the TPC. Its key role is to coordinate the planning efforts of the specialized research and design institutes and the production Ministries involved in the development of the enterprises for the TPC. Their main task is to organize an integrated regional environmental package which not only meets national standards but may exceed them depending upon particular conditions of the local environment. The local Soviet has the power to generate research to substantiate the particularistic aspects of its local environment by drawing upon the advice of specialized research institutes via contracts. Funds for such research emanate from GOSSTROI.

Once the plans are approved at all levels from the local Soviet to GOSPLAN, then funds are allocated by GOSPLAN for the construction of the enterprise in the TPC. For each enterprise added to the TPC, an additional unit of housing, schools, stores, services, and recreation facilities are provided. This basic package or unit of social facilities for workers required at the new enterprise is simply added to the existing city in the TPC. From experience supplemented by local conditions as espoused by the local Soviet, this package of social facilities is created, located, and constructed. Funds are marked by GOSPLAN for the construction of this social package as a given percentage of the cost of the new enterprise. This approach to funding of the social infrastructure means that such social costs are seen as a legitimate and integral cost of the enterprise itself. With funds set aside for social construction purposes on the basis of given formulae and research, the local Soviet receives adequate funding. Operating funds for such services including local environmental conditions are also based on formulae that often must be supplemented from other sources because of particular local conditions such as extreme cold.

In actual practice, however, it is not always simple for the local Soviet to implement its environmental protection strategy. To carry out its responsibilities, the local Soviet requires adequate funding for implementing both research and the findings from such research for bettering the local environment. The implementation of a set of strict local environmental standards requires a bargaining session with local industrial enterprises, if such enterprises are opposed to stricter-than-national standards. Since some funding for operating social and environmental programs comes from such enterprises, it is not always possible for the local Soviet to insist on the enterprises following its interests. For example, a weak local Soviet that requires funds for one of its social programs, say public transportation, may have to offer immunity from its local sewage standards to a strong public industry in order to obtain the necessary funds to operate its program adequately. (This point is more fully developed in [42, pp. 241-242, 247].) In Bratsk, however, the local Soviet appears to be in a strong position for enforcing its environmental standards. Both the timber complex and the aluminium plant participate in an informal coordinating body with the local Soviet in the implementation of environmental standards. In fact, the Soviet scientists accompanying us noted that the local Soviet was influential in locating elsewhere for environmental reasons a second proposed aluminium plant, even though Bratsk offered all of the requisite economic advantages of proximity to rail transport, cheap power, and adequate raw materials. Thus, the local Soviet is an important body in the coordination and integration of environmental factors in the TPC.

No central environmental office exists for the TPC. Each unit within the TPC has its own environmental office for operating and monitoring waste treatment facilities and coordinating with other environmental offices and units. The Bratsk City Soviet has a committee concerned with environmental matters both for its inhabitants' health and for the pollution the city generates. This local Soviet is also in contact with the environmental offices of each of the enterprises for coordinating waste treatment practices, payments, etc.

Pollution control can be handled in different ways; for example, pollution can be avoided by concentrating pollutants in areas with no or fewer inhabitants, by treating the pollutants as they are discharged and by recycling the pollutants to eliminate discharge. The TPC seems designed to use all three of these means for pollution control. TPCs are located in Siberia not only to be near the available natural resources but also to shift pollution from the crowded areas of the western USSR. TPC enterprises appear to have good waste treatment technologies and procedures, and these enterprises are employing recycling where technologically feasible. So from both the national and the local scale, pollution control is of interest in the location of the TPC and the enterprises within the TPC.

The Bratsk Hydropower Construction Enterprise (Bratskgesstroi) is the only organization involved with construction in the TPC; it has constructed the power dam, transportation routes, city housing, enterprises, etc. Thus it has a wide range of experience. Having one organization for all construction and some operational aspects of the TPC avoids costly duplication of overheads and can reduce the environmental impacts of such construction if proper planning is done. No environmental unit exists within Bratskgesstroi to plan, instruct, and inspect the environmental aspects of its construction activities. Bratskgesstroi was the only major operational organization encountered that had no integrated environmental component. Given the organization's major role in the construction and operation of the BITPC, it would seem important for it to develop an environmental office to aid its activities.

From the national point of view, Bratskgesstroi is already accomplishing an environmental task by being permanently located in the region where it undertakes its construction activities.

This approach to creating and locating construction units in the region where they work helps to avoid untimely and unseemly construction problems by enhancing their ability to understand the nature of their environmental impacts over time through their experience in the region.

Lake Baikal and the Angara River

Lake Baikal has special significance in both the geographical and the ecological sense while also being important as a potential water resource. It is fed by 336 tributary rivers, but water flows out from the Angara River only. It has about 23.6×10^3 km^3 volume of water storage, which represents about 20 percent of total world fresh water. In addition, it is the deepest lake in the world with a maximum depth of 1620 m and contains some of the world's purest water. Several hundreds of unique plants and animals have been found in the Lake alone.

Special attention has therefore been taken to protect the natural ecosystem of Lake Baikal. For example, the Limnology Institute of the USSR Academy of Sciences, founded in 1925, is located at the very source of the Angara. The Institute studies almost all aspects of the problems related to the nature of the Lake Baikal basin and has also done work for the protection of the natural environment. Studies are being conducted for the future development of hydroelectric power stations related to the interaction of the Lake Baikal and Angara system, in addition to basic limnological studies.

Large-scale and rapid development of industries in this region, in particular those whose potential for pollution is very high, has caused several pollution problems to arise in the Lake Baikal and Anagara Basin since 1950. A very high potential for generating serious pollution effects exists if there is no comprehensive environmental management in regional planning efforts. Unfortunately, until recently, economic planning has given very little consideration to the ecological balance of the natural environment in the developing regions throughout the world. Environmental issues have been defined exclusively from the point of view of efficiency of the use of natural resources. The Lake Baikal-Angara River Basin was probably in the same situation until recent years.

In the early 1960s, the Supreme Soviet and all of the Union Republics had already passed comprehensive environmental and conservation-related laws. Also, several famous scientists had considered the effects of the deterioration in the quality of the natural environment in major industrial centers together with progressive pollution in the rivers and lakes. For example, in 1962 Professor G. Galazii of the Institute of Limnology of the Siberian Branch of the USSR Academy of Sciences warned that the discharge from the timber plants would endanger the lakes ecological balance [31]. However, it was not until the late 1960s that the public and officials became aware of the environmental pollution problems in the Siberian regions, mainly because, until recently, they lacked sufficient scientific knowledge of the ecological impact of waste products. This problem was true of most of the highly industrialized countries.

In 1971, the USSR Council of Ministers issued a special decree concerned with the environmental protection of Lake Baikal and its basin. This decree prohibited fishing in any river that flows into Lake Baikal, and the construction of new plants without sufficient purification installations [21].

Restrictions were also placed on lumbering activities within a special water conservation zone (about 20×10^3 mi^2). Also special standards for water quality were created. Thus one of the main pollutors of Lake Baikal, the cellulose mill in Baikalsk, had to complete special purification facilities by the end of 1971. Also, the wood processing plants along the Selenga River (which is the largest tributary flowing into Lake Baikal) had to enlarge their purification facilities in order to continue production. In addition, the adjacent cities were instructed to purify their municipal wastes. Scientific institutes and government organizations involved in the protection of the natural environment as well as journalists in the USSR have played an important role in enforcing these environmental laws. For example, the Institute of Limnology has joined an ad hoc committee on Lake Baikal which has made important recommendations concerned with the determination of the standards for water quality.

The cellulose plant on Lake Baikal has a three stage purification process: biological, chemical, and mechanical. The plant needs 30,000 m^3/h fresh water but it takes only 12,000 m^3/h from the Lake as the rest is obtained from recycling. The purified waste water which flows into Lake Baikal is deposited at a distance of 160 m from the shore and at a depth of 40 m to make the dispersion of pollutants more effective. Statistics for the purified waste water in 1972 are shown in Table 1. The Selenga

Table 1. Purified waste water, Lake Baikal, 1972.

Source: [21]

Suspended matter	5 mg/l
BOD_5	3 mg/l
COD	80-85 mg/l
DO	5-9 mg/l
Phenol	0.02 mg/l
Organic sulfate	0.75 mg/l

timber plant has shifted the discharge flow of the treated waste matter to another river with a non-Baikal end point which has a large reservoir [34].

For comparison purposes, in the case of the Bratsk timber complex the plant has a large capacity for purification which can treat a volume of $50{,}000^3$/h of waste waters; it consists of one mechanical and two biological processes. The contents of its purified water are of good quality although the emission standards are lower; they have a much larger amount of discharge load when compared with the plant on Lake Baikal, such as BOD_5 of 20 mg/1 and a DO of 2-6 mg/1 [31].

A schematic description of Baikalsk's purification facility is illustrated in Figure 5. It features the usual biological and chemical processing (decolorization process) after which the water is passed to a special physical treatment facility composed of a charcoal filter and a forced aeration pond.

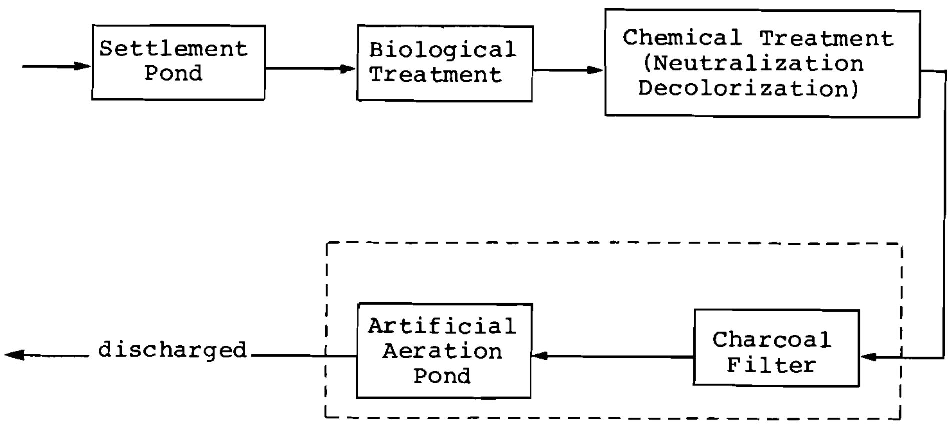

Figure 5. Water treatment diagram of Baikalsk plant.

From the point of view of the economic efficiency of the investment, the additional physical treatment facility seems to make no return on the enterprise base. Almost all timber and pulp plants in developed countries do not have these kinds of special processes [16]. Investment in the Baikalsk purification facility was estimated to be about 50 percent of the total construction costs of the cellulose plant. In addition, for the USSR as a whole, the average investment in purification facilities was said to be 14 percent of total construction costs [9].

HMS has the main responsibility for monitoring the water quality in the Lake Baikal-Angara River Basin. The organization has fixed and mobile monitoring stations along the whole Lake Baikal and Angara River Basin. For Lake Baikal especially, the water is monitored at the nearest point to the cellulose plant every six to eight hours. Among the many items that are measured, DO, mineral matter, and pH are continuously and automatically observed.

Hydrological and hydrochemical inspections are carried out two to three times per year particularly in the area of Lake Baikal, the Angara River and 14 of its major tributaries. These inspections are carried out by the Hydrochemical, the Hydrological and the Limnological Institutes, and the University of Irkutsk.

Owing to past investigations, it has been discovered that a polluted area in which the suspended pollutants have been distributed into the lake bottom occupies about 0.0002 km^2. This suspended matter includes the following pollutants (in percentages): cellulose (10), lignin (7), minerals (80) and resin (1). This particularly polluted area of the lake bottom is reached at approximately 2 km^2. These scientific observations also showed that for the past 15 years the amount of minerals and organic matter flowing into the Lake has increased since the development of the lake basin. This development has added such pollutants to the Lake as minerals 3.5 percent and organic matters 12 percent [21].

Table 2 shows the pollution standards associated with the Bratsk reservoir as part of the Angara River Basin. Taking into account the huge water storage capacity of the Lake, the figures indicate the seriousness of the Lake's environmental pollution problems and the urgent need for comprehensive environmental management associated with and integrated in regional development. Additional comments concerning water resource development and environment are discussed in the paper on water resources contained in this Report.

Table 2. Present standards for water quality in Bratsk reservoir.

Source: [32]

ITEMS	ANGARA RIVER
BOD_5	2.0 mg/l
DO_{+2}	6.0 mg/l
Mg	50.0 mg/l
cl^-	350.0 mg/l
SO_4^{-2}	500.0 mg/l
Mineralization	1000.0 mg/l
NH_4^+	2.0 mg/l
NO_3	10.0 mg/l
Fe^{+2}	0.5 mg/l
Fluroine (F)	1.5 mg/l
Terpene $(C_5H_8)_n$	0.2 mg/l
Oil Product	0.05 mg/l
Methylmercaptane	0.0002 mg/l
Formaline	0.01 mg/l
Phenol Acid	0.001 mg/l
Reaction (ph)	6.5-8.5 pH

The Bratsk Timber Processing Complex

The timber complex, located a few kilometers from the city of Bratsk, is one of the largest of its type in the world, with a planned yearly production capacity of 7.5×10^6 m^3 of timber. The plant is relatively independent of timber suppliers outside the TPC because of the allocation of 3 million ha of forest for its processing demands.

The plant was constructed in 1958 under the auspices of Bratskgesstroi in order to provide abundant timber products in the Region, secure fresh water supplies from the Angara River, and ensure cheap electrical energy from the Bratsk Dam.

The sulfate or Kraft processing method of digestion is used for the separation of wood fibers for further manufacturing processes. The Kraft process basically involves using sodium hydroxide and sodium sulfate as active delignification agents in the chip-cooking phase of the process. New or recently built Kraft processing mills in the United States and Europe employ methods designed to recycle as much of the chemicals as possible. This is done for two basic reasons. Many of the chemicals that are recovered can be reused in the pulping process giving them commercial value. Also, the reduction of chemicals in the effluent reduces the amount of pollutant material that has to be processed before release into the environment, thus lowering the cost of pollution control facilities.

The timber processing complex in Bratsk is designed to conserve and recycle as much as possible during the various manufacturing processes. Data for the amount of materials recycled were not obtained. For the purpose of this Report the recycling process can be divided into two phases. The first phase deals with the recycling of materials before the chemical process of pulping begins, and the second phase deals with the recycling of chemicals and materials during the pulping process.

This first phase in the recycling process involves the collection of materials during the timber preparation process. These materials consist mainly of the collection of bark from the timber stripping process, the sawdust from the chipping process and the saw timber portion of the plant, and other parts of timber which cannot be used for pulp production. Bark and sawdust are used in the plants to produce steam. Large quantities of sawdust are also used to manufacture nutrient yeast compounds. Tree stumps are collected and processed in a special compound for the manufacture of rosin materials.

The second phase of the Bratsk recycling process is shown in Figure 6 and deals with the chemical pulping portion of the complex. Cellulosic fiber is the only material desired during this phase of the plant operations. Depending on the type of pulp wood used, as much as 50 percent of the organic materials

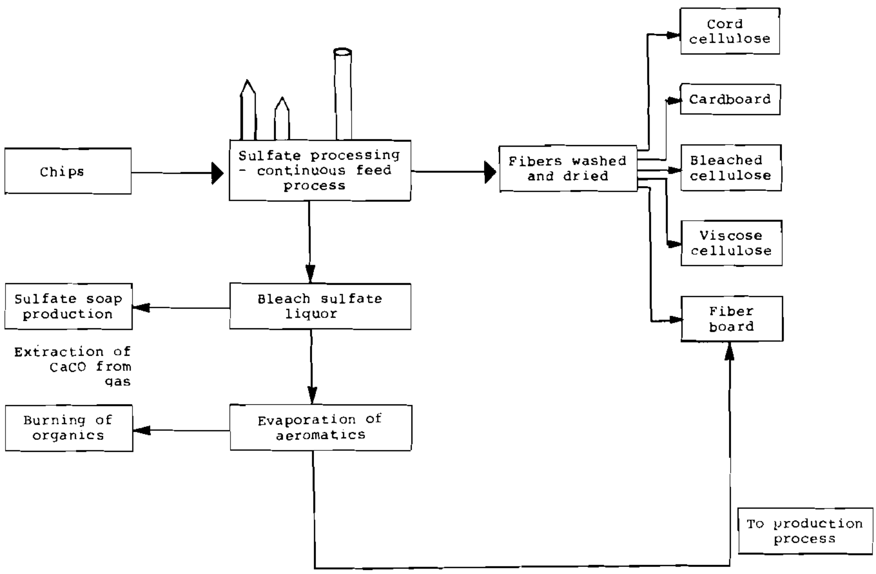

Figure 6. Timber processing–Bratsk Complex (Phase 2).

are the main sources of potential water pollution in the discharge water. Substantial portions of this discharge contain such items as wood sugars, carbohydrates, and other nutrient substances. If untreated these compounds can lead to a rapid increase in the growth of water micro-organisms, a decrease in the oxygen content of a stream or river, resulting in biological death for aquatic life.

The Kraft process of pulping is designed to recycle many of the chemical components present in effluent waters. This process results in the BOD of effluent water being the lowest of all the chemical pulping methods. Figure 7 presents the sources of pollutants from the Kraft pulping method. In the second phase the main effort is in recycling the main components present in the black sulfate liquor, an alkali substance containing both organic and mineral components. The Bratsk timber complex uses modern technology for recovering usable materials and for reducing the pollution potential of the black liquor.

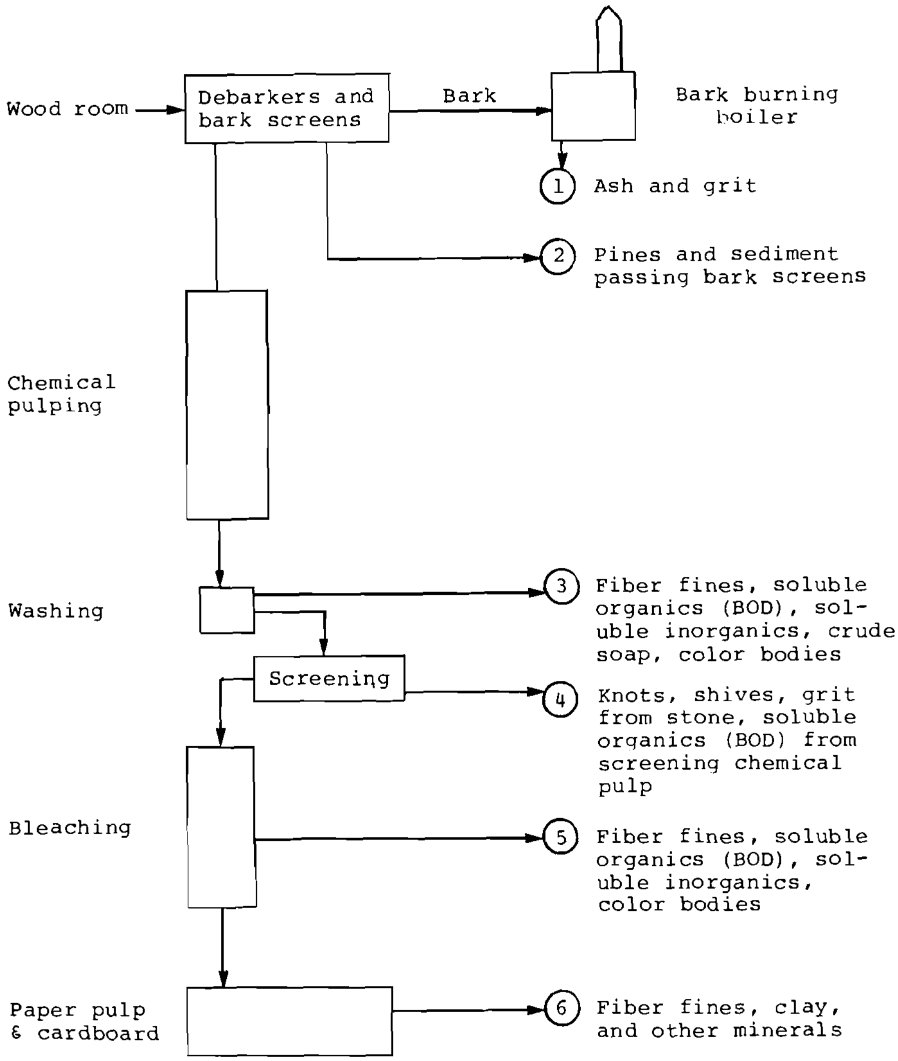

Figure 7. Sources of pollutants from pulp processing.

Source: [29]

A continuous feed process is involved in the chip-cooking phase, allowing for more uniform pulp processing and more efficient recycling of needed components. The pulping liquor is continuously extracted from the bottom of the pulping boilers. It is then routed to a heating vessel where the aeromatic compounds are evaporated and collected. These are resinous substances that can be used as bonding agents or reprocessed into usable compounds such as turpentine. The remaining pulping liquor is further heated to reduce the moisture content to a level of 50 to 60 percent. A small amount of this substance is used for producing a sulfate soap for rosin extraction. The remaining organic portion of the liquor can be burned and the heat generated used for steam production. During the burning process chemical compounds are extracted both from the flume and the residue which are then used over in the pulping process. The major compounds derived in this manner are Na_2CO_3, $CaCO_3$, NaOH, and $NaSO_2$.

The recycling process is not a closed cycle. Large quantities of water are used throughout all phases of production, and it is necessary to process this water before it is released into the Bratsk reservoir.

