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Regional Systems Analysis Applied to the Silistra Region of Bulgaria - A Progress Report

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REGIONAL SYSTEMS ANALYSIS APPLIED TO THE SILISTRA REGION OF BULGARIA - A PROGRESS REPORT

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PREFACE

Regional policy problems are universal. This means that all countries need good methods for analyzing and solving their regional problems. Models for regional policy making and planning have also been worked out in scientific institutions. It is obvious that these abstract models are often not specific enough to be used in policy making but have to be adapted to the institutional, historical and natural conditions of the specific region to be planned. It is also necessary to integrate the models within a comprehensive system analytical framework. It is one of the ambitions with the Silistra regional case study reported in this paper, to test the possibility of applying regional policy models, developed in Bulgaria, at IIASA and elsewhere, to the solution of the Silistra development problems and to regional planning issues in other Bulgarian regions. This paper describes briefly the work undertaken by scholars within the Regional Development Task and elsewhere at IIASA on this topic.

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REGIONAL SYSTEMS ANALYSIS APPLIED TO THE SILISTRA REGION OF BULGARIA - A PROGRESS REPORT

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INTRODUCTION

In the middle of 1977, a formal agreement between IIASA and Bulgaria was signed which foresaw joint work on the Silistra case study. This work was begun in the beginning of 1978 when the group of collaborating institutions in Bulgaria began active participation in the work, and the liaison between the two groups became regular. Since then, periodic meetings, seminars and workshops have been held:

1. Task Force Meeting I, held at IIASA (May 1978).
2. Seminar "Interdisciplinary Discussion on the Coordination of work on the Silistra Region Development," held in Sofia (March 1979).
3. Task Force Meeting II, held at IIASA (May 1979).
4. Workshop "Models of Regional Development Planning," held in Burgas (October 1979).

The results of the first meeting have been published in the IIASA series (CP-79-7).

The aim of the present paper is to briefly evaluate the work done to date and formulate the aims of future work.

PROBLEMS ADDRESSED IN THE SILISTRA STUDY

The