The initial design of the Bratsk timber complex included provisions for the treatment of waste water. The rates allowed for in the initial design proved to be less than adequate, and provisions were made to increase the capacity of the water purification system. In addition, a target of 0.5 percent pollution in the discharge water was set by the plant managers. An interesting aspect of this decision is that the plant director was the main instigating force. In this example production and protection appeared to be considered as integral obligations of the timber plant.

The present installed capacity of the water purification system is 50,000 m^3/h of discharge water. The total surface of the purification installation is 184 ha. The cost of the system was 62 million rubles, or 5 percent of the total plant construction cost. In addition to the present facilities, another station is being constructed which will increase this capacity. The increased volume that would be processed was not determined, but the construction costs were given at 80 million rubles. Planned completion of the addition is scheduled for the end of 1976.

Figure 8 is a schematic of the existing pollution treatment system for water. It is a three-stage system representing the latest technology in aerobic biological treatment systems. It employs mechanical filters, settling ponds, aerobic biological degradation, and aeration of the treated water before discharge. The problem of color bodies present in the discharge water is still not completely solved.

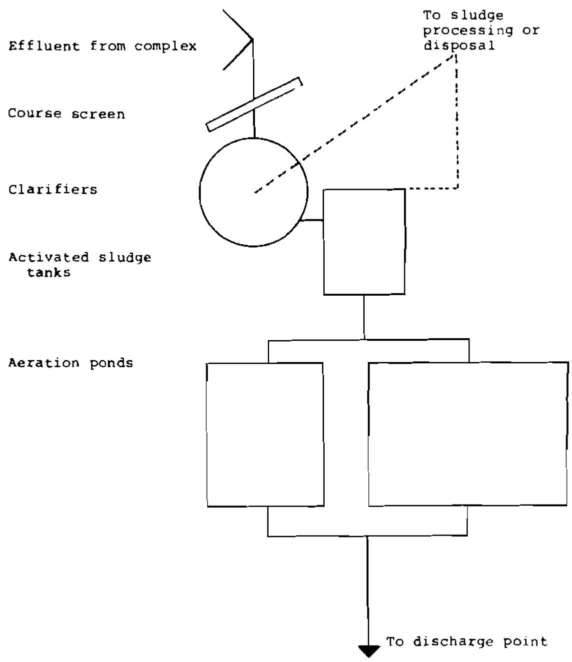

Figure 8. Biological treatment system of Bratsk Timber Complex.

The system both in the handling capacity and in the effectiveness of pollution reduction appears effective. When the plant was first placed in operation in 1970, the BOD of discharge water was 106. By 1975, the BOD was reduced to 15. When the additional system is put on line, the BOD is planned to be reduced to below 7 mg/l. In addition, the dissolved oxygen demand is currently less than 6, with further increases in this level anticipated. Tables 3a and 3b indicate the pollution control improvements attained and the funds allocated for such control since 1970. Since the costs of pollution control equipment and pollution control systems come from production funds, it appears that there is support for environmental protection from this Ministry. Funding mechanisms for environmental protection were not observed. It was stated that the procuring of funds was "no problem" as they were entirely supported by the plant manager. It was also stated that an additional sum of 150,000 rubles was allocated for research in pollution problems to the environmental staff of the Bratsk timber complex. In the light of the heavy importance placed on production in the Soviet Union, the ease with which funds were attained for pollution control is interesting. It appears that Siberian development planners now place much greater importance on environmental protection than was previously the case.

Table 3a. Improvements over time in basic pollution indicators.

Source: [37]

	1970	1975	% improvements
BOD	106 mg/l	15 mg/l	707
DOD	22	67	305
Suspended solids	92	21	438

Table 3b. Costs allocated to pollution control systems.

Source: [37]

	1970	1975	1980
Air pollution control	1.34×10^6 rubles	6.02×10^6 rubles	65.0×10^6 rubles
Water pollution control	17.64×10^6 rubles	42.41×10^6 rubles	60.0×10^6 rubles

Observations from the study group's evaluation of the environmental operations of this timber complex included the following:

- The role of personal accountability and interest of the plant director is strong in emphasizing environmental factors;

- A separate environmental protection office was created in the plant with good access to the plant director;

- The treatment process appears to be rather complete given the technologies and costs at the existing time;

- There is a willingness to change production technology to increase recycling.

One problem in the plant's sphere of operation is its lack of control over the timber before it reaches the plant's timber port. Environmental impacts from harvesting and transporting logs to the plant can be very high. Since the timber processing complex has no responsibility for these logs until they reach its timber port, the question arises as to who is responsible for these logs prior to delivery. It is unclear who is responsible for the environmental impacts of these logs before they reach the plant. The timber plant does not exercise control over its inputs because of the possibility that it may accelerate cutting beyond the capability of the growing process.

The Bratsk Aluminium Smelting Plant

The Bratsk aluminium smelting plant has been planned and developed as a typical high energy consuming industry in the BITPC which would use the low-cost electricity generated in the Bratsk hydroelectric power station (HEPS). The plant began operations in 1966, and in 1968 was one of the largest in the world in terms of monthly production; it is still increasing its production capacity. It produces aluminium ingots, alloy ingots, rolled elements, pipes, etc., from the refined alumina which is brought from other parts of the USSR and other countries [17].

The main production flow is described in Figure 9. Refined bauxite (the chief raw material) is mixed with cryolite sodium aluminium fluoride (Na_3AlF_6), calcium fluoride (CaF2), and aluminium fluoride (Al_2F_3) to promote the efficiency of electrolysis through an electrolylic cell. The charge is melted and an electric current is passed through the cell. The carbon in the electrodes reduces the alumina to aluminium metals. The molten aluminium is pumped out from the cell periodically. After going through the heating furnace the final products are formed by the rolling mill or other machinery.

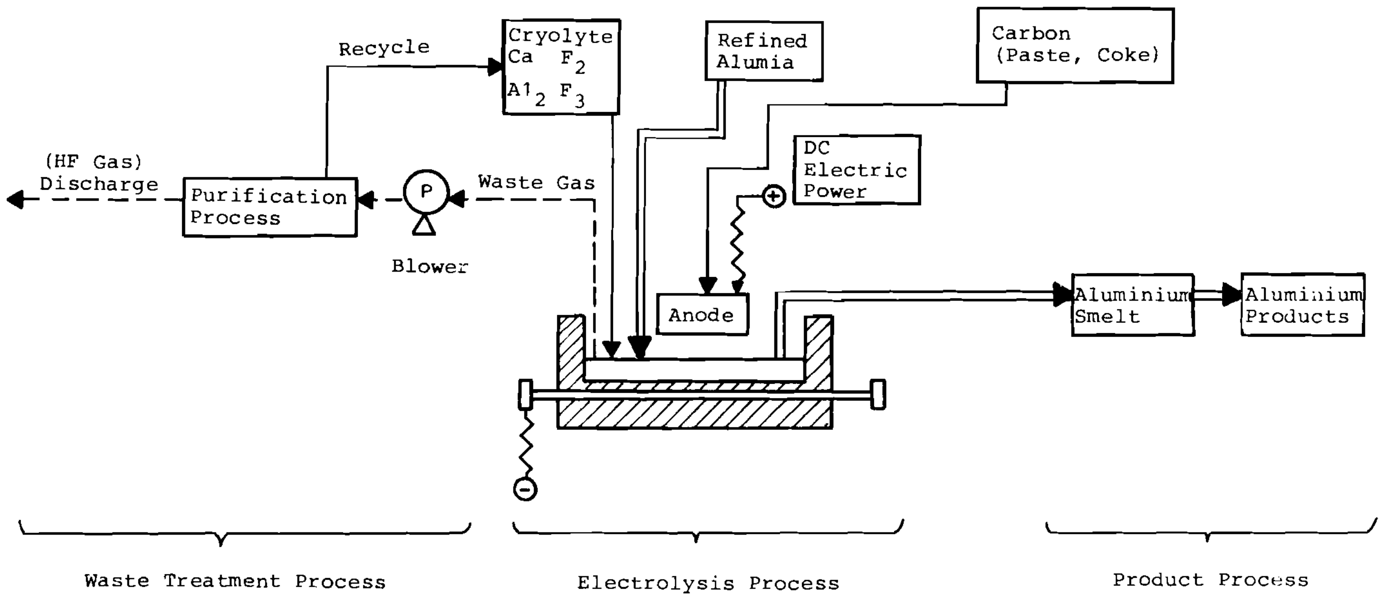

Figure 9. Bratsk Aluminium smelting plant.

The major source of pollution in the aluminium smelting process is waste gas from the cell [16]. The volatilized fluoride compounds in the waste gas react with the vapor and form hydrogen fluoride gas (HF) which has an adverse effect on plant life.

Another source of pollution is the rolling mill or heating furnace. Here aluminium ingots are heated and rolled into a temporary shape in a hot mill and finished in a cold mill. These facilities need much water for cooling and oils for lubrication, similar to those used in the steel industry. The waste water from this stage normally contains oil, suspended matter, and dissolved solids. Data on wastes generated from the Bratsk aluminium plant were not given to the study group.

The waste gas purification system is shown in Figure 10. The treatment process of the waste gas generated in electrolytic cells is divided into two parts. One is the ground system which directly draws the waste gas through the bell facility of the cell and the duct; the gas is then filtered by means of electric precipitation for particle collection. Approximately 90 percent of the total waste gas is filtered by this system. The remaining 10 percent escapes from the cell. Finally, the gas is washed and scrubbed with a sodium-hydroxide solution to remove fluorides. The other part of the treatment system is the ceiling system which treats the gas that leaks from the cell.

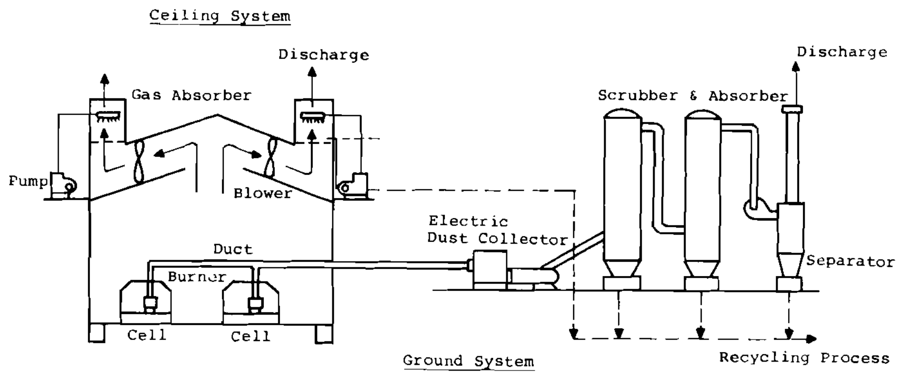

Figure 10. Typical scheme of waste gas treatment system.

The efficiency of the ground system reaches 98.5 percent for removing fluorides from the drawn-off gas [30]. However, the efficiency of the ceiling system is less than that of the ground system because of the difficulty in absorbing a weak concentration of fluorides in the air. Experience elsewhere has shown the maximum efficiency to be approximately 80 percent [41]. Thus the average discharge of fluoride gas in the atmosphere can be calculated by taking both of the above mentioned figures into account. In this calculation it is assumed that 10 kg of fluoride gas is given off per ton of aluminium (see Table 4).

Table 4. Estimated discharged fluoride gas per ton of aluminium.

	Rate of Withdrawal of Gas (%)	Absorption Rate (%)	Discharged Fluoride Gas (kg)
Ground system	90	98.5 [30]	0.135
Ceiling system	10	80 [41]	0.2
TOTAL			0.335

The environmental office at the plant is responsible for monitoring the air pollutant concentration inside and outside for an area of 1.5 and 8 km around the plant. Observation data are reported every three months to various organizations such as the Ministry of Nonferrous Metallurgy, the Sanitary Service, and the HMS of the Angara River.

According to their investigations and monitoring of data, the zone of pollution which affected pine trees was classified as shown in Table 5.

Table 5.

Distance from the Plant (km)	Degree of Pollution
5	Strong
8	Medium
10	Slight

The head of the local plant's environmental office is the deputy chief engineer of the plant; the rest of the staff consists of five engineers and fifteen technicians. The office's main function is the in-plant environment including safety. The analysis of air and water samples is carried out by a laboratory in the plant. The other main functions of this office are to make recommendations to the chief engineer concerning pollution and labor protection problems, and to develop a comprehensive plan for improving the air and water pollution levels approved by the associated Ministries. A typical example of one of these tasks is that they have been developing a green zone around the plant site where trees that are fluorine resistant are being replanted instead of the polluted pine trees. The Leningrad Design Institute had originally sent them tulips for placing around the plant, but such flowers were unsuitable to the Siberian climate. One problem that may exist with the new green zone species is their lack of pollution sensitivity so that no indicator species will be present for detecting pollution from possible equipment malfunctions.

Another example is the improvement in the removal efficiency of the ceiling system and the ground bell system. For this purpose, at present, a pilot plant is now being constructed with special environmental funds of 36×10^6 rubles for the coming five years.

The aluminium plant has as its main environmental concern the occupational health of the workers in the plant. From the interview at the plant it was clear that the environment surrounding the plant was of far lesser concern. This view is probably defensible given that the engineering staff feels they have gone to the limit on feasible technology in air pollution control and water recycling within the plant. Such a position can, however, become quickly outmoded if constant vigilance is not made of changes in technology and standards. It is of interest that the environmental office of the plant is subordinated to labor protection as possible conflicts could occur over the budgeting for these two areas of responsibility.

One problem with this plant is having to rely on external sources outside Siberia for its design information. One striking example is that of the Leningrad tulips to be used in Siberia for making the plant attractive. However, this physical distance problem can be significant in creating a mismatch between plant design and environment which would lead to an adverse impact on the environment.

Observations on Operations of the TPC

It is clear from interviews and Study Team observations that environmental factors are being integrated in the operations of two of the several enterprises of the BITPC. In these two examples, environment is now seen as a legitimate cost of production which allows for environmental factors to be incorporated in plant design, location and operations without major conflict within the plant management systems. These funds come from the production and construction Ministries with whom no contact was made during the study.

Production technology is being changed through the incorporation of recycling methods. Recycling has become important not through the rising costs of inputs but solely because waste treatment alone is seen as unsatisfactory for removing pollutants.

One interesting precept is the implementation of the "polluter pays principle" which is often discussed but seldom done. The principle appears to be a concept for regional environmental management in the BITPC where the polluting enterprise must pay for additional treatment if a downstream enterprise requires purer water as an input to its production process. Whether or not this principle is successfully applied throughout the TPCs in Siberia is not known from this visit.

The operation of the enterprises from an environmental point of view must comply with a set of environmental indicators from the oblast in the rating of the overall performance of these enterprises. However, primary control figures for these enterprises come from the production Ministries to which they are subordinated. These target figures contain no environmental indicators.

In addition, a system of bonuses and taxes is used as monetary incentives to enhance environmental quality [35]. This incentive system includes:

- Additional funds being made available from the production Ministry for recycling water;
- Increased taxes for using more than the standard amount of water as inputs;
- Reduced charges for using less than the standard amount of water as inputs;
- A progressive system of bonuses and fines which are determined by the Ministry of Health and added to or paid from the wages fund of the enterprises affected.

How this system actually works is not known; however, for it to operate effectively, the bonuses and fines must be high enough to actually influence decisionmaking.

ENVIRONMENTAL MONITORING AND CONTROL SYSTEM

Environmental monitoring in the Soviet Union is based on environmental standards which have been established and revised since the early 1960s. The setting of standards was formerly the responsibility of the Ministry of Health, Sanitary and Epidemiological Center in Moscow. In 1971, a special panel of experts was formed from the major monitoring services to further investigate standards and to cooperate in the design of a more extensive system. Standards now used are based on the recommendations of this permanent expert body who also ensure that the necessary research to support its standards is undertaken by appropriate institutions. A standing State Committee for Standards aids in developing a total system for environmental standards.

At present, the USSR has a multitude of official agencies involved both in monitoring activities and in legal enforcement. In the release of pollutants the enterprise has final responsibility for its own pollution impact on the environment. The head of the production unit is held personally accountable for damages caused by emissions from "his" plant. To aid management in its task of ensuring that emissions and discharges meet the standards set for their location and type of waste products, each major enterprise has its own monitoring section which monitors the plant's discharges and sends the information both to the plant management and to the local HMS branch. Any minor violations of emission standards detected can lead to fines being levied against either the director or the enterprise or both, depending upon the nature of the violation and its cause. The money for such fines comes from the director's personal income and from the enterprise's economic incentive and wages funds.

The role of journalists and the general public are also of interest at this point. Both of these groups can and do report pollution violations to local media, local Soviets or relevant government services which the newspapers report on in detail. Answers are then required by the offending enterprise and the relevant production Ministries as to why the violation occurred and what is being done to correct it. This system of citizen involvement has had some impact on the Government and enterprises. It certainly played a role in the protection of Lake Baikal [23, p. 174]. In the description that follows of pollution monitoring, the role of journalists and citizens should be kept in mind. For a critical look at the impact of "watch-dog" journalists see [40].

Organization of Monitoring

Three main bodies are involved in monitoring the quality of the environment. These bodies and their basic functions are summarized below.

The *Ministry of Health* has the Sanitary Service within it which is responsible for public environmental health. It monitors water quality only at the discharge points of enterprises and cities because its interest is restricted to the zone of potential pollution in water bodies. The Ministry has final say over the adequacy of waste treatment facilities in enterprises both in the planning and operational phases. It can halt production if necessary to protect health and has the power to levy financial penalties as well.

The *Ministry of Melioration and Water Economy* has the River Basin Inspection Service which is responsible for monitoring water quality of an entire watershed, especially those waters where discharges occur before the waters reach the lake or reservoir. It also has control over water inspection practices throughout the entire watershed, as well as administrative powers over water pollution activities. The Ministry's responsibility is to oversee the river basin as a whole regardless of administrative boundaries.

The *Hydrometeorological Service (HMS)* is supervised by the Council of Ministers and has responsibility for monitoring water quality only within lakes and reservoirs, and air quality. This agency is the only one dealing with air quality. It has no control functions as it only supplies information to the above two Ministries, the enterprise, the oblast, and a monthly report to the Council of Ministers.

Each of the agencies is represented at all administrative levels of the USSR and none is subordinated one to the other. The division of water quality monitoring is particularly fine, being divided into discharge point, rivers above and below discharge point but above lakes and reservoirs, and finally, waters comprising lakes and reservoirs.

The main agency is the Ministry of Health through its sanitary and epidemiological stations. These stations parallel the organizational structure of the Soviet Union. The local levels have some epidemiological stations, but these are mainly restricted to the oblast center. City sanitary services perform the main monitoring and enforcement functions in relation to conditions that affect human health. The sanitary-epidemiological services and the city sanitation services are responsible only to the Ministry of Health. These units have the power to request industrial closure if health standards are threatened through excessive industrial discharges.

Sanitation units are also located in the main industrial enterprise, and are in reality double organizations being responsible to the Ministry of Health and to the enterprise management. The units are important because they exercise constant control over plant pollution control systems and the health of the workers in the enterprises. They have the power to stop production or to close specific units of the plant. They are paid by the enterprises. They act as a link between the Oblast and city sanitary services and also play an active part in the formation of plans for their enterprises. Their data, however, are not given as full credibility as that accorded to the HMS data, for example, because of their dual allegiance.

The monitoring of discharge water is done through the river basin inspection bodies responsible to the Ministry of Melioration and Water Economy. These bodies are not administratively restricted but are organized on the basis of river basins or watersheds. They are primarily concerned with the use of water as a multipurpose entity, and attempt to uphold the water quality of basin river systems and to perform water quality monitoring which includes chemical analysis (BOD_5, DO, etc.). These units also have the authority to close plants when above-standard pollution levels are detected.

The Ministry of Fisheries also advises on monitoring. Other organizations are also apparently involved but none was mentioned by the interviewees [23, p. 164].

During the course of this study of monitoring, only the HMS was interviewed. The other agencies were not represented in any of the interviews organized; therefore, this section emphasizes the role of the HMS in monitoring environmental quality. Where noted in the interviews of the HMS, the links to other monitoring agencies are included here.

The Role of the Hydrometeorological Service

The HMS is the major monitoring body ofthe Soviet Union, with branches located in every Oblast of the Republics. At present this body is a monitoring and information service only and is not responsible for enforcing emission standards and antipollution laws. It has an active research program dealing with air and water quality and also employs the largest scientific staff of all the monitoring services. The HMS branches are located on a parallel with the administrative sections of the USSR: State, Republic oblast, district, and city. The data collected on water and air are used mainly in the planning of industrial centers or nodes, including the location and operation of individual enterprises. These planning activities include forecasts of specific climatic conditions and the assimilative capacity of water and reservoir systems.

As of 1973, the HMS was given a larger set of tasks for environmental matters, with responsibility in such areas as research, monitoring, planning and approvals of certain pollution control designs. Table 6 outlines these tasks and shows the role of the HMS vis-à-vis other organizations involved with environment. Rather fine lines are drawn between responsibilities for different

Table 6. Aggregated environmental tasks of the Hydrometeorological Service and linkages to other organizations.

HMS Task	Informational Link	Approval Link
Research on calculating pollution concentrations	Results to GOSPLAN and GOSSTROI	Approval by GOSSTROI for construction standards
Research on Standards	Work with Acad. of Sci., State Comm. for Sci. and Tech., Ministry of Health, Fisheries, etc.	Approval by GOSPLAN and by State Committee for Standards
Research on environmental base of proposed enterprises	Results to GOSPLAN and affected production Ministry	GOSPLAN and GOSSTROI approval of new enterprise design and location
Monitoring of air, lakes, reservoirs, shore areas	Data to enterprise, its Ministry, its Oblast, Council Ministers, GOSPLAN, Ministries of Health, Fisheries, Irrigation and Water Management	Approval of water purification designs by Ministries of Health, Fisheries, Irrigation and Water Management
Warning of excessive pollution	Data to same as above	Ministries of Health, and Irrigation and Water Management can stop production (HMS stops production only on Lake Baikal)
Approval of air purification designs for enterprises	GOSPLAN decides which design to submit to HMS	HMS on ad hoc Comm. on State Comm. for Sci. and Tech. for approvals of TPC
Preparation of environmental aspects of five-year plan	Results to GOSPLAN which coordinates environmental plans received from each of the individual production Ministries.	GOSPLAN approves environmental aspects (Ministry of Irrigation and Water Management prepares water mgt. aspects of five-year plan)

environmental media and the information and approval parts of environmental planning and regulation. Only in the area of Lake Baikal does the HMS play more than an informational role in the water quality area. The environmental quality of the air is the only media with which the HMS has a role in the approval process.

Given the central role of economic incentives, some people in the HMS consider that they must demonstrate that integrating environmental factors in production actually increases the efficiency of the enterprises' operations in order for their information to be wholly adopted [36]. Thus the increase in investment for recycling and purification of wastes would be paid for through the enhanced efficiency of the enterprise. This definition of environment has certain strengths and limitations as noted earlier.

Because no State Committee for Environment exists, the complex array of environmental tasks are split among the HMS and other organizations. Production stoppages and purification design approvals are split among several agencies, including the HMS.

At the TPC level, the HMS plays a broad and significant role in this more local situation. At Bratsk, the HMS is involved in the planning for the Bratsk and the Ust-Ilimsk reservoirs and in the study of their hydrometeorological conditions. Their role at this level is seen from the point of view of economy in that the HMS investigations of reservoirs aid in avoiding losses in natural and environmental resources in the operation and construction of reservoirs.

Also at the TPC level the HMS sees the enterprises as their clientele for monitoring data and forecasts. This relationship allows a mutual confidence to develop so that individual enterprises may voluntarily halt production based on the forecast of impending weather conditions by the HMS. This early warning service allows the enterprise managers to take whatever measures are necessary, including temporarily suspending production, for ensuring the health protection of the local populace and workers.

The Bratsk HMS was established during the construction of the Bratsk hydroelectric power dam. The HMS participated in the planning and design phase of the hydro project for two major reasons: to avoid increased costs which may result from reservoir formation, and to minimize the negative results of water impoundment. With the planned entrapment of 170×10^9 m^3 of water in the Bratsk reservoir, preplanning activities of the Bratsk HMS were extremely important. It was known that climatic conditions would be affected such as changes in wind patterns, shoreline erosion, and the possible formation of swamps. In addition, the initial studies done in relation to the Bratsk reservoir could be used as a research basis for further reservoir development in the Bratsk-Ilimsk Region. The HMS, in conjunction with the geographical institute, was able to determine the limits of the reservoir before impoundment began. This allowed villages and settlements to be relocated and timber in the reservoir to be harvested.

The end result of the preplanning and planning efforts of the Bratsk HMS was the completion of a plan for the Bratsk reservoir. The final plan included forecasts of water conditions done in relation to the various features of individual enterprises. These forecasts included 10 day, monthly, and quarterly conditions. On the basis of the efforts of the Bratsk HMS, plant location decisions were made which included hydrometeorological effects and the types and characteristics of pollution control equipment.

In the case of the BITPC, active coordination between the Bratsk HMS and the timber industrial complex existed for relaying monitoring information. It appeared that an active cooperative effort existed not only in the design stages of the timber complex but also in the operation process.

The Bratsk HMS operates a continuous monitoring service in the Bratsk reservoir and in the Ust-Ilimsk/Bratsk watershed. The monitoring service deals mainly with the water system of the Bratsk reservoir and with the meteorological conditions of the Bratsk area. As regards the water monitoring activities, a series of observation posts are maintained which also include remote telemetry stations at key points.

The HMS has established an emergency warning service for dealing with reservoir conditions which include ice formation, subsurface ice, and imminent storms. The remote stations also provide data dealing with weather and atmospheric conditions. Again, an emergency warning system directly related to individual enterprises exists in which adverse climatic conditions, such as an inversion layer or changes in wind direction, are relayed to plant operators so that plant operations may be curtailed. The HMS has no power to demand curtailment; information is merely transmitted. In the event that the HMS discovers pollutants in excess of allowed pollution levels, either in the reservoir or in the atmosphere, this information is passed to the appropriate enforcing agency, the Ministry of Health, to the relevant production Ministry, to the Council of Ministers, and to the Oblast Executive Committee. The specific pollutant source is determined by the characteristics of the pollutants found. The HMS does not monitor pollution at the discharge point of individual plants as this area is monitored by the Sanitary Service of the Ministry of Health.

The environmental standards against which the HMS measures its pollution readings vary by region. Standards applied in a region depend primarily upon the decision of the nature of its economy and the use to be made of its natural resources. The next important item with respect to applying standards is that of whatever fisheries are present in the region's waters. Of course, public health standards are always a constraint on allowable pollution levels. In general, some mix of industry and fish is decided upon and standards based on local HMS data are set at the national level for that particular region. Then the HMS passes data on to the relevant production Ministry so that it can design the necessary water and air purification equipment to meet whatever standards have been approved for that location. The HMS, however, only approves the air purification technology designs. Thus the environmental standards seem to be set by a specific region and by the specific industry to be located in that region. These standards are then translated into the design of its production and purification technologies. Therefore, HMS monitoring data are important for both plant location and design. When location and design decisions are being taken, the environment is only one aspect of production design and location; therefore, trade-offs undoubtedly occur since the HMS is only an information agency.

Observations on the Monitoring and Control System

Several observations on the monitoring and control system were made to the study group. As these were described, a State Committee for Environment would go far in resolving the problems associated with these observations. Such problems to be resolved would include:

- Industrial emphasis of the environmental data systems;
- Status of a key monitoring and control organization;
- Extreme differentiation of the environment and organizational responsibilities;
- Overlapping of monitoring responsibilities;
- Coordination process between research institutes and monitoring organizations;
- Coordination and data problems with ecological and environmental information on criteria for standard setting and monitoring;
- Possible difficulties with production stoppages for environmental reasons.

Two problems occur with the process of setting design and location standards and deciding on the trade-offs necessary to come to a final decision. The first problem is that this process is an industrial rather than an environmental approach to regional development and planning. The Bratsk HMS clearly identified this problem in its interview. The second problem is the strong and rigid hierarchical arrangement of the Soviet planning system where an environmental organization does not have direct ministerial status and therefore is of lesser rank than the various Ministries representing industrial planning. This problem was corroborated elsewhere [23, p. 165]. In this pattern of hierarchical arrangement the subordination of one unit to another is the overriding principle of interest rather than the content or concern of the subordinated unit. To offset this hierarchical rigidity is the coordination system of the Soviets at the various planning and operational levels.

The standards set for the environmental media of air, water and land are so finely divided that monitoring can become disjointed and hence rendered more complex. Again the local Soviet is to coordinate this information. However, the splintering of responsibilities over the environmental media among the many organizations creates both overlap and gaps in the monitoring process. For example, although the water regime has several agencies involved in monitoring and setting of standards, there is no one organization concerned with the aesthetic aspects of the landscape.

Coordination between the monitoring agencies and research institutes is also done through the local Soviet. Because of the nature of the monitoring process in the control of environmental violations, a research link is vital to success in widening the scope and understanding of environmental pollutants and media. Detection instruments and new pollutants are also important research areas to be relayed to monitoring units as well as researchers understanding and contributing to the monitoring process.

Finally, every organization interviewed noted that if environmental violations occur it is really a simple process to halt production until the problem is solved. It is difficult to give complete credibility to this posture when the experience and literature elsewhere are taken into account. In addition, knowledge of how organizations behave would tend to cast doubt on the ease with which production could be halted, regardless of where it is located. How nonproduction pollutants were halted was not discussed. Observations on the monitoring and control system in the USSR indicate that this system is evolving. Environmental factors are of increasing concern to many different organizations and administrative levels. Therefore, it can be expected that greater emphasis and status will be given to the environment in the future, especially if a State Committee for Environment is formed.

CONCLUDING OBSERVATIONS AND RECOMMENDATIONS

These concluding statements are based on impressions gained by the study group from its three weeks experience in the USSR. Naturally, many of these statements and findings are subjective in nature.

After the completion of this study including interviews, research, and writing, the difficulty of doing complete justice to this study has been emphasized. The key role of the interviews as the basic information source has made this effort both enjoyable and frustrating. It is enjoyable for having been able to meet many dedicated people and to observe firsthand many of the actual things being discussed. On the other hand, frustration was present in attempting to learn both past and present criteria and decisions as well as following up on many of the interesting comments and leads suggested or opened during the discussions. Over all, however, the interview sessions proved illuminating and stimulating to further research in this area.

All members of the environmental research group concurred that environmental factors do appear to be integrated in each of the five phases used in this paper to classify the organizations interviewed. For example, integration of environment in regional development occurs in the following ways:

- *Research:* environmental base studies are conducted for aiding in the design and location of productive enterprises.

- *Modeling:* environmental-economic models are constructed for constraining economic optima for enterprise location.

- *Planning:* environmental aspects are integrated via preplanning in the design and location of enterprises.

- *Operations:* waste treatment and recycling processes are included in enterprises.

- *Monitoring:* environmental information is linked to planning and operation of enterprises.

Thus, the major finding of this study is that *the Soviet Government attempts to integrate environmental factors in regional development programs or TPCs*. These integration attempts have been described to us in varying degrees of detail and from a variety of Soviet sources. Of course, this study has emphasized *process* rather than *performance* as noted in the introduction because of the nature and limitations of the study.

There are some precepts created by the Soviet Government's approach which would be useful for other countries to consider for possible application. These items include the following:

- Environment is integrated at important stages of the development process from pre- to post-development;

- Environmental research and assessment begins even before the proposal is completely defined;

- Environmental factors are integral to a comprehensive location decision;

- The environmental assessment process is initiatory rather than responsive (except at the local level);
- The planning structure allows for comprehensiveness in the planning for industrial-environmental factors;
- Environmental factors are determined at the local level with research inputs as required.

These items were selected for presentation here on the basis of the Study Team's observation of what might be of interest to other countries and regions. Of course, any of the points mentioned could be of interest to others based upon their preferences and problems faced. The Study Team agreed, however, that given the common interests, problems, and analyses of the USSR, there is a basis for common understanding and working together on an international basis.

The question of the quality of the integration process remains. Integrating environment in development has been uneven and limited because of the very character of the development process. Since we stressed in the introduction that one goal of this paper is to strengthen the integration of environmental factors in development planning, the sections that follow are written for this purpose. Their intention is not to be interpreted purely as criticism but as aids to better planning.

<u>General Problems in Integrating Environment</u>*

It should not be necessary to elaborate on each of the points listed because they were discussed in earlier sections of this paper. Therefore, only the basic points are noted for brevity as a summary and economy of effort on the part of both readers and writers:

- *No separate comprehensive environmental planning system;*
- *Environment is viewed as a constraint on the economy at higher levels and not as an opportunity to be pursued;*
- *Environment is defined primarily in economic terms at the higher level;*

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*In this and the following sections the views expressed here are solely those of the authors. Our Soviet colleagues may or may not agree with these views. In the views noted, all of the limitations mentioned in the introduction should be borne in mind, particularly that of representativeness of the data base, familiarity with the system, and the length of the study time.

- *Some of the key environment planning aspects are ad hoc;*

- *Environmental factors are splintered among many organizations.*

These five general problems seem to pervade all five aspects of the environmental management process as it interfaces with the development process. Each of these problems has been discussed previously but a few remarks here may expand their meaning.

The main problem with the process of integrating environmental factors is the lack of a separate cohesive and comprehensive source for environmental management aspects of development. While each of the environmental functions of research, modeling, preplanning, operations, and monitoring are represented in the development process, there is an overall development bias to this approach. Each environmental function at the higher levels of planning occurs within an industrial context which remains the basic integrating factor for these environmental factors. The consequences of an industrial development planning approach at these higher levels is that environmental functions remain splintered among separate committees, services, Ministries, Soviets, and institutes. No counterbalance to this development approach at the State level can exist if environmental facets remain splintered in such a strong and mature development planning structure. This point is not to criticize or ignore the current institutes, Soviets, committees, etc., that now deal with environmental factors. It merely acknowledges the great complexities and intricacies that now exist in environmental planning and management.

By viewing environment as a constraint on the economy rather than as an occasion to re-orient the approach to planning a great opportunity may be missed. The basic nature of environmental factors and the attention being given to them have provided an unparalleled occasion for changing the planning process. Approaches to environment in the planning system can either perceive it as something prescriptive to tidy up spillovers from the economic system without considering basic changes to that system, or environment can be promoted as an overriding principle that allows the planning system to be restructured along broader lines of interest.

Environment can be viewed in many different ways. Even within the economic view there is a range of perceptions from no-growth to constrained growth. No evidence was found that any other image was being discussed than that of a growth orientation. Environment can be viewed from a host of images such as aesthetic, consumptive conservation, access, nature, art, social, ancestral, and scientific as well as a factor of production. To emphasize the one perception at the expense of others can be significant given the opportunities present. Viewing the environment from the basic concept of economic efficiency places a bias on research, modeling, and planning efforts. For example, why simply maximize efficiency when other maximands are available such as maximizing environmental stability or human longevity? Both of these maximands might yield greater returns in the long run than merely minimizing costs for the sake of promoting only efficiency. Multiobjective planning can be used to allow both economic efficiency and environmental quality to be considered simultaneously in the planning system.*

Ad hoc planning processes for environmental factors can have a reduced impact on a planning system with a strong economic orientation, particularly at the regional and the local levels where local expertise and experience are vital for ensuring the success of projects with major potential environmental impacts. On the other hand, ad hoc adherents did play the major role in helping to halt the pollution of Lake Baikal [23, p. 176]. The problem with depending solely on an ad hoc response to environmental aspects of development is both to miss environmental planning opportunities and to overlook environmental factors in development planning.

Splintering environmental functions among a variety of administrative organs dividing the environment into many parts each under a different jurisdiction sets the stage for needless complexity, conflict, and, more important, gaps in environmental protection. An environmental advocate is needed to unify the disparate parts of the environmental program into a central environmental management system. A major undertaking of this kind can only be done by creating a central environmental ministry or committee at the State level to articulate environmental goals and to create the process to support them through a planning structure at each jurisdictional level. The Soviet Government recognizes this problem and discussions are currently being conducted on this topic.

Specific Problems in Integrating Environment

The problems listed in this section are important and follow from the above more general problems. These areas of concern are as follows:

- Many key successes of environmental integration appear to have been more from individual concern at local and regional levels rather than from the character and structure of the upper level planning system;

- Formal linkages do not seem to exist for connecting research institutes with monitoring organizations and operating enterprises;

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*Some consideration is being given to enlarging the impact of environmental integration on the economic system although at a more theoretical level. See [27].

- Design institutes are physically separated from operating sites which makes local environmental factors difficult to perceive;

- Lack of environmental and ecological indicators in the operational incentive structure and in the standards structure mean environment remains less integrated;

- Shifting polluting industries to areas of less population is still a concentration problem;

- Environmental research and modeling directions appear affected by planners viewing environment as a constraint.

Given the personal dedication of scientists and planners at research institutes such as those in Irkutsk and at Lake Baikal, it is readily seen that environment is of concern in the Angara River Basin. How environment has fared elsewhere in the USSR is not known by our study group. One observation is that the planning system does not appear to give adequate credence to environment without intervention on an ad hoc basis via personal, local or oblast committee strength from the area affected. This observation only supports the need for a central environmental advocate with regional environmental representation at all levels.

From the interviews it was not clear what links, if any, exist between research institutes and the operating and monitoring phases. The operating enterprises can be the source of much feedback to research institutes for directing their efforts to problems of practical importance. Also, monitoring organizations seem to lack a feedback loop to the research institutes for aiding in practical monitoring problems, even though such agencies have their own research areas.

The vast distance of design institutes from the areas being designed for is a major problem from the environmental point of view. It would appear preferable to develop a Siberian design institute with local branches throughout Siberia just as a Siberian Branch of the USSR Academy of Sciences and the Bratskgesstroi were developed.

The indicators used to judge the economic performance of productive enterprises have played an important role in enhancing the efficiency of these units. To include environmental indicators in this set would also be an important step in integrating environment at the crucial operational level. The environmental standards now used are external to the operation of the unit. In addition, these standards do not at present contain elements based on environmental and ecological factors but rather emphasize public health.

The impetus to shift industry to Siberia is to take advantage of the energy and natural resources there. At the same time this shift allows potentially high polluters, along with their associated secondary industries, to be located in Siberia. Even though this Region has a low population density, there are regional industrial concentrations and combinations that can make living conditions in the area more difficult. No regional environmental models seem to have been employed to investigate this problem.

Finally, if at the top level of Government environment is emphasized as a constraint, then the research and modeling efforts of scientists can be constrained as well. A wider scope for regional environmental research is important for learning of environmental opportunities present and their optimal environmental uses.

Recommendations

The above concluding observations can add an important contribution to the existing strengths of the Soviet Government's approach to environment through setting the stage for the recommendations that follow. These recommendations may not meet all of the problems noted, but they should help to overcome many of the major ones. Such recommendations include:

- *Creation of a State Environmental Committee to take a lead role in creating and guiding a separate cohesive and comprehensive environmental planning structure with strong local and regional inputs;*

- *Creation of an environmental research institute based on an interdisciplinary core with multidisciplinary support for linkages at all levels with the above planning structure;*

- *Development of an overall technological assessment systems capability for taking a broad applied systems approach to large-scale development programs with massive regional impacts;*

- *Development of a broad and practical research study program for supporting economic development planning and research institutes.*

Figure 11 shows both (a) the existing system as it is understood from the interviews and (b) how a more integrated system would appear. A formal separate and comprehensive environmental planning advocate at the center of the State planning system could integrate the current disparate environmental elements and further integrate this environmental system in regional development programs, including TPCs. On the other hand, it could be another layer of bureaucracy. On the assumption that it would be

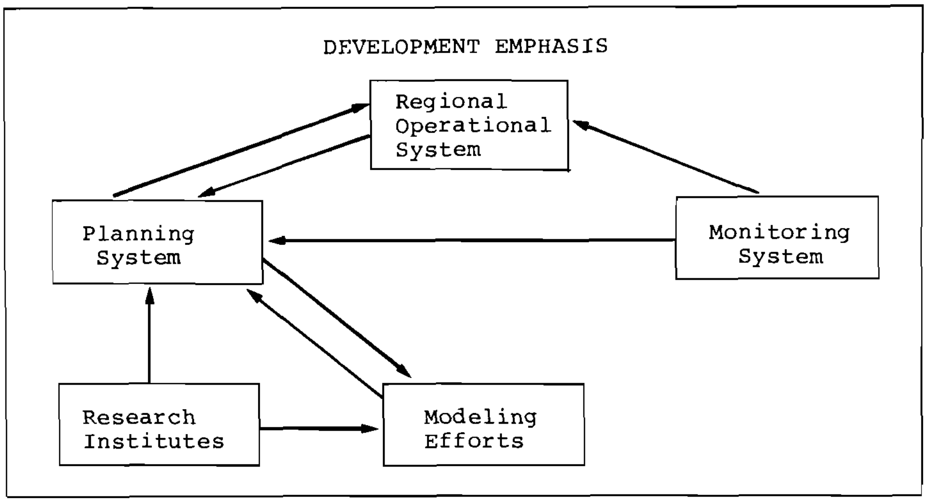

Figure 11a. Environmental management system as presently organized and linked together.

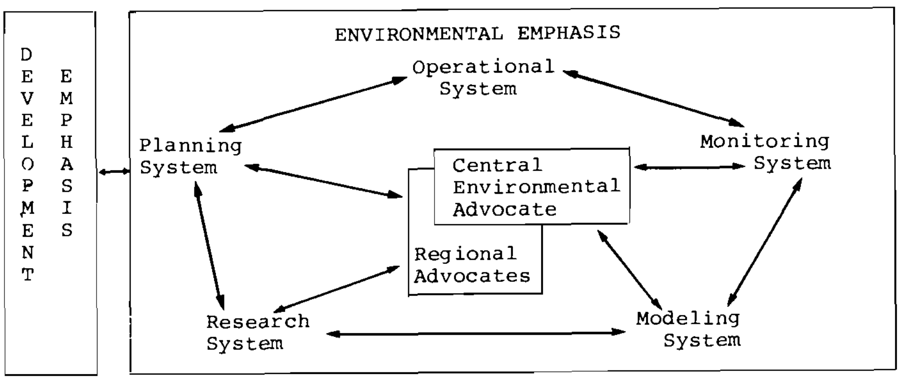

Figure 11b. Environmental management system based on a core environmental agency linked to regional agencies.

effective we support those in the USSR who are working for a central environmental management system capable of taking a wide systems approach to the environment.

A coordinated environmental management system at the State level would not only strengthen the development planning process but would also aid the regional or TPC level. One major difficulty in the development and operation of the TPC is the lack of an overall planning and management capability. Should this capability be created along with a strong well-integrated environmental component, then many of the environmental problems would be even further reduced. Environmental problems can only be alleviated if the will to do so exists. Simply creating a planning and management organization would not suffice. To be effective an organization must interpret policy, monitor performance, and enforce its findings.

Figure 12 shows how the existing environmental coordination system is perceived to function. In this system the local Soviet plays the key role by merging and interpreting varied environmental information from a variety of bodies including research institutes, enterprises and various Ministries, and HMS. This approach implies severe difficulties in the organization, interpretation, and reconciliation of disparate environmental information splintered among many different sources.

In a possible recommended approach a new cohesive and comprehensive environmental management system would be imbedded in a separate planning structure to counterbalance the existing economic development planning structure. This new environmental structure would bolster the local and oblast Soviets in their environmental responsibilities as well as provide a central and coordinated system at the state level. As a research support system for this new environmental planning structure a new interdisciplinary and multidisciplinary research institute is suggested. This institute is described below. It would be designed to interface with other research institutes as well as with the environmental planning system and the soviets. Its functions would be similar to those of CEMI and SOPS with respect to GOSPLAN, but would be much expanded.

To support such an environmental planning structure with planning committees at each jurisdictional level, a comprehensive research and teaching arm should be created and funded. This research and teaching institute should have the following characteristics:

- An initial multidisciplinary core staff with a goal of becoming integrated in an interdisciplinary core staff;

- A core interdisciplinary staff with multidisciplinary support staff who also act as liaison with their respective disciplinary institutes;

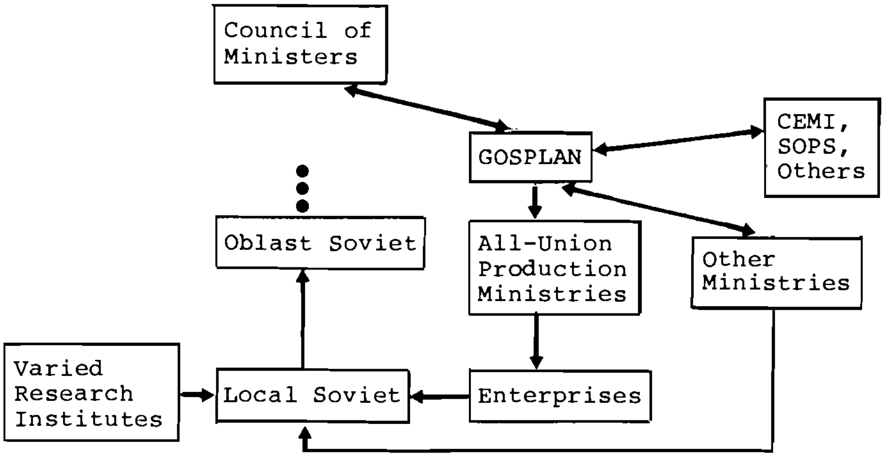

Figure 12a. Environmental coordination system as presently organized and linked together.

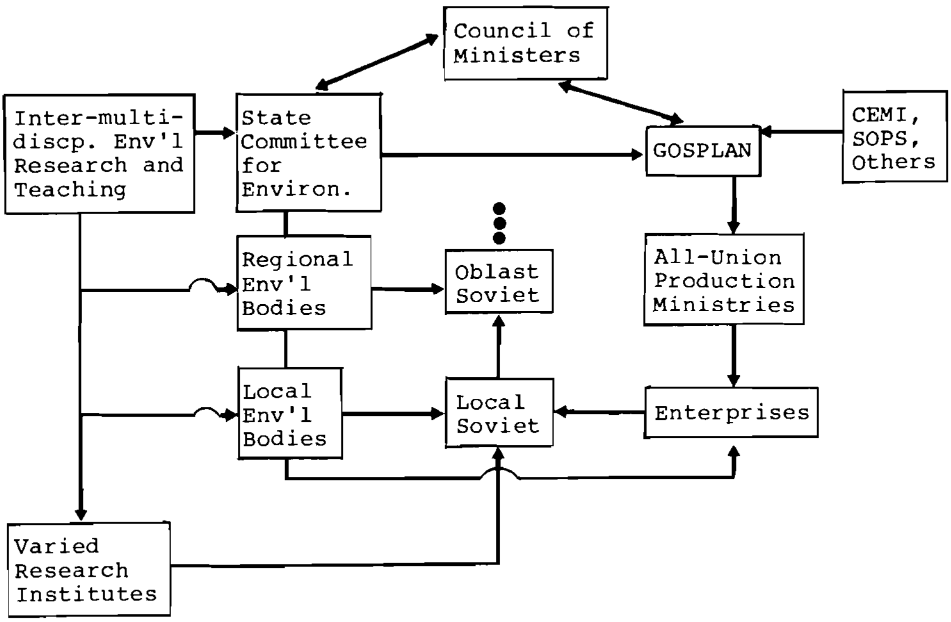

Figure 12b. Possible environmental coordination system based on a core environmental planning structure.

- A lead position with regard to defining, supporting, and coordinating environmental research tasks;

- A regular liaison staff to communicate research results to environmental and development planning committees;

- Temporary assignments of core and support staff to development planning committees and institutes and vice versa for knowledge transfer;

- A regular advisory board of Soviets selected from all jurisdictional levels to ensure a two-way flow of practical considerations to the staff and educational experiences for the Soviets;

- A regular advisory role on research projects for all other research institutes that undertake specialized environmental research tasks;

- A regular advisory role for the different levels of Soviets for commenting on planning for regional environments and on modifying development proposals;

- An educational program for communicating and teaching the interdisciplinary approach in an environmental systems context to practitioners and students.

Such characteristics would combine strengths of universities, public research institutes, consulting firms and government agencies into one organization for supporting an environmental planning structure. Cross-linkages at all planning, research, and political levels should ensure that this institute be of major assistance in creating, shaping, and protecting the varied environments in the USSR.

Comprehensive assessments are important. They should include information about a wide number of issues such as technological, environmental, economic, social, and political antecedents and consequences related to development activities. While viewing the effects of actions in the short, medium and longer terms, they should be anticipatory, flexible, wide-ranging and on-going as a set scanning activities. They should be structured to permit all those involved in the planning and implementation of programs, including those who will be affected, a meaningful role in the identification and evaluation of programs, options, and impacts.

The wide array of potential actors in regional development, each with varied objectives and interests, clearly demonstrates the need for an overall assessment coordination capability. These actors include such diverse groups as: the raw materials and fuels industry, support industries, manufacturing industries, state production Ministries and advisory bodies, oblasts and oblast departments, cities and districts, universities, research institutes, foreign financiers, regulatory bodies, international businesses, and environmentalists. Each of these potential actors interacts or fails to interact in various ways with others in the system. The actor, information and decision strategies vis-à-vis other actors raise issues that can affect both the decisionmaking system and the substantive issues or impacts generated by those strategies.

Should an overall assessment capability be created, many of the deficiencies mentioned previously in the present analysis could be rectified through its scanning process. This change does not imply that conflicts, competition and variations in preferences would be eliminated. Rather, participation by all interests, improvements in the flow and quality of information, identification of opportunities and consequences, and the evaluation of underlying assumptions of regional development goals would be enhanced. Trade-offs would be illuminated and effectively communicated. Coordinated and integrated planning would occur more efficiently through such wide-ranging interchanges. The proposed environmental and research structures comprise one set of activities for achieving this broad assessment capability.

Finally, a long-range environmental research program independent of development proposals should be created. This program should go beyond the more fundamental physical-biological-chemical research which is currently being conducted in various scientific research institutes. Rather the foci of this research should consider the interface between society and the environment, especially the kinds of information inputs necessary to provide a basis for successful developments with minimal adverse impacts, and a successful management program for handling such impacts. Some on-going research programs with such goals might include:

- Development of a diverse set of ecological-environmental-social indicators for defining, measuring and classifying the dynamics of environmental quality;

- Development of a program involving managerial and social preference and behaviors as they interact with the environment;

- Determination of the parameters and variables of an applied environmental systems analysis framework;

- Development of an environmental futures approach for providing a technology assessment capability for decisionmaking;

- Development of a framework for assessing institutional behaviors in an overall decisionmaking context for a given technology or region.

Many other such research projects could be suggested. The important point to note is that each of the above projects is comprehensive and of particular importance for integration in a development context. Such research can cover the dynamics of development at the interface with the dynamics of the environment.

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Energy Supply Systems

This paper deals with the energy supply system (ESS) of the Bratsk-Ilimsk Territorial Production Complex (BITPC), and its place in the development of the Siberian Joint Electric Power System (JEPS). First, there is a review of the general concepts of planning and management of ESSs in the Soviet Union. Two IIASA publications are of special interest here since they deal, inter alia, with the ESS and water resources of the BITPC and the country as a whole [4,14]. These publications provide information on the formation of the ESS in the BITPC, and on how energy is being utilized according to hierarchical planning and allocation procedures, in line with directives and guidelines of the national economic planning system of the USSR.

BASIC APPROACH TO ESSs IN THE USSR

The centralized planning system of the USSR has developed a comprehensive approach to ESSs which treats an ESS as a combination of industries contributing to the overall needs of society. Energy resources of a region are not isolated from the overall energy needs of the society as a whole; each energy resource contributes to the total development of the national economy of the USSR, according to the extent and criteria of national economic planning.

Figure 1 shows the hierarchy of the general ESS of the Soviet Union according to territorial and branch levels, and in terms of the five main power sources: coal, oil, gas, electricity, and nuclear. The hierarchical components are connected vertically and horizontally in order to ensure that energy resources are considered in their entirety, and are not isolated from the requirements of the country and the economic regions.

Figure 2 gives the general organizational scheme for ESS planning. Planning of ESSs is organized mainly by branch but also by territory. Ultimate coordination is the responsibility of GOSPLAN in conjunction with the Fuel and Power Ministries. (This subject has been discussed in detail in [4].)

ESS MODELING

Models are extensively used at all phases of planning and management of ESSs in the Soviet Union. The accepted view on ESS modeling may be expressed by the following principles:

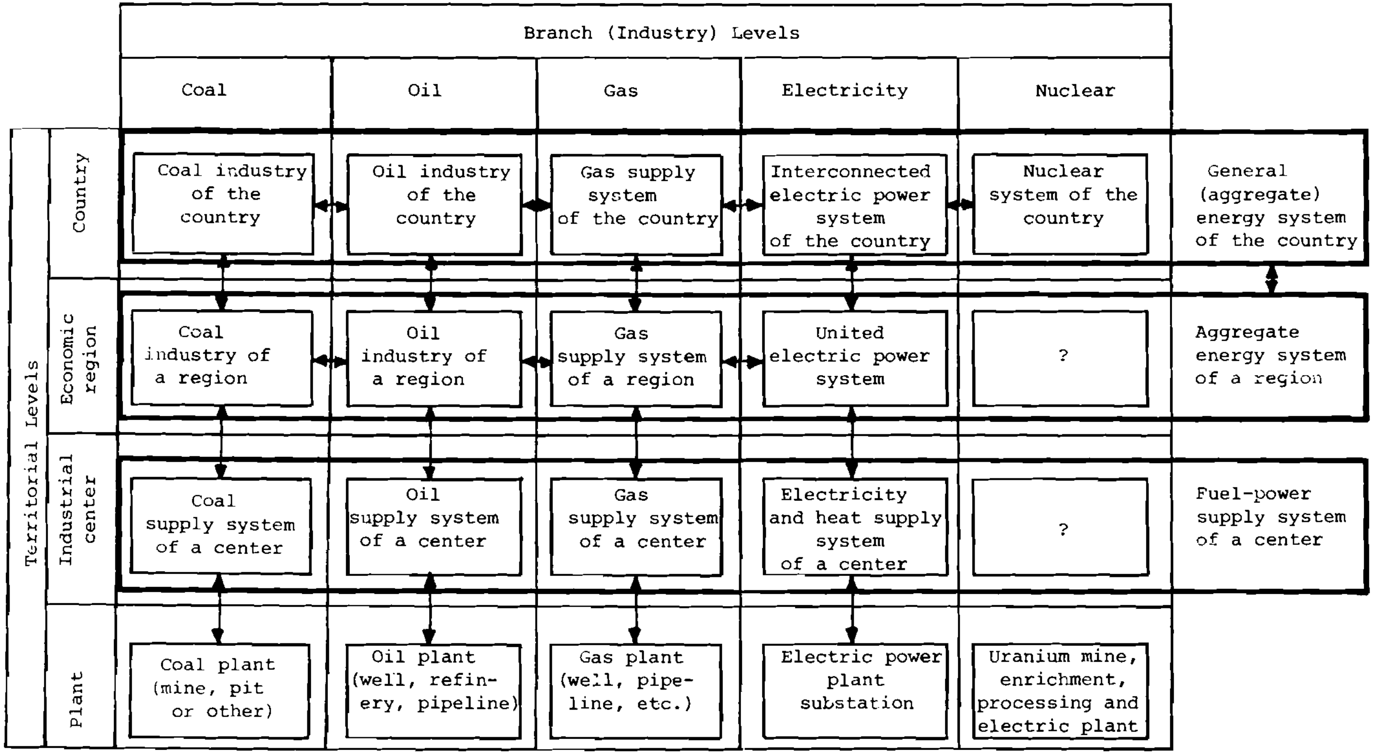

Figure 1. Hierarchy of the general energy supply system of the Soviet Union.

Source: [4]

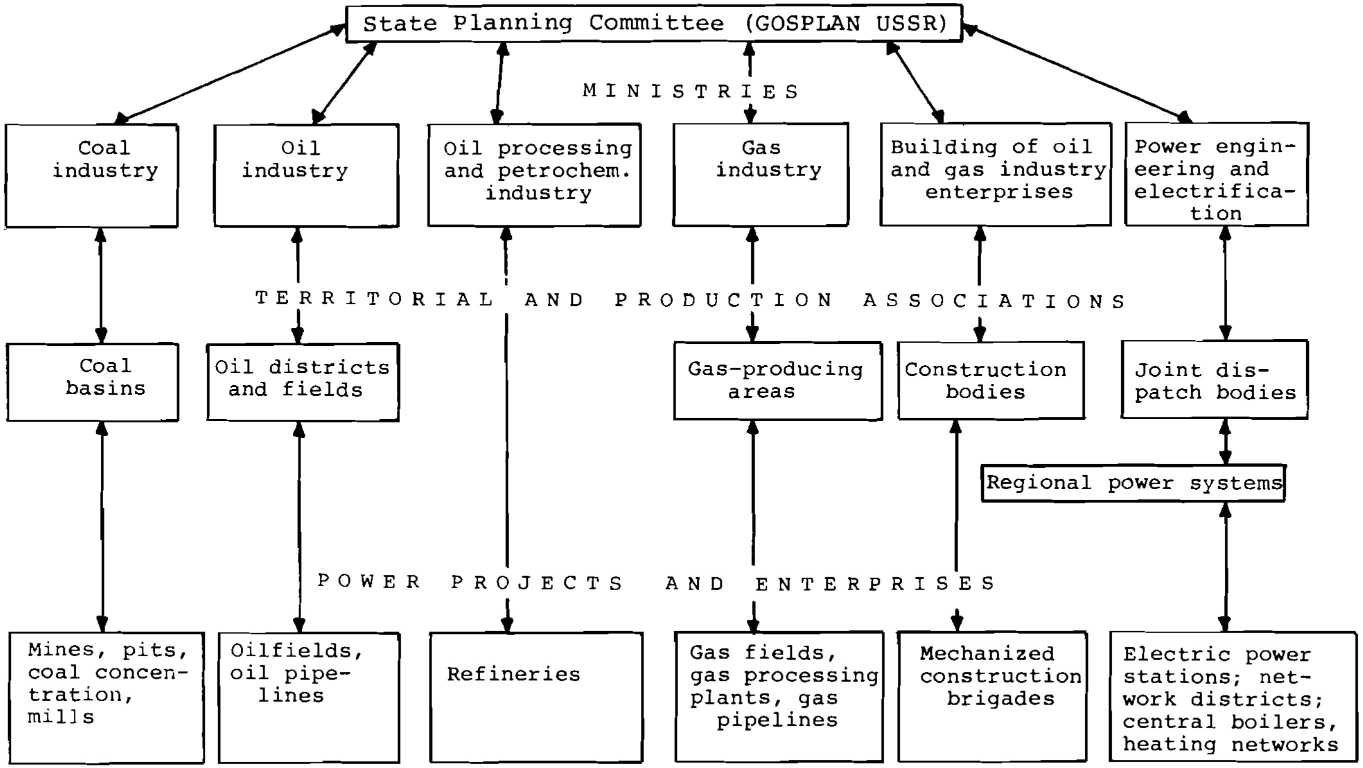

Figure 2. Aggregate scheme of organization for ESS planning in the USSR.

Source: [4]

- Principle 1: While mathematical models are necessary and useful, they are basically tools for investigating trends and means for ESS development and as decision aids for policymakers.

- Principle 2: The composition, type, and basic characteristics of a model are determined by the nature of the problem and by the organizational structure of management. That is, a set or a system of models is required whose structure corresponds to that of the hierarchy of the major ESSs and their optimization tasks (Figure 3).

- Principle 3: ESS models should be differentiated according to planning stages. This differentiation includes block composition relating to power production facilities and the degree of specificity. This is essential because of differences among the tasks being treated and the need to use simplified models for long-term projections where input data may contain major error characteristics.

These three principles are the underlying guidelines for the use of ESS models in the Soviet Union. The study group visited the Central Economic Mathematical Institute (CEMI) of the USSR Academy of Sciences in Moscow, the Institute of Economics and Industrial Engineering (IEOIP), and the Siberian Power Institute (SPI), both of the Siberian Branch of the USSR Academy of Sciences. Here we were introduced to a set of models covering all levels of the above hierarchy. (See also [7,12,13,15,19,20,22,23,27].)

ENERGY DEMAND

The general ESS of the country has the task of satisfying demand for various kinds of fuel and energy carriers--one of the principal variables linking both the general models (national and regional) and the specialized models with societal development. The needs for energy carriers are estimated in two different ways. One is the extrapolation of current growth trends, using some relationships between energy demand and various macroeconomic indicators. The other is based on process analysis; when based on the perspective of development of the consuming sectors, a normative approach is used for estimating energy demand. Account having been taken of the strengths and weaknesses of each of the approaches to estimating energy demand, a method combining both has been developed in the Soviet Union [4,28]. Its core is the second approach, which serves to estimate the main part of energy demand; the remaining (so-called unnormed) energy consumption is projected by extrapolation.

Three kinds of problems arise in this kind of estimation: the right proportion between computation and extrapolation, the forecasting of the norms for energy consumption, and the choice of the kind of fuel or power for a consumer.

	Country	Economic Region	Industrial Center	Plant
General (aggregate) energy systems	Complex of models for optimization of the general energy system of the country	Models for optimization of regional general energy systems	Models for optimization of energy supply systems of industrial centers	-
Branch energy systems	Models for optimization of the country's systems. - electric power - gas supply - oil supply - coal industry - nuclear industry	Models for optimization of branch regional energy systems	Models for optimization of systems of industrial centers: - electric power supply - heat supply - fuel supply	Models for optimization of equipment and technological schemes of individual plants

Figure 3. Classification of energy models.

Source: [4]

The selection of a group of sectors and products whose energy needs must be estimated according to the consumption norms of energy carriers is usually made by listing the most power-intensive products (or the most representative products involving a long chain of intermediate products). Here a compromise is sought between minimizing the list of products and covering the largest possible share of the economy's energy demand on the basis of this list. Table 1 indicates the method now used for estimating energy carrier needs. It can be used to compute up to 80 percent of the demand for electricity and heat and about 90 percent of the demand for fuel

To estimate the demand for *electricity*, approximately 40 industrial products are considered. From these the electricity consumption in the light and the food industries is assessed according to gross output; machine-building consumption is determined on the basis of the energy needed for machine-tool operations and the heat needed for thermal treatment (including smelting and heating) of metal products. For the industry as a whole, the norm-based computation gives up to 70 percent of the total consumption.

For other sectors of the economy (e.g., transportation, public utilities and services, agriculture), electricity needs are estimated according to the applications and processes indicated in Table 1; this practically excludes any significant unnormed electricity consumption.

To estimate the industrial demand for heat, 27 products (Table 1) are considered; they consume up to 65 percent of the total industrial heat consumption. Heat for heating and ventilation in houses and public utilities is calculated on the bases of housing standards, the heat-engineering characteristics of buildings, and the temperature in various regions. Heat needed for the supply of hot water is assessed according to projected requirements for this kind of utility.

The demand for *fuels* used directly by consumers is determined from its several uses: e.g., in industrial furnaces and technological installations; in small heating units serving the needs of these installations. For other uses, the rated share is even higher. In the estimation of fuel consumption in the Soviet economy as a whole, the normed share is about 90 percent.

Using this set of products and services, the computation method can determine a large share of the overall demand for energy carriers. Since there are also norms for determining the total fuel expended on electricity, steam and hot water, the total share of the normed part in the overall demand for energy resources can be up to 85 percent.

Selecting a representative list of indicators of the development of the various economic sectors is one way of enhancing the accuracy of the computation method. Another is to correctly

Table 1. Number of products covered by energy demand calculation and their share in the total consumption of energy carriers.

Source: [4]

Economy Sector	Electricity		Steam and Hot Water		Fuels	
	Number of products and services	Normed consumption (%)	Number of products and services	Rated consumption (%)	Number of products and services	Normed consumption (%)
Industry (whole):	41	66-70	27	50-65	32	85
Fuel industries	3	95	3	80	1	99
Ferrous metals	10	70	6	42	10	99
Nonferrous metals	8	80	4	33	7	90
Chemistry	10	55	8	55	4	95
Paper and pulp	4	40	3	45	-	-
Building materials	2	60	1	55	4	90
Machine building	2	80	-	-	1	95
Light industries	1	100	1	100	-	-
Food industries	1	100	1	100	5	75
Transport:	4	88	-	-	4	95
Domestic sector and services	7	100	7	100	4	100
Farming	11	100	11	100	5	90
Total for economy	63	75-80	45	68-78	45	90

predict the consumption norms of energy carriers. Since the kind of energy carrier and its consumption norms depend directly on the kind of manufacturing techniques for a given product, it is essential to take into account such factors as the unit equipment capacity, the technological progress, the quality of the raw materials, and the climate in the region. To predict norms, it is essential to have planning experience, information on projects for new technologies, and expert assessments of technological progress. These are important factors for formulating energy policy.

Usually, the choice of the kind of fuel or power for a consumer involves a comparison of the alternative schemes for supplying energy and for optimizing energy supply sources, with systems for energy transport and distribution. Existing strong feedbacks are extremely important for these interlinked calculations. Basically, this means that in making calculations to compare the competitive energy carriers, one must know the costs of extraction (production) and distribution of all kinds of fuel and power. However, these costs greatly depend on the integrated results of the choice of energy carriers. This problem is overcome by using special indicators--marginal values (or expenditures) of fuel and power--for selecting energy carriers, optimizing energy supply schemes, and solving other specific energy problems. The marginal values of fuel and electricity are a set of interlocked unit economic indicators representing an increase in the total expenditure of the national economy for the additional demand for these kinds of fuel and power in different regions. Marginal values are formed with regard to the different mining and geological conditions, location, and the quality of the fuel. They have been worked out and officially established in the USSR [10].

EXTERNAL PRODUCTION RELATIONS OF THE GENERAL ESS

The ESS consumes products and services from many other production sectors. If related branches of the economy are not developed sufficiently, they can considerably affect the production rate of efficient energy resources. The examination of the complex's external relations is important not only for identifying the required development of related branches but also for determining constraints on the development of the ESS. This is also important in decisionmaking for the development of the ESS.

For a quantitative evaluation of the direct and indirect relations of the ESS with other sectors, a special multisectorial dynamic model has been developed at the SPI. The model [11] was presented by Dr. Yu. Kononov at the IIASA conference on the Bratsk-Ilimsk experience. Here we will mention only some characteristics of the model and the set of industries and products included in it.

The model covers explicitly the construction lags and the distribution of material expenditures during the construction period. For a given ESS development alternative, the model approximates the following requirements for implementing the alternative:

- Volume of various industrial products, amount of construction and mounting works, and transportation turnover (considering indirect as well as direct relations);

- Required capacities commissioned in related branches, with dates and priorities of this commissioning;

- Demands of related branches for additional capital and labor.

These additional investment and labor requirements have to be added to the direct expenditures for ESS development; they are an added objective when the final choice for ESS development alternatives is made.

Quantifications of the complex's external relations take into consideration only those sectors and industries of the economy that strongly react to the fuel and power production pattern and growth rate and consume a large amount of the economy's resources. What is sought is not a plan for developing the related branches, but one for measuring their response (extra output and commissioned capacities) to a given change in the production and consumption dynamics of a specific kind of energy.

Such a statement enables external relations to be estimated, even when no detailed plan for the development of the related branches is known. Since only a part of their production is considered, constraints on the existing capacities cannot be incorporated in the model, because the proportion of these capacities serving to develop energy production through direct and indirect ties is not known in advance. Without these constraints, it is impossible to immediately determine from the model's solution whether the given alternative can be implemented. Additional analysis outside the framework of the model is required.

A study of the intersectorial balance model [16] has identified the set of industries and products which depend considerably on the optimization results for the general ESS of the Soviet Union (Table 2).

Table 2. Industries and products included in the intersectorial balance model of the production relations of the ESS of the USSR.

Source: [4]

Economy Sector	Number of Products
Industry as a whole namely:	56
Ferrous metals	10
Nonferrous metals	6
Building materials	6
Power machines	5
Machines for the fuel industries	8
Electrical engineering	5
Machines for metallurgy	5
Other machine-building industries	11
Construction	2
Transportation	2
Total	60

Regional Energy Models in the Modeling of Regional and TPC Development

The models of ESSs in different hierarchical levels and the modeling of external relations presented above are used in the planning and management of the ESS of the Soviet Union. In this hierarchy, the ESSs of the territorial production complexes (TPCs) are a part of the regional ESSs. The regional energy models, which take into account the amount of fuel of interregional importance and the marginal values of fuel and electricity for the region, optimize the ESS of the region (i.e., production and consumption of local fuels and secondary energy intraregional energy links, allocation of power carriers, and consumption). But, in order to optimize all opportunities for the territorial organization of the productive forces, the optimal exploitation of natural and human resources, and the building of a rational infrastructure, it is necessary at this level to assume a complex approach to modeling the relations of the energy complex within the regional and the TPC economy. This is of particular importance to the new TPCs and to the BITPC. It is felt that the best methodological solution to this problem can be found in the work of the IEOIP [1,2,3]. According to the approach of IEOIP, the modeling of the productive forces of an economic region and its parts is done in two interrelated stages. In the first stage, the production pattern is examined; in the second stage, the spatial pattern of the economy of a large economic region and its parts is analyzed (Figure 4).

The task of the first stage is to identify the best alternative for the production pattern, for the distribution and the utilization of multipurpose resources of the region, and for the development of elements of the production and social infrastructure, provided that the region fulfills its quota of deliveries of specialized industries' products, meets the living standards requirements, and observes the introduced restraints. Initial data for the first stage may be found in the solutions to national scale problems, which involve the use of intersectorial interregional and sectorial models. The production pattern of an economic region is studied in two substages. First, the region's economy is analyzed as a whole and then individual intraregional intersectorial complex problems (programs) are examined.

The tasks of the second stage are to shape the main intraregional TPC, to define their place in the inter- and intraregional labor division, to identify the best alternatives for utilizing resources and for improving the structure, mutual relations, and spatial organization of all elements of the economy. A logical scheme involving a group of models for TPC formation optimization is proposed. The approach is based on the principle of stepwise, element-wise analysis of the components of a region's economy and involves a gradual transition from the solution of general problems to special ones that includes the problem of forming big TPCs in an economic region to problems of developing and locating individual elements of the economy and territorial subdivisions of each TPC--intensive development zones (IDZs) and industrial centers (ICs) (Table 3). Production, infrastructure, resources, and forms of the territorial organization of production are analyzed at all substages.

We will not go into detail about the models and their relationships. Nevertheless, the following points are made about the place of specialization industries in this group of models.

The national production sphere of every TPC consists of groups of specialization industries and of competing productive activities as well as infrastructural elements. Specialization industries could be divided into interregional and intraregional ones. The interregional industries determine the place of a TPC in the regional and national economy. For example the ESS, together with the aluminium and the wood industries, is one of the three interregional industries of the BITPC. (The place of the BITPC ESS in the ESS of Siberia and in the BITPC development will be discussed later in this paper.)

The pattern of development of interregional specialization industries is determined mainly by national sectorial models.

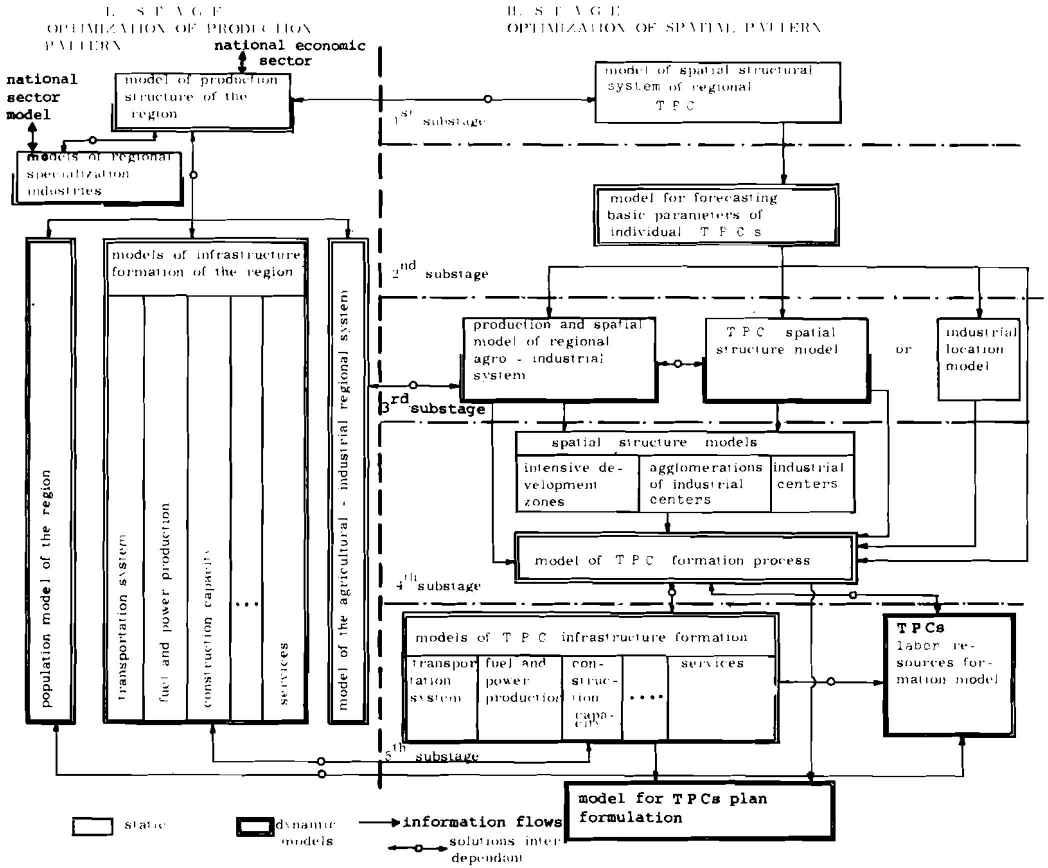

Figure 4. The scheme of optimization of regional economic pattern.

Source: [9], 282.

Table 3. Sequence and content of optimization stages of the spatial economic pattern of an economic region.

Source: [9]

		Regional Economic Pattern
Variants of location of production sectors	First stage	Location of regional specialization units and elements of interregional and regional infrastructure. Determination of layout of TPC and of isolated large industrial centers and their specialization.
Conditions of development of local resources	Second stage	Specification of pattern, analysis of time variants of formation. Determination of main parameters of each TPC.
	Third stage	Location of all the elements of the economy and population within each TPC. Determination of the layout of intracomplex industrial centers and zones of intensive development of agriculture and their specialization.
Level of development and spatial distribution of production in basic year	Fourth stage	Location of all elements of the economy and population by subunits of intracomplex industrial centers. Determining the functional zoning layout of the territory of intracomplex industrial centers and the population settling.
	Fifth stage	Determination of the variant of formation of TPCs as a whole. Determination of the variant of formation of individual elements of the TPC economy. Determination of the variant of TPC creation plan.

Regional and TPC modeling is essential for the effective concentration, combination and location of production processes, for the optimization of national and human resources, and for the creation of a modern infrastructure. This fact should be borne in mind in determining procedures for the coordination of sectorial and TPC models for improving the system of planning of the national economy.

The methodology of modeling the TPC development is in the experimental stage. Within the group of models there is no experience with the strict coordination of solutions achieved by using these models, nor is there experience with strict procedures for connecting the group of models for regional (and TPC) development and the system of national economic planning. Furthermore, the planning of TPC development is not yet officially included in the system of planning of the national economy.

AUTOMATED INFORMATION SYSTEMS AS A NEW STAGE OF MODELING AND MANAGEMENT OF ESSs

Automated information systems (AIS) are a new means for improving the planning and management of the national economy in the USSR, and are being developed for all levels of the national hierarchy. As for ESSs, they include the following subsystems: fuel and energy balances of the USSR, the AIS of GOSPLAN, the branch information systems of the Fuel and Power Ministries and their territorial and production associations. The objectives of AIS are as follows:

- Improvement of the task formulation and management procedures of the corresponding levels of the hierarchy;
- Improvement of methods of planning and modeling including new methods for allowing uncertainty in the development of ESSs;
- Development of an integrated data base for dealing with management problems;
- Development of a system of mathematical models with modular structure, each model being available in several modifications that differ from the varieties of software operation;
- Improvement of computer techniques and building of a computer network adequate for managerial goals.

We will mention the main directions of the complex of models of the subsystem for the development of the branch automated information systems of the Ministry of Power of the USSR (AISPD) dealing more directly with the development of the Siberian JEPS. The subsystem AISPD deals with the planning and design of the Integrated National Electric Power System (INEPS) in the Soviet

Union and the electric regional power systems. The subject of the integration of the Siberian JEPS with the INEPS are discussed later in this paper. Two types of interconnected AISPD, corresponding to two hierarchical levels of the subsystems INEPS and the Siberian JEPS can be considered. At each level its own set of problems will be solved [5].

The AIS for the INEPS will be concerned with the following tasks:

1) Estimating the system efficiency and the utility of creating new types of basic generating and electrical engineering plants;

2) Choosing an efficient futute INEPS pattern in terms of power station types and generating plant types;

3) Choosing ways for developing the basic grid of INEPS (configuration, voltages, carrying capacities of the intersystem power transmission lines (PTL)) for different time ranges;

4) Setting a scheme for the near future and fixing the time sequence for commissioning the individual intersystem PTL;

5) Coordinating decisions on the development of power stations and PTL in the individual Siberian JEPS from the point of view of INEPS.

The functions of the AIS for the Siberian JEPS are to:

6) Determine the set of efficient development alternatives for power stations in the Siberian JEPS;

7) Set the priorities for power stations to be constructed immediately after current projects are completed;

8) Choose development trends for the basic grids of JEPS for different time scales;

9) Choose a scheme for the Siberian JEPS grids in the near future and fix the time sequence for building the first priority PTL.

Also, at this level it is important to determine the optimum scope of heat production and development of heating and power plants as well as other parameters. Characteristics of some software sets have been determined [5,14], and are given below.

The first one is *software for determining an efficient INEPS pattern in terms of power station types and generating plant types.* The core is a linear optimization model representing INEPS as a sectorial system. Besides the optimization pattern of INEPS' generating capacities, the model enables one to select the required carrying capacities of the intersystem links. Apart from the model, the software includes the data bank and some interlinked functional or auxiliary programs.

Programs and data bases for studying the system efficiency of power units are the software devised for solving the first problem in the above list. The core of the software package is a dynamic discrete simulation model, which enables the dynamic balance of a system's capacity to be computed with given priorities in the building of power stations and the commissioning of their individual plants.

The third set includes a *computation software package for problems of power station development at the Siberian JEPS level.* This software package is intended for aiding tasks 6 and 7 above. The package has a modular structure, each module being available in several modifications differing from one another by the specific factors they incorporate. In this way a variety of software operation modes can be organized. For optimum calculations, simpler module versions are used, while modules accounting for more details of the system's power and economic characteristics are applied to assess different alternatives.

The main modules of the package are:

- A balance module intended to assess the time sequence for commissioning power stations, given their level of priorities;

- A scheduling module which optimizes the operation schedules of the power stations and PTL and fuel cost estimates;

- A PTL module evaluating the costs in the power grids for alternative variants of commissioning power stations and locating them in Siberian JEPS nodes;

- An optimization module which organizes the optimization process; it is based on the competition method.

Each module is an autonomous model having its own data files and fixed formats of input and output data. A special executive routine will manage the operation of this software package.

A *computation programs package for techno-economic calculations of the basic power grids of the Siberian JEPS* is intended for solving the network problems. It comprises modules of main and operator programs as well as a data base. The program's package includes the executive routine, the routine formatting the data base, the routine preparing the computing operation, and the module of main operating programs. The latter comprises the following programs:

- Optimization programs which choose the optimum configuration of a power grid using an algorithm of optimization by coordinates;

- Estimation programs for assessing the techno-economic merit of different configurations of the power grid submitted to it by the designer;

- Optimization programs based on dynamic programing principles and some heuristic algorithms.

The package is already in practical use at some departments of the Energosetprojekt.

The software sets listed above are standard tools for computational research that can be used in optimizing the development of various territorial subunits of INEPS, one of which is the Siberian JEPS. The problems of the Siberian JEPS development, which necessitate a consideration of the system's relationships with other power systems, will be tackled within the framework of AISPD of the INEPS. A special AISPD for the design of the Siberian JEPS is to be developed to deal with "internal" problems of the development of power stations and power grids in Siberia. The mathematical models it will incorporate in its software packages will take due account of the specific features of this particular power system.

ENERGY RESOURCES OF SIBERIA AND THE DEVELOPMENT OF THE ELECTRIC POWER SYSTEM OF SIBERIA

The first part of this paper discussed the concept of the planning and management of the general ESS of the USSR. We will now deal with the development of the Siberian JEPS and the ESS of the BITPC.

Two main features characterize the development of the ESS in Siberia: its place in the energy complex of the USSR and in particular in the energy supply of the European part of the country, and electric power in the Siberian energy systems development.

The place of Siberia in the fuel and energy balance of the USSR is determined by the Region's positive energy balance, and by the negative energy balance of the European part of the country. (Siberia has the greatest reserves of oil, coal, gas, and hydropower resources, and a relatively small energy consumption.) Table 4 gives data for the energy supply structure of the European part of the country and the energy supply from the Eastern part (mainly Siberia) of the USSR.

Optimizational considerations determine the very favorable conditions for the development of the Siberian JEPS.

Table 4. Energy supply structure of the European part of the USSR (in rounded off percents).

Source: [18]

Index	1960	Current Status	Perspective
Own energy resources supply	96	90	52-55
Nuclear energy used	-	insignificant	8-10
Energy supply from Eastern part of which:	4	10	35-40
oil and oil products	-	1	15-18
natural gas			16-14
electric energy			3- 4
coal	4	4	1- 4

East Siberia accounts for 43 percent of the aggregate energy potential of the USSR. Geological reserves of coal [26] reach 4×10^{12}t, i.e. 45 percent of the country's total resources. Of particular importance is the Kansk-Achinsk brown coal basin where coal mining is economically even more effective than in the Kuznetsk coal basin. Unit capital investments per ton of comparative fuel and the cost of mining of one ton of coal in the Kansk-Achinsk basin are one third to one fourth as high as in Kuzbass. The prospected coal reserves of this field will permit a coal output of up to 10^9t/a. These large and cheap coal resources and the very favorable hydroelectric power (HEP) resources lead to a very low closed cost of electricity production--two to three times less than that of the European part of the country. Owing to the unfavorable location of the major deposits of the high quality fuels--oil and gas--the closed cost of these fuels is almost equal to the cost in the European part. As a result, Siberia has a large gap between the cost of high quality and low quality fuels and hydroelectric power capability for electricity production.

The two times lower cost of electricity production and the low cost of fuel for centralized heating supplies have made it feasible to locate power-intensive industries (e.g. aluminium plants) and other industries using natural resources (e.g. wood products, chemical plants, and cellulose production units) in Central Siberia in general, and in the BITPC in particular.

The large gap between the costs of high quality fuels and that of hydroelectric power production has led to the efficacy of increasing the electrification of heavy and consumer service industries in Siberia. The comparative cost of fuel as opposed to electricity, for example, in the production of steel and in the processing of metals for the rolled metals industry showed that in the European part of the country it is advisable to use high quality fuels, whereas in Siberia electrical energy is more efficient from a cost viewpoint.

These favorable conditions for the production of cheap electricity as well as the predominance in the development of Siberia of electricity-extensive and labor-saving industries stimulated electricity production. The unified Siberian JEPS disposes now with 27.5 million kW installed capacity which will increase to 36.7 million kW in 1980 (Table 5). Over the next 10 to 15 years, the Siberian JEPS will be integrated with the power systems of Kazakhstan, Central Asia, and the European part of the country.

Table 5. Basic performance data of the Siberian Joint Electric Power System (as per 1975).

	1975	1976-1980	1980
Number of regional power systems included in Siberian JEPS	8	-	8
Installed capacity of HEPSs (in 10^6 kW)	27.5	9.2	36.7
Including			
Thermal power stations	14.6	4	18.6
% from total	53.4	44	51
Hydroelectric power stations	12.9	5.2	18.1
% from total	46.6	56	49
Electric power generation (in 10^9 kWh)	135.0	52	187
Including			
Thermal power stations	85.0	29	114
% from total	63.0	-	61
Hydroelectric power stations	50.0	23	73
% from total	37.0	-	39
Number of power plants with capacity over 400 MW	18	7	25
Number of hydraulic power units of unit capacity over 200 MW	33	11	44
Length of 110-500kV transmission lines (km)	43,700	10,800	54,590
Including			
500kV lines	4860	1000	5860
220kV lines	10,700	4600	15,300

Moreover, with the building of the Baikal-Amur Railway (BAM) line, it will be possible to link it up with the Far East JEPS. The Siberian JEPS will then function as the middle link, so that its development should be closely coordinated with that of other power systems and with the formation of the INEPS.

The organizational structure of the Siberian JEPS is given in Figure 5. Two additional characteristics of the production of electricity should be mentioned. The first is the combined

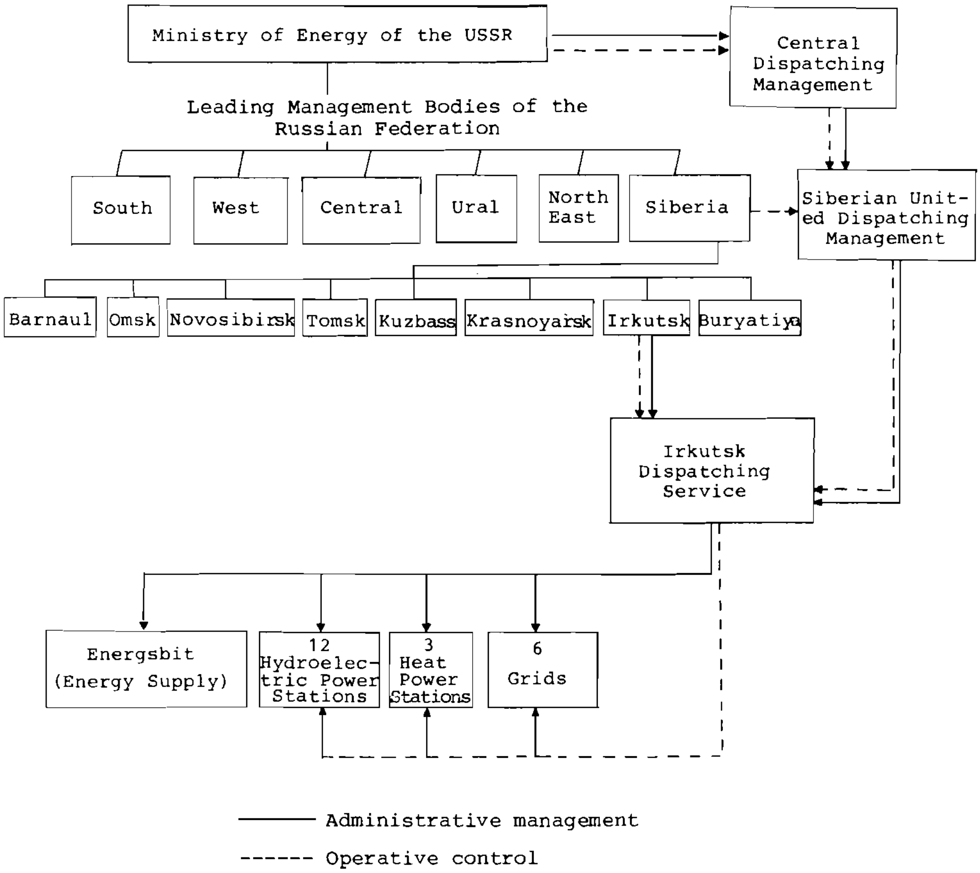

Figure 5. Organizational structure of electric power system management in the USSR and Siberia.

production of heat and electricity by the thermal power station in Siberia as a method for increasing the efficiency coefficient of the power plant (from 40-42 to 60-75 percent) and as a method for improving the environmental impact of the final use of coal for residential heating. The second point concerns the very high production of electricity in Siberia by hydroelectric power stations (HEPSs). The share of capacity of Siberian HEPSs is now 12.9 million kW (46.6 percent of installed capacity) and the share of electricity production is 37 percent (the average corresponding figures for the USSR are 19 and 18 percent respectively). In 1980, the installed capacity will be 18.1 million kW (49 percent of installed capacity). This is due to Siberia's unique HEP resources both as to the concentration of electrical capacity and the cost of power production. (The Siberian stations exceed economically the European stations by a factor of several times.)

In conclusion it should be mentioned that the investigations of the Siberian Institute of Energetics showed that the actual structure of the Siberian JEPS provides for the maximum economic utilization of energy resources. In the future, it will be necessary to accelerate the construction of thermal power stations in view of the gradual utilization of hydroelectric power capacity and the need to transmit large amounts of electrical energy to the European part of the country.

ESS OF THE BITPC

Energy Resources of the Angara-Yenisei Rivers and the Construction of the Bratsk and the Ust-Ilimsk HEPSs

Yenisei, with its tributaries, is the biggest river of the Soviet Union. Its basin [24] has an area of almost 2.5 million km^2, with an annual average runoff of 585 km^3. The total length of the Yenisei River is 90,000 km. The economically efficient hydropower resources [26] of the Angara-Yenisei basin exceed 50 million kW, which is equivalent to a potential annual electricity output of $250\text{-}290 \times 10^9$ kWh.

The basin of the right bank tributary Angara is especially rich in mineral resources. The hydrographic exploration of the Angara started intensively in the early 1930s [24, 11]. The first research project, "Hypotheses of Using the Power of Angara River", was completed in 1934. We shall mention only two aspects of this study. The systematic, priority approach to the development of the hydroelectric power resources involved the division of the HEPSs in the Angara and its tributaries into four groups, in accordance with their efficiency, transportation accessibility, and the readiness of the regions for construction. Second, the comprehensive approach was designed for the utilization of raw materials, the development of energy-intensive industries, the timber industry, the transportation and the multipurpose utilization of hydroelectric power resources.

The 1953 scheme of Gidroprojekt provided for the building of six HEPSs on the Angara River, with total capacities of more than 10 million kW (at present a greater figure is envisaged) and an average power output over many years equal to some 20×10^9 kWh/a. Gidroprojekt also worked out a scheme for the development of major industrial sites and transportation activities for the regions of the HEPSs, and in particular for the Bratsk Region which has the largest HEPS. A remarkable feature of this cascade was a very high degree of regulation of runoff to be secured by the construction of the Bratsk reservoir and the backwater of Lake Baikal.

There were many reasons to start the construction of the future Angara-Yenisei Cascade by the Angara River. The Angara River combines many qualities important for this construction:

- A high-water level typical of rivers flowing through plants (from Baikal, 1950 m^3/sec increasing rapidly to 2906 m^3/sec for the Bratsk HEPS, and to 3132 m^3/sec to Ust-Ilimsk HEPS).

  Impetuous mountain rivers--0.2 to 2.5 m/sec--which can be explained by the great fall of stream 20.4 cm/km. (A comparative figure for the Volga River is 7 cm, and for the Dnieper River, 9.8 cm.)

- Evenness of water discharge during the year--the maximum water discharge at the river head exceeds the minimum by 6 times only. (On the Dnieper HEPS the difference is 200 times; at the Kama HEPS on the Kama River, 100 times; at the Lenin HEPS on the Volga, 30 to 40 times.)

- The geological conditions especially of the Mid-Angara Region are very favorable for the construction of a HEPS.

- The Angara-Yenisei Region is unique in its concentration of natural resources: coal, wood (90 percent of the total area), iron ore, etc. (For more details see [25].)

The decision to construct the Bratsk HEPS was adopted in 1954. The construction proceeded at a rapid pace. Work on the main structure of the station began in 1957, and in 1959 the Angara River was spanned. In 1961, the first units were coming into operation, and in 1967 the station's capacity reached 4100 kW with 18 turbo sets. The HEPS was built at the Padun narrowing, its normal affluent level being 402 m, and the difference in levels, 108 m. The reservoir of the Bratsk HEPS was formed in the Angara River valley, its water surface being over 5400 km^2. Its volume is about 170 km^2. The new reservoir made it possible to develop water transportation over a distance of 1300 km. Operating in conjunction with the Irkutsk HEPS reservoir, the Bratsk reservoir makes it possible to control all the

Angara water regime and to carry out an interbasin control of runoff. The operational aspect of the Bratsk and the Ust-Ilimsk HEPSs within the Siberian JEPS will be discussed later in this paper.

The timing of the construction of industrial enterprises of the Bratsk industrial center was given elsewhere in this Report. Here we wish to point out that the first installation of the Bratsk timber complex was coming into operation in 1965 and that of the aluminium works in 1966.

The preparation for the Ust-Ilimsk HEPS started in 1962. In 1967, the construction of the HEPS began. The normal affluent level is 296 m, and the difference in the levels used at the station amounts to 88 m. The Ust-Ilimsk HEPS is hydraulically linked up with that of the Bratsk HEPS, since the backwater of the Ust-Ilimsk HEPS reaches as far as the Bratsk hydroproject tailwater. Inflow to the HEPS site is largely controlled by the Irkutsk and the Bratsk HEPSs' reservoirs. The total volume of the reservoir will amount to about 60 km^3, the useful volume for a 1 to 5 m draw-off depth will be about 3 km^2. The rated capacity of the power station will be 4.3 million kW and the annual electric power output, 21.6×10^9 kWh. The first units of the Ust-Ilimsk HEPS were coming into operation in 1974.

The actual stage and the siting of the HEPSs of the Angara-Yenisei Cascade [29] are given in Figure 6.

Bratsk and Ust-Ilimsk HEPSs in the Development of the BITPC

The role of the Bratsk and the Ust-Ilimsk HEPSs in the development of the BITPC has been discussed in detail in [6,8,17,24]. We would like to summarize briefly the leading role that these stations played in this development and discuss the place they hold in the Siberian JEPS.

The siting and the construction of HEPSs played a determinative role in the production and spatial pattern of the BITPC. Cheap electricity led to implementation of labor-saving and energy-intensive industries--e.g. aluminium, iron and timber, chemical and mining industries as well as consumer product industries. The siting of the HEPSs also served as a base for the two big industrial centers of the BITPC--the Bratsk and the Ust-Ilimsk.

The HEPSs satisfy all electricity requirements of the industrial, construction, transportation, agricultural, and residential sectors. The total electricity consumption by the entire economy of the Bratsk complex in the tenth Five-Year Period will amount to 21 - 22 10^9 kWh [26], i.e. 50 percent of the potential output. This positive power balance of the BITPC will remain for a long period. It characterizes the electricity production not only as a key industry for the BITPC but also the specialization of the BITPC as a producer of electricity for Siberia.

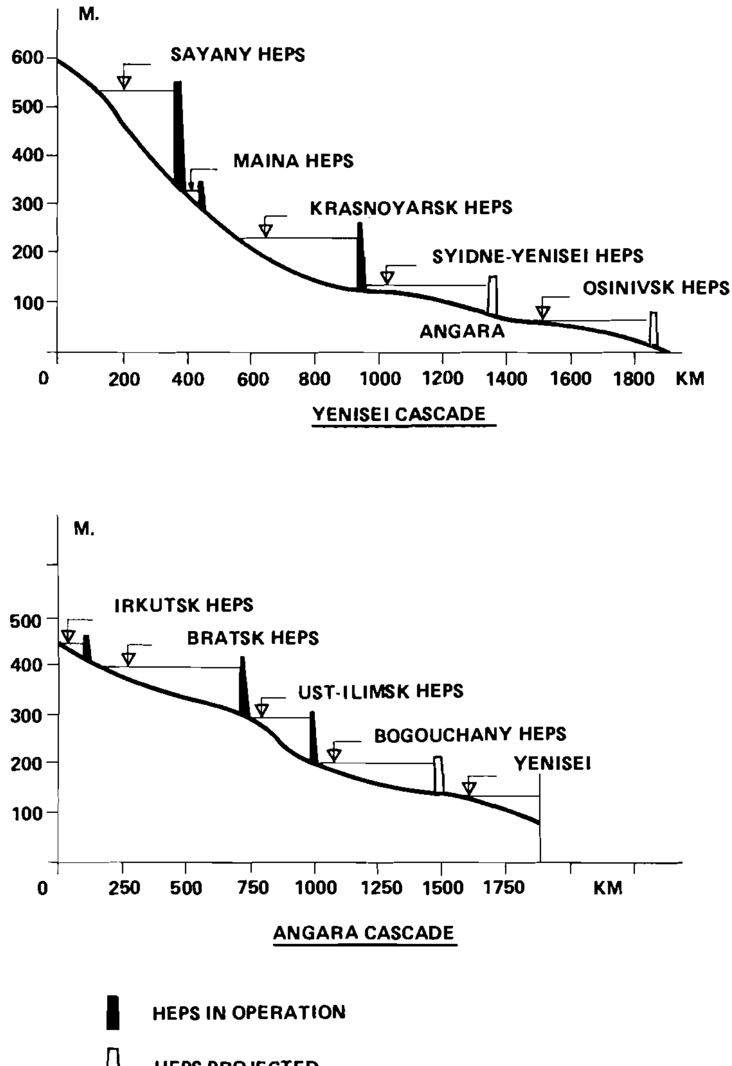

Figure 6. The Angara-Yenisei Cascade: HEPS sitings.

The Bratsk and the Ust-Ilimsk HEPSs and their reservoirs play an important role in the runoff regulation of the Angara-Yenisei Cascade.

The development of Bratsk and Ust-Ilimsk HEPSs has played a great role in determinating the multipurpose use of the water resources of Angara-Yenisei Rivers (transportation, fishing, water supply, etc.) It has had a large environmental impact on the Region and on the BITPC. This aspect of the development of the Bratsk and Ust-Ilimsk HEPSs and the Angara-Yenisei Cascade is discussed elsewhere in this Report.

Role of the Bratsk and the Ust-Ilimsk HEPSs in the Siberian JEPS

The main characteristics of the Siberian JEPS are given in [21]. The HEPSs generate almost 40 percent of the total electricity production of the Siberian JEPS. The Angara-Yenisei Cascade [17] produces 98 percent of this amount, no less than 70 percent of which was accounted for by the Angara HEPSs (i.e. Irkutsk, Bratsk, Ust-Ilimsk). But these figures do not reflect the important role of the operation conditions of the Angara-Yenisei Cascade and the Bratsk and Ust-Ilimsk HEPSs in the Siberian JEPS.

The Angara-Yenisei Cascade is unique in many respects--e.g., the capacities of the HEPSs, their economic indexes, and the regulating capacities of the reservoirs [6]. Table 6 gives the main hydroelectric power characteristics of existing HEPSs and

Table 6. Hydropower indexes of the HEPSs of the Angara-Yenisei Cascade.

Source: [6]

Indexes	Irkutsk	Bratsk	Ust-Ilimsk	Bogouchany	Sayansk	Krasnoyarsk
River	Angara	Angara	Angara	Angara	Yenisei	Yenisei
Commissioning year	1956	1961	1974	1985-1990	1978	1967
Design head (m)	26	100	86	65	194	93
Average annual runoff (km^3)	60	92	101	107	47	88
Reservoir capacity (km^3)	46.0	48.0	2.8	2.3	14.0	30.4
runoff (%)	77	52	3	2	30	36
Installed capacity (MW)	660	4,600	4,320	4,000	6,400	6,000
Average long-term output (10^9/kWh)	4.1	22.6	21.9	17.0	23.7	20.4
Regulation	long term	long term	seasonal	seasonal	seasonal	annual

those to be commissioned shortly. Because of the large reservoirs, especially at the Irkutsk and the Bratsk HEPS, the Cascade is capable of the following:

- Accounting for the fluctuations in the daily load curves and controlling the frequency in the Siberian JEPS;
- Supplying the main bulk of the emergency and operational resource capacity;
- Acting as multiyear power regulator in the system by accounting for the discrepancies between the power consumption growth and the new capacities commissioned in the Siberian JEPS;
- Meeting the needs of other water resorts and consumers (water transportation, fisheries, city water supply, etc.).

The fulfilling of these functions is the result of a systems approach to designing the development and operation of the HEPSs, mainly based on three kinds of investigations:

- Runoff regulations to determine the water power indexes of HEPSs needed for drafting the long-term development of the power system (5 to 15 years);
- Coordination of the HEPS runoff regulations with the power system development in the near future. (The aim of this calculation is to coordinate the choice of long-term storage conditions and a commissioning schedule of new power units to come in two or three years. The calculations are based on the available storage at the beginning of the period, long-term river runoff forecasts, energy demand, development of thermal power stations in the Siberian JEPS, etc.)
- Scheduling of runoff regulations during the operation of HEPSs and the Siberian JEPS as a whole.

The use of system analysis, statistical modeling and control theory, and computer applications characterizes these calculations, discussed in detail in [5,25,29]. On the basis of those methods, special operating conditions of the Angara-Yenisei Cascade were developed that take into account the runoffs of the Angara and the Yenisei Rivers and the regulating potential of the reservoirs. These conditions became known as the interbasin electric grid. According to these conditions, the Upper-Ilnisei HEPS, which has relatively small reservoir regulating capacities, was placed at the lower level of the control hierarchy, ensuring a most efficient use of the Ilnisei runoff for power production. The Angara HEPS and especially the Bratsk and the Irkutsk HEPSs were placed at the upper level of control hierarchy, and act as compensators for the power output variations of the Yenisei HEPS. Owing to these operating conditions and to the runoff, the total guaranteed output of the Angara-Yenisei Cascade has greatly increased. With only three HEPSs of the Cascade operational, their assured output increased by over 500 MW. This figure will be as high as 1500 MW when eight HEPSs of the Cascade become operational.

The important role of the Bratsk HEPS, prior to the commissioning of the Ust-Ilimsk HEPS, is illustrated in Table 7.

Table 7. Share of the Bratsk HEPS in the total output of HEPSs of Angara-Yenisei Cascade.

After: [17]

	1970	1971	1972	1973	1974
Total electricity output of HEPSs of Angara-Yenisei Cascade (10^9 kWh)	42.2	44.3	46.1	48.9	48.5
Output of the Bratsk HEPS (10^9 kWh)	20.3	22.8	23.3	23.0	28.0
Percent of cascade in total output	48	51	50	47	58

The role of the Bratsk HEPS may also be seen from its contribution to the covering of the winter peak load of the Siberian JEPS [Table 8].

Table 8. Contribution of Bratsk HEPS to covering the winter peak load of Siberian JEPS.

After: [17]

	1970	1971	1972	1973	1974
Contribution of HEPSs of covering annual peak load of Siberian JEPS (thousand kW)	5990	6470	6590	7160	7700
of which					
Bratsk HEPS (10^9 kWh)	2760	3660	3420	3040	4090
Percent of total HEPS contribution	46	57	52	42	53

When the first units of the Ust-Ilimsk HEPS became operational in 1974, the importance of the Angara-Yenisei Cascade increased substantially. As a result of two cycles of drawing down and filling during a single year, the Ust-Ilimsk HEPS has increased the role of the Bratsk HEPS as compensator of the Angara-Yenisei Cascade's output, increasing the efficiency of the Siberian JEPS in summer when the runoff of the Angara-Yenisei Cascade has to satisfy the navigation constraints and considerably increase the accumulation of water for the winter load.

CONCLUDING REMARKS

The ESSs of the USSR determine the production structure of the BITPC. The development pattern of these systems is a product of the centralized planning of the national economy, particularly in the fuel and power complex of the USSR. We briefly presented the general concept of the current methods of planning and management, and discussed the systems of models for energy systems development in the USSR. This is a wide area of human, scientific and managerial activity comprising, in an aggregate manner, environmental, technological, economical, and social problems and relationships. The AIS and ESSs and the complex modeling of regional and TPC development were also briefly discussed. The ESSs of Siberia and of the BITPC, viewed as part of the hierarchy of the general ESS of the Soviet Union, were reviewed in the second part of the paper.

IIASA has been studying the development of the energy systems of the BITPC. It may be asked how universal is this problem. Any approach to planning and management mainly depends on the societal organization and the system of planning of the national economy. Nevertheless, it is felt that the vast experience in developing and managing ESSs in the USSR would have universal interest when viewed from the following three directions:

- *The Approach*: The systems approach to the global optimal development of energy systems, the hierarchy of management, the time stages of planning, and planning procedures could be of managerial interest to many countries.

- *Models and methodology*: Many models of ESS development are universal and could, after some adaptation or development, be applied in many countries, e.g., the model of the production relations of the energy systems of a country, the set of models for the development of electric power systems presented at the IIASA Conference on the BITPC [5,6], and the systems of mazomodels for TPC development of IEOIP. Also of possible interest are marginal values as means for optimizing ESS development and the advanced methods developed in the USSR for taking into account uncertainty in the modeling and planning of this development.

- *Design and technological solutions for energy systems development*: The ESSs of Siberia and of the BITPC have some characteristics of future large-scale world energy systems. For example, the Siberian JEPS covers a surface of more than 3000 km. The Angara-Yenisei Cascade is one of the largest hydropower cascades in the world, and the design and operation of this Cascade is an example of the large-scale accumulation of energy and its integration into the operation schedule of an electric power system. The integration of the Siberian JEPS with the INEPS and the transportation of fuel and energy from

Siberia to the European part of the USSR are two additional features that should be of interest worldwide.

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Water Resource Development in the BITPC

MOTIVATION FOR WATER RESOURCE DEVELOPMENT

Interest in large-scale water resource projects in the USSR has increased considerably over the past few decades, due to:

- The vast industrial and related water resource developments that have taken place following the Great October Revolution of 1917;
- The enormous amount of fresh water resources, and in particular the potential hydroelectric power available in the USSR (Table 1) (only 39.1 percent of the economically feasible hydroelectric power has been developed in the European and Caucasus parts, and 12.4 percent in the Asian part, of the USSR [9]);
- Uneven distribution of water resources throughout the country;
- Long-standing interest outside the country in the results of a planned economy system.

Table 1. Economically feasible potential hydroelectric power on the Angara River in the USSR and in Selected Countries.

Source: [9]

Potential Hydroelectric power (TWh/a)						
USSR	USA	Brazil	Canada	France	Italy	Angara River
1100	685	657	218	70	70	90

Seeing the vast amount of construction under way for the development of water resources along the Angara-Yenisei River basin, one wonders what forces have led to this development. Three factors have supported the concept of water resource development since the Angara-Yenisei Region was discovered by the first Russian settlers about 300 years ago. First, the Region has abundant water, supplied by Lake Baikal, the Angara and the Yenisei Rivers, and their tributaries. Secondly, the Region is rich in mineral resources e.g. iron ore, and coal, and has almost unlimited timber resources. Thirdly, the need for processing the available resources to meet the Country's growing economic and social demands has been generally recognized.

From the outset, there has been interest in developing the water resources of the Region. The right men were in the right place but unfortunately not at the right time. Because large amounts of cheap power were needed to support the development of the national economy, the GOELRO Plan was set up for the electrification of the country. During this period, construction of hydroelectric power stations (HEPSs) reached a point at which large projects could be initiated. All this had an enormous impact on the activities concerned with development of water resources, in particular of the Angara River.

NATIONAL AND REGIONAL WATER RESOURCE DEVELOPMENT

Approaches to Meeting Future Water Demands

It is difficult to base conclusions regarding the development of water resources in the USSR on a short visit to any one region. The study of national water resource development is essential to an understanding of regional development. These two development levels are closely related, theoretical and practical achievements at one level influencing the other.

If water and other resources were evenly distributed worldwide, physical, social, and economic phenomena could be investigated in a small region. Unfortunately, this is not the case, particularly in the USSR. To assure smooth economic activity under extreme water resource conditions (flood or drought), one can use two economically justified approaches:

- Water storage and/or water transfer from/to adjacent basins;

- Redistribution of economic activities over several regions, or over the whole country, in accordance with water availability.

The following discussion is limited to water transfer and redistribution of economic activities, because the work in this direction is rather promising and is applicable to many regions throughout the country.

Water Transfer

In the USSR, water transfer has received much attention since the first quarter of this century. As early as 1932, the General Assembly of the USSR Academy of Sciences pointed out that in order to meet future demands, waters of the northern rivers should be transferred to the Volga River basin [6]. Interest in water transfer has recently grown. An indicator of this is the All-Union Workshop which took place in April 1975 [14], devoted to the impact of interbasin stream-flow redistribution on natural conditions in the European part of the USSR, Central Asia, and Western Siberia. The Workshop reached the conclusion that water transfer, if staged properly (i.e., for the first stage transferring 25 to 30 km^3/a to the European part and 35 to 50 km^3/a to Central Asia), would not markedly disturb the environment of the northern parts of the country where the water originates.

Current work on interbasin water transfer uses a systems analysis approach and is carried out under the following hypotheses [15]:

- Water technology will not change appreciably by 1990 or even beyond. Tons of water per unit of consumption will decrease at a slower rate than the production growth in all water-consuming branches of the national economy. To meet water demands, under this hypothesis, great amounts of water should be transferred from the northern rivers.

- Water technology will change rapidly and perhaps several times. Water quality control technology will be developed to a point where there is little or no pollution of water bodies. Overall water consumption will decrease, and water per unit of consumption will reach a stable point. This hypothesis leads to the extended and rationalized use of local water resources--surface and ground waters, melting of glaciers, etc.

- The third hypothesis is a combination of the other two. It calls for both a considerable change in water technologies toward decreasing water demands and for intensive global and regional measures (not tied only to water transfer) to provide more water in a particular basin.

As Voropaev [15] has pointed out, five water transfer options are now being discussed in the USSR:

1. Meeting the demands of the southern regions of the European part of the USSR by water transfer from the northern rivers into the Volga River basin; water transfer from the Danube River is also envisaged.

2. Meeting the demands of Central Asia and Kazakhstan by water transfer of part of the Ob, the Irtysh, and the Yenisei Rivers.

3. Meeting the demands of the European part, Central Asia, and Kazakhstan by withdrawals from the Volga River basin; the latter is recharged by water transferred from the northern rivers and the lower part of the Ob River.

4. Meeting the demands of the European part, Central Asia, and Kazakhstan by water from the Volga River basin, with subsequent transfer of water from the Black Sea to the Caspian Sea.

5. Meeting the demands of the European part, Central Asia, and Kazakhstan through joint use of water resources in the European and Asian regions, including diverting rivers from the north to the south and water transfer from the Black Sea to the Caspian Sea.

These options do not exhaust all the variants that have been worked out. For example, Dunin-Barkovskyi and N.N. Moiseev [6] have elaborated a possible variant within option 5 and have designed a simulation model. The model is aimed at helping decision-makers choose the best variant, taking into account the water demands of various users, water quality and impact on the environment, and available and/or transferred water in a particular region.

Figure 1 illustrates two proposals within option 2 and partly of 5 [4]. The first is to divert the Pechora River to the upper reaches of the Kama River through man-made channels;

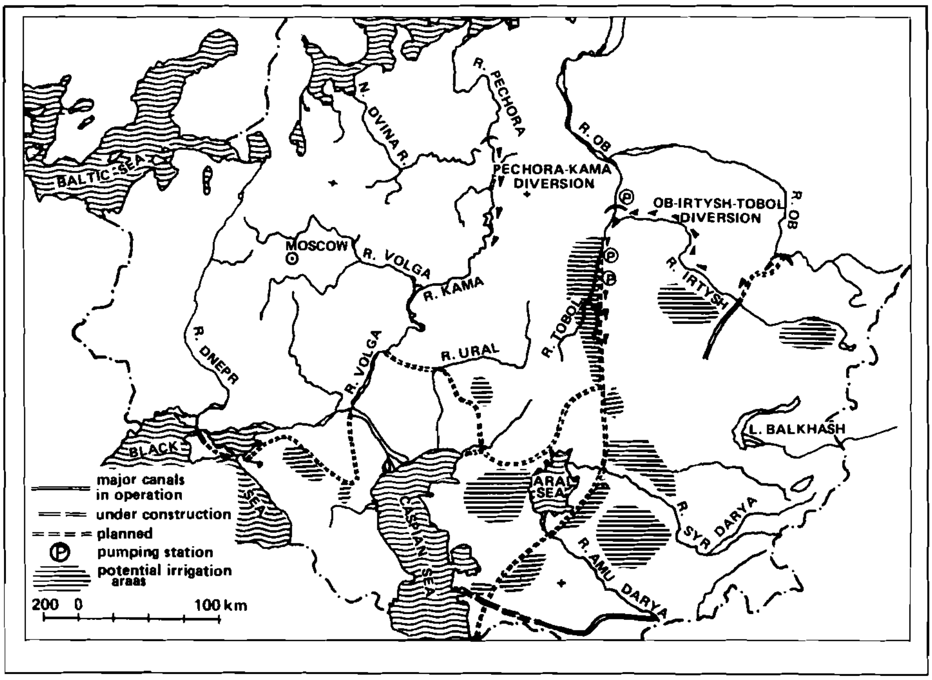

Figure 1. Some planned river diversions in the Soviet Union [5].

this would augment the flow of the Volga River and supply the Caspian Sea, which has been depleting since the mid-1920s. The second is to divert some of the flow of the Ob-Irtysh River system from north to south. This would involve building a dam near the confluence of the Irtysh and Tobol Rivers and so reverse the direction of flow of the Tobol River. Through a network of channels this flow would carry the water to the Kazakhstan and to the Caspian and Aral Seas.

There seem to be two bottlenecks that have prevented implementation of the water transfer project: the great capital investment needed, and, perhaps more important, the many unknown facts about environmental consequences if water transfer and especially diverting rivers became a reality.

Redistribution of Economic Activities

The second main approach to overcoming extreme water resource situations is redistribution of economic activities over several regions or over the whole country. This approach does not exclude water transfer; water transfer is a result of solving the following type of problem.

Up to a certain time horizon, say 1990, we shall have a wide variety of high use water consumers and final products--industry, municipal activities, agriculture, and recreation. Certain constraints--available surface and ground resources; amount of soil for agricultural activities; planned crop yield; available labor; economic indicators to be achieved in each region and for the country as a whole; possible options for inter-regional and regional water transfers, etc.--restrict water resource development. An optimal development strategy for the whole country, and for large regions, river basins, and the like, is to be obtained under these conditions. This implies the following:

- Find the best allocation of various types of agricultural production over different kinds of soil;
- Find an optimal amount of water to be transferred among regions;
- Find an optimal output mix of products requiring large amounts of water;
- Find an optimal allocation of reservoirs and water resource systems throughout the country; find an optimal use of ground waters, etc.

Such studies are the subject of attention in many organizations, such as the Siberian Power Institute of the Siberian Branch of the USSR Academy of Sciences; the All-Union Corporation Sojuzvodprojekt of the Ministry of Land Reclamation and Water Resources; the Institute of Water Problems of the USSR Academy of Sciences.

Several recent papers describe attempts directed to developing linear models. Further elaboration concerned with developing of nonlinear models is under way and is quite promising.

Stages in Water Resource Development

The various stages of water resource development do not differ appreciably from those of other resource and economic developments in the USSR. We shall therefore concentrate on the organizational structure of the development--namely, the authorities involved; the methods of interaction among the authorities; conflict resolution between different planning levels, and the like. In this context only management procedures concerned with comparatively large projects of national interest will be discussed.

The six main stages every large project must pass through (usually several times) before it becomes a reality are shown in Figure 2. The right-hand column indicates the main organizations involved in planning and implementation. We shall comment only on the procedure at the approval stage.

For any water resource project, regardless of the level of approval needed, an ad hoc committee (a so-called committee of experts) is set up. It consists of specialists from various organizations responsible for implementing the project, organizations the project will have an impact on, and the like. The committee gives advice and recommendations to the organization (usually one of the Ministries) responsible for the project. If the evaluation is negative, the project is sent back to the organizations that designed it; in some cases it may be returned to the investigation stage.

The preliminary investigation stage reflects the hierarchical essence of the USSR planned economy. Much work is under way by the Institute of Economics and Industrial Engineering (IEOIP) of the Siberian Branch of the USSR Academy of Sciences in Novosibirsk [7,1,3,2] on modeling the three subordinated activities of that stage (Figure 2).

The main types of organization--top-level authorities, Ministries, oblast and local authorities, scientific organizations --involved in initiating and carrying out a particular project are shown in Figure 3. The idea for project development may come from any area shown in the boxes, but must almost always pass through all other boxes, especially if the project is of national interest.

The decisive role of local authorities when a water project is initiated must also be mentioned. They may call for initiation of a project, and the higher authorities must investigate its economic feasibility and expedience. Or if the higher authorities want to put a project into operation, they must have approval from the local authorities concerned. If the latter do not agree with the proposal, the former cannot build the project in the desired location.

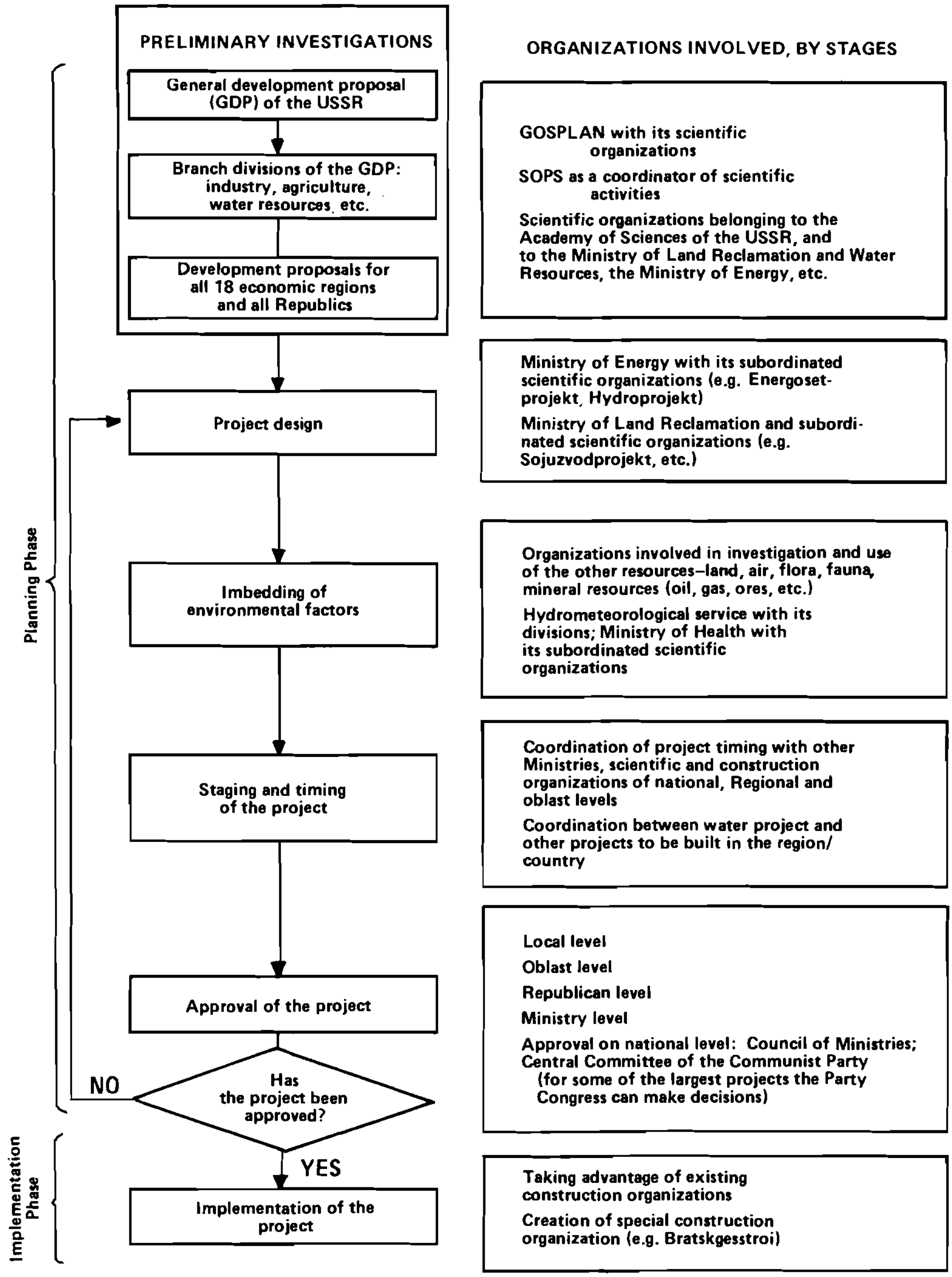

Figure 2. Stages in water resource planning and implementation.

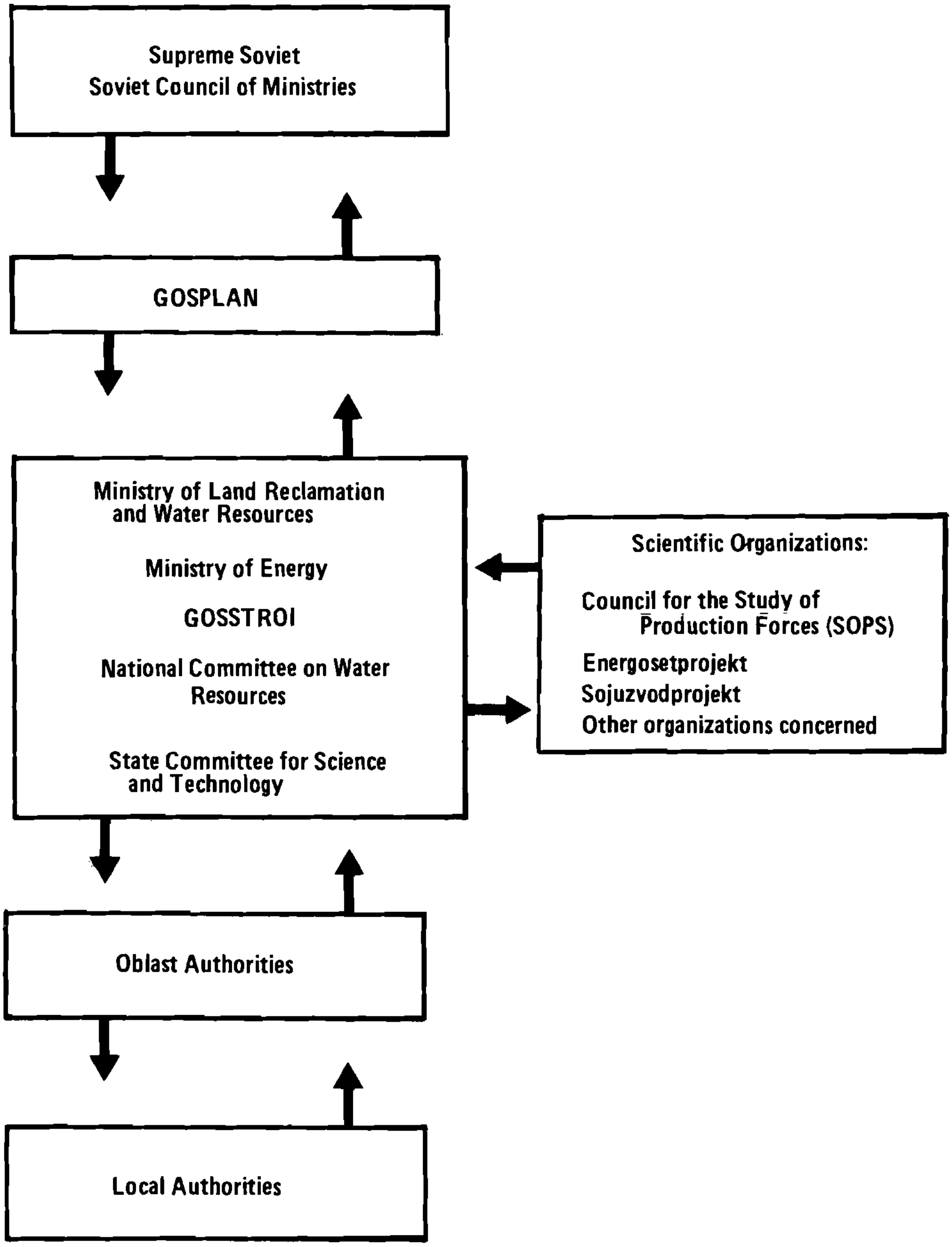

Figure 3. Type of organization that may propose initiation of water project.

WATER RESOURCE DEVELOPMENT IN THE BITPC

Angara River Basin as the Next Link in Water Resource Development

It would not be an exaggeration to say that the BITPC has emerged mainly as a result of the vast development of the Angara water resources. The Angara River is one of the most suitable for hydroelectric power (HEP) development. Its source is Lake Baikal, which has 336 inflow rivers; the Angara is the only outflow. From its source to its point of confluence with the Yenisei River it is 1854 km long, with an elevation of 378 m and a speed of 0.9 to 1.5 m/sec. Its annual flow is more evenly distributed than that of other rivers flowing in adjacent basins (see Table 2).

Table 2.

Source: [13]

River	Percent of annual flow over seasons			
	Winter	Spring	Summer	Autumn
Angara (at Padun Rapids)	16	29	24	31
Lena (at Grusonovsk)	8	50	21	21
Yenisei (near Tungusk tributary)	18	18	44	20

The ratio between the maximum and the minimum flow of the Angara, Dnepr, and Volga Rivers are shown in Table 3.

Table 3.

Source: [9]

River	Maximum flow/Minimum flow
Angara	6
Volga (at Volga HEPS)	40
Kama (at Kama HEPS)	100
Dnepr (at Dneproges HEPS)	200

The almost constant flow of the Angara River over a considerable period of time is due mainly to the constant level of Lake Baikal. The water level fluctuates only between 0 and 1.5 m (maximum 2 m). Further evidence of the importance of Lake Baikal is the fact that near Bratsk 60 percent of the Angara waters come from that lake (at the mouth of the river, 40 percent).

The unique possibilities of the Angara River for vast water development have attracted many Soviet scientists and politicians since the beginning of this century. In the 1920s A.A. Velper [9] proposed to the GOELRO committee that a cascade be constructed on the Angara River with the enormous (for that time) capacity of 2 MW. After more detailed investigations, a plan for water resource development (mainly HEP generation) was suggested in 1935 (Table 4). A new plan was initiated after World War Two, and fully established in 1953 (Table 4).

Table 4. Two proposals for development of the hydroelectric power potential of the Angara River.

Source: [10]

1935		1953		Actual 1976 Capacity of the HEPSs (1000 MW)	Annual Power Output (TWh/a)
HEPSs	Distance from the Outflow of Angara River (km)	HEPSs	Distance from the Outflow of Angara River (km)		
Baikalsk	60	Irkutsk	65	0.66	4.1
Barkhatovsk	210	Sukhovsk	108	-	-
Bratsk	717	Telminsk	177	-	-
Shamansk	912	Bratsk	697	4.5	22.6
Kezhemsk	1235	Ust-Ilimsk	1008	4.32*	21.7*
Bogouchany	1515	Bogouchany	1451	4.0**	17.0**

*Capacity and annual output to be reached in 1977.
**Construction of the HEPS has not started yet.

The following changes have been made in the 1953 proposal:

- The Sukhovsk and Telminsk HEPS will not be constructed until the year 2000, because their output is considerably less than that of other HEPS, and additional reservoirs on the Angara River would cause flooding of the area near the town of Angarsk.

- Due to the discovery of great amounts of natural resources both the Angara bed and the proposed location of the Bogouchany HEPS will be changed.

- There have been changes in the projected capacities of the other HEPSs, as shown in Table 5.

- Since the envisaged capacity of the Angara River, including its tributaries, amounts to 90 TWh/a, much remains to be done to take advantage of this unique endowment of Siberia. However, because of increasing concern over the past 15 years about environmental constraints--land and other natural resource use, water and air pollution, etc.--there may be less water resources and in particular less HEP development than was supported 15 to 20 years ago.

Table 5. Basic data for various Bratsk HEPS projects.

Source: [10]

Year	Head (m)	Capacity (1000 MW)	Annual Power Output (TWh/a)	Development State
1935	90.5	2.5	17.5	Proposed
1953	102.1	3.2	21.3	Draft design
1957	102.0	3.6	21.7	Draft design
1961	102.0	4.5	21-24	Draft design
1969	100.0	4.5	22.6	Constructed

Staging and Timing of Water Resource Development and the Energy Consuming Industry in the BITPC

The previous section outlines how development of the Angara River began and how different proposals changed over time. Now let us concentrate on the organizational structure of the development, the ways in which difficulties and bottlenecks have been dealt with, the staging of projects in a planned economy, and the like.

Three main reasons dictated that development of the Angara River start from its source near Lake Baikal. First, up-stream reservoirs can be used for regulating the inflow into down-stream ones; secondly, this area (town of Irkutsk) is well populated, which implies adequate labor, accessibility of construction materials, and energy for heating; and thirdly, much experience has been gained and subsequently used in constructing the biggest HEPS of the cascade.

Tables 6 and 7 indicate the staging and timing of the two biggest Angara HEPSs and other activities related to the development of the energy consuming industry and economic structure of the regions concerned. Upon examining the tables one may ask whether the staging and timing of the HEPSs and the energy-consuming industry were optimal. But what is optimal? Some consider the staging and timing to be optimal when there is no loss/shortage of energy due to improper timing of related energy consuming industries. Figure 4 illustrates the timing of the Ust-Ilimsk HEPS and its associated consumers: high voltage transmission (HVT) lines both to Bogouchany and to the timber processing complex are to be put into operation almost simultaneously with the commissioning of the HEPSs.

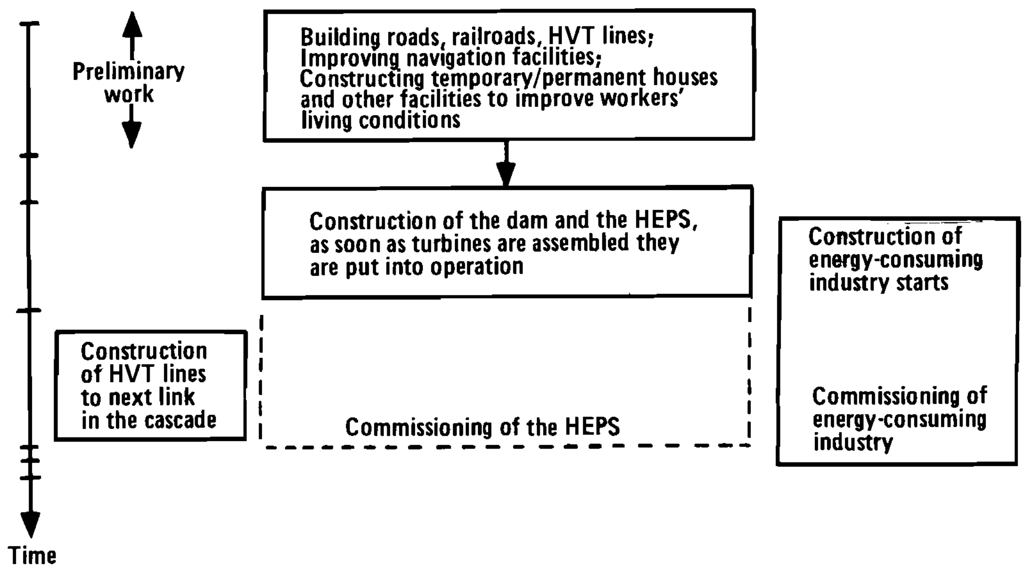

Figure 4. Timing of various types of jobs in the Ust-Ilimsk HEPS and related industries.

Table 6. Staging and timing of the Bratsk HEPS and associated industries.

Year	Bratsk HEPS	Year	Timber Processing Complex	Year	Aluminium Plant	Year	Other Activities
1954	First construction workers came to the Padun Rapids; Creation of Bratskgesstroi	1954	Building site determined	1954		1954	Commissioning of the Taishet-Lena railroad
1955		1955		1955		1955	
1956		1956		1956		1956	
1957		1957	Construction started	1957		1957	Commissioning of a HVT line connecting the Irkutsk and the Bratsk HEPSs; building of the town of Bratsk started
1958		1958		1958		1958	
1959	19 July, damming of the Angara River	1959		1959		1959	
1960	Construction start of the HEPS building	1960		1960		1960	
1961	Commissioning of the first two turbines	1961		1961	Construction started	1961	Commissioning of HVT line to Krasnoyarsk
1962		1962	Assembling of plant equipment began	1962		1962	
1963		1963		1963		1963	
1964		1964	First turbine of the thermal station commissioned	1964		1964	
1965	Putting into operation of the last (18th) turbine	1965	First stage commissioned	1965		1965	

Table 6. (Continued)

Year	Bratsk HEPS	Year	Timber Processing Complex	Year	Aluminium Plant	Year	Other Activities
1966	Commissioning of the HEPS; at that time there was a recovery of capital investment from the HEPS	1966		1966	First electrolysis shop put into operation	1966	Commissioning of a HVT line to Ust-Ilimsk
1967		1967		1967		1967	
1968		1968		1968		1968	
1969		1969		1969		1969	
1970		1970		1970		1970	
1971		1971		1971		1971	
1972		1972		1972		1972	
1973		1973		1973		1973	
1974		1974	Planned full capacity reached	1974		1974	
1975		1975		1975		1975	
1976		1976		1976	Planned full capacity to be reached	1976	
1977		1977		1977		1977	

Table 7. Staging and timing of the Ust-Ilimsk HEPS and associated industries.

Year	Ust-Ilimsk HEPS	Year	Timber Processing Complex	Year	Other Activities
1963		1963		1963	First regular navigation between Bratsk and Ust-Ilimsk HEPSs established; 250 km temporary road between Bratsk and Ust-Ilimsk HEPSs put into operation
1964		1964		1964	
1965		1965		1965	
1966	March: construction work began	1966		1966	Commissioning a 225 km HVT line between Bratsk and Ust-Ilimsk HEPSs
1967	February: first damming of Angara River August: second damming of Angara River	1967		1967	
1968		1968		1968	
1969		1969		1969	
1970		1970		1970	
1971		1971		1971	Commissioning of 219 km railroad between Hrebtovaya and Ust-Ilimsk HEPSs
1972		1972		1972	

Table 7. (Continued)

Year	Ust-Ilimsk HEPS	Year	Timber Processing Complex	Year	Other Activities
1973	December: three turbines put into operation	1973	Bratskgesstroi started construction work	1973	
1974		1974		1974	
1975		1975		1975	
1976		1976		1976	Construction of HVT line to the future Bogouchany HEPS
1977		1977	First stage to be put into operation	1977	
1978		1978	Second stage should be in operation	1978	First stage of the town of Ust-Ilimsk to be built

At Bratsk, there was a deliberate discrepancy in the timing of the HEPS and the aluminium plant, planned before construction work started for the following reasons:

- There was a lack of labor in the early construction stages; all available materials and labor had to be concentrated on a restricted number of projects to obtain maximum output in a short period of time. Construction was carried out in an almost unpopulated area; the construction equipment had to be developed simultaneously with implementation of the projects. Climatic conditions in the region are severe: the average annual temperature at Bratsk is -5.3 °C, with an absolute minimum of -58 °C and a winter/summer deviation of about 80 to 85 °C; the temperature is above zero for only 154 days a year (and sometimes as few as 86).

- The severe climate demands special construction materials; for example, specifically the water of the Angara River dissolves concrete, so that the best concrete mixture had to be investigated. Transportation costs and salaries are up to twice as high as in the populated European part of the USSR. As the Bratsk Region of the BITPC was the first multipurpose large-scale project in that area, there was not enough experience to rely on. A great deal of experience has since been acquired and has given fruitful results in the Ust-Ilimsk Region.

Multipurpose use of Angara Water Resources

Multipurpose use of Angara water resources has a specific character. The development plans were set up as multipurpose from the outset, but their implementation requires continuation of the development over a specific period of time.

Multipurpose use of running water requires that it be available at any time and any place in a particular region. Construction of the two large reservoirs, Bratsk (170×10^9 m^3) and Ust-Ilimsk (70×10^9 m^3) satisfied this requirement.

The second requirement, especially concerned with the unpopulated area, is to develop appropriate users/consumers of the available water. In the Bratsk-Ilimsk Territorial Production Complex (BITPC) this has been done from the early stages of the project. As a result, the Angara River is now being used for the following purposes:

- Power generation,
- Navigation,
- Industrial water supply,
- Fishing,
- Agricultural water supply,
- As a collector of purified waste waters.

As for power generation, we would like to stress again that it is an important, well-developed user with comparatively low (but not always the lowest) priority over the others. Its main competitor is navigation, which has a comparatively great economic significance. After the Bratsk and the Ust-Ilimsk dams were built, two navigation channels were established, Irkutsk-Bratsk and Bratsk-Ust-Ilimsk. The two dams turned the Angara rapids into a calm, easily navigable river for transporting bulky goods such as turbines and generators, timber, and other construction equipment at very low cost. This user is now considered to have the highest priority during the navigation season (120 to 130 days/a). The reason for this is that the Angara reservoirs have to augment the summer/autumn low flow of the Yenisei River, which is more important for navigation than the Angara. That is why navigation is the main constraint in the operation programs being developed for control of the Angara water resources. The operational aspects of the Angara Cascade are not discussed in this paper.

Industrial water supply also has specific features in the Angara River basin. The type of industries located there have been determined by the availability of large amounts of cheap energy, enormous amounts of very clean water, and large amounts of raw materials.

Because of the unique quality of the Angara waters, the local authorities do not allow location of industrial enterprises that might heavily pollute the withdrawn water, e.g. the chemical industry. The Bratsk aluminium plant, which could have been supplied by the Angara River, is now supplied by ground water as a result of the strict water quality standards. For both the aluminium plant and the timber processing complex the waste waters, after passing through sophisticated purification equipment, are discharged into one of the Angara tributaries.

Industrial water supply has also imposed some restrictions on the deviation of the Bratsk reservoir level. When the project was being designed, it was assumed that the maximum deviation would be 10 m. After construction of many industrial enterprises, the maximum deviation has been reduced to 5 m.

In the future a conflict may arise between industrial supply and fishing and agriculture if, for some reason, a great quantity of waste water is discharged into the Angara River. Conflict may also arise between downstream and upstream industrial enterprises, and for the same reason.

Fishing is not an important user. Due to man's interference (building reservoirs without fishways, changing the natural conditions and velocity of the river), only a small fish population has survived. Today, new kinds of fish have been artificially bred in the reservoirs. Fishing and the fish processing industry will have a substantial place in the future regional economy.

The last but not the least user is agriculture. Because of a plentiful water supply and the comparatively restricted areas for development of up-to-date agriculture, there will be no water shortage. Water quality might become a problem if fertilizers and pesticides are widely used.

Using the Angara River as a collector of purified water is a purpose the river has not served before. To prevent its pollution, special standards have been set and strictly enforced. Thus after almost ten years of operation of the Bratsk timber processing complex, the water in the river is still potable. Of course, the growth of permanent industrial activity in the BIPTC would probably change the water quality; but special measures have recently been taken for the country as a whole. For example, two new decrees of the USSR Council of Ministries were issued in June 1976 [8]. The first deals with partial or full prohibition of water use in basins /water bodies of special national significance or scientific/cultural interest. The second determines the procedure for development and approval of plans for multipurpose water resource use. It provides for three types of schemes:

- General schemes for multipurpose water use, including preservation of water quality, aimed at determining the main direction of water resource development in the USSR;
- Basin schemes for multipurpose water use, based on the general schemes;
- Territorial schemes for economic regions, union and autonomous Republics, oblasts, etc., within the framework of general and basin schemes.

All these measures and the favorable attitude of local authorities toward water quality problems ensure wise multipurpose water development.

ENVIRONMENTAL IMPACTS OF WATER RESOURCE DEVELOPMENT

How Does Nature Become Environment?

In the narrowest sense environment can be defined as an intersection between man's activities and nature; i.e., it is man's interference which makes the virgin area an environment (Figure 5).

In the sense of this definition environmentalists would like to see no difference between nature and the environment. Economists, on the other hand, would like to see maximum development of a region, taking from it all possible resources to meet society's demands. The tradeoff between these two groups has so evolved that development takes place under restrictions imposed by environmental standards, which allow some disturbance of virgin nature.

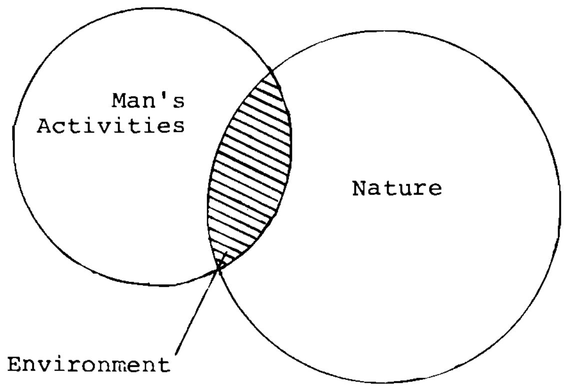

Figure 5. Man's activities, nature and environment.

In the USSR this tradeoff is made at several hierarchical levels (central government, Republics, oblast, local authorities). All of them are constrained by a number of laws governing where, how, and by whom natural resources can be used in order to prevent irreversible changes in the environment. Two recent laws of this kind have been mentioned above.

Impact of Large Reservoirs on the Environment: Climate, Land Use, Fishing

Environmental problems are discussed elsewhere in this Report. Our purpose here is to evaluate how large reservoirs on the Angara River have contributed to changes in nature and whether those changes have been significant.

Hydrometorological Changes

Although the Bratsk and the Ust-Ilimsk reservoirs cover a territory of about 7400 km^2 [10], they affect the climate in an area of only 60 km on either side of the lakes [11]. The changes observed so far are the following*:

*Data for quantity evaluation were not available at the time of writing this Report.

- Springs have become cooler;

- Autumns have become a little warmer;

- In the Irkutsk Region, no floods occurred after construction of the Irkutsk dam;

- The coastal flora has changed slightly in both quality and quantity;

- Due to increased evaporation, the number of foggy days in autumn has increased. In winter, especially in Irkutsk, fog has decreased; (due to the slower river current, the Angara remains frozen longer).

The decrease in foggy days has had a positive effect on both air navigation and land transport. Fog also has a certain urban impact. In the Ust-Ilimsk Region, construction of the Ust-Ilimsk reservoir and putting the Ust-Ilimsk HEPS into operation will increase the speed of the river current over tens of kilometers, and the river will not freeze even at very low temperatures. Due to the big difference between the water temperature (+6 °C, +8 °C) and that of the air (-25 °C, -40 °C), stable fogs will cover the area along the river beyond the Ust-Ilimsk reservoir. Therefore, construction of houses in this particular place is not recommendable.

These climatic changes have no substantial negative consequences for either the population or the environment: the environment is resilient enough to absorb man-made disturbances provided man's activities are wisely directed.

Land Changes

The impact of reservoirs on the land in the BITPC is at least threefold:

- Flooding of fertile land that had been cultivated for many years;

- Flooding of low-level roads;

- Flooding of forest areas and areas that would have been used in the future for mining ores and minerals.

In the Angara River basin, thorough investigations have been made to minimize the negative aspects of reservoir impact on the land. Nevertheless, it seems that the tradeoff was made in favor of maximizing reservoir volumes, and hence increasing power production, instead of minimizing the flooding of fertile land. For example, the Bratsk reservoir flooded 144,000 ha and the Ust-Ilimsk 36,500 ha of fertile land, respectively [9, p. 186; 13, p. 143]. This has led to a decrease both in production of agricultural goods and in people working on collective farms. Between 1950 and 1960 the farm population decreased 25 to 30 percent [13].

The reasons for this population-goods pattern are that most of the collective farmers have become construction workers--the USSR and other developed countries have experienced this phenomenon for many years--and that the amount of fertile land has decreased.

We by no means argue that to make a tradeoff between land lost and construction of big multipurpose reservoirs is a simple problem. This fact is well illustrated by the discussion, started in the early 1960s, about location of the Ust-Ilimsk dam. There were two proposals [9, p. 186-188]. The first suggested that the dam be built above the confluence of the Ilim River with the Angara River. The total area to be flooded along the Ilim River would be 94,300 ha, 14,700 of them fertile land. The capacity of the HEPS would be 1 MW less,and the total annual production 5 GWh less, than in the second proposal; but in the latter, 36,500 ha of fertile land would have to be flooded.

Hence, with the two proposals the tradeoff was between a temporary (at least 10 to 20, perhaps even 50 years) loss of 36,500 - 14,700 = 21,800 ha of fertile land, and 5 GWh annual power production. Which one is preferable? It was considered preferable to produce 5 GWh/a additional power rather than to keep 21,800 ha of land. This decision was approved by both national and local authorities. At that time, when energy was an extremely scarce resource for the projected development of the region, the decision might have been a wise one; today, with the realization that land too will be a scarce resource, one might think that the local authorities would have been wiser to accept the other alternative. However, for society as a whole, we can hardly say that the wrong alternative was chosen. This example shows that the tradeoff between alternatives for solving economic, social, and environmental problems cannot be made within the framework of a considered system. Various conditions in larger (ambient) systems should decisively contribute to decisions made in smaller systems.

Reservoir Impact on Fish and Other Water Inhabitants

According to V.M. Brown [16], "...There are four physical aspects of water which can be considered to be of major importance to fishes, namely, the volume (which determines among other things the depth of water available at any point), the velocity, the temperature, and the hydrogen ion activity (PH)."

Building the Irkutsk HEPS has led to an increase of 1 m in the level of Lake Baikal. Fortunately, because of the lake's steep sides its surface increased by 500 to 600 km^2, less than 1.4 percent. Investigations carried out by the USSR Limnological Institute have shown that small changes in the number of the fish population have appeared only near the Selenga estuary. The increased lake level disturbed the estuary and some of the islands disappeared. Under these conditions fish larvae stay longer in a comparatively low stream current, which increases the probability of their death. There would probably have been more changes in the entire Baikal fauna if, as was proposed, the lake's level had been decreased by 5 m to ensure faster filling up of the Bratsk reservoir. Fortunately, at that time there was a great environmental concern in some scientific organizations (e.g. the Limnological Institute) and by national and local authorities. Public awareness was also a decisive factor. These combined forces did not allow the ecological equilibrium in the lake to be disturbed.

Changes in the fish population of the other reservoirs in the Angara Cascade are not negligible. Because two high dams were built without a fishway, the fish population, which used to come into the upper streams of the Angara River to spawn, has decreased and even disappeared. Over the past years new kinds of fish (omul, bream, etc.) have been artificially bred into the Bratsk and Ust-Ilimsk reservoirs. A fishing industry has been developed in Bratsk, and its significance will increase in the future.

There has been one rather positive environmental effect of building the Bratsk reservoir. Before and during construction an enormous number of small insects (gnats) had been a great problem: the local population and construction workers had to wear special clothes in order not to be bitten by gnats. Ecologists and medical scientists had tried a number of pesticides and other preparations, but with only modest success. Building the dam turned out to be the solution to this problem. The gnat larvae used to breed and mature in the fast river current; when the Bratsk reservoir slowed down the current, the gnats disappeared.

Of course, not all the impacts of the Angara lakes could have been predicted at the outset. Some of the environmental consequences are probably still unknown since the region is still being developed. In this respect the most valuable thing we saw during our visit is the great awareness of environmental problems on the part of both scientists and managers. This fact will assure more comprehensive imbedding of environmental factors in future plans for development of the BITPC.

CONCLUSIONS

Water resource development in the USSR as well as in the rest of the world has been following two patterns:

- Development forced by extreme water resource situations (floods, droughts), typified by the great scientific and construction effort made in water transfer in the USSR;

- Water resource development initiated to promote industrial, agricultural, and social development, to change the face of a certain region.

In the BITPC it is certainly the second type of development that has taken place. In this formerly unpopulated area neither floods or droughts could have been dangerous. But all the development experience indicates that sooner or later people become aware of the inadequacy of water, in quantity or quality or both. Most of the industrialized regions of the world have reached this stage. The BITPC still has an abundant water supply of high quality; and according to some authors, 50 percent of the Angara water resources (including its tributaries) is yet to be developed. Projections indicate further industrial development. It is a challenge to scientists, practitioners, and various levels of authority to continue development under environmental standards that are becoming stricter and stricter. It is a great hope that if they succeed, mankind as a whole will greatly benefit.

In conclusion, we should like to make one further comment. In order to understand the whole process of water development in the USSR, to study economic, engineering, and environmental problems is not enough. Many of those who came to this virgin region (of extremely severe conditions) did not do so just because salaries were higher. Other forces were at work--among the, people's consciousness and gratification in seeing things grow before their eyes. A real systems analysis of these factors would round out the picture and would be of help to many world regions with unfavorable climatic conditions.

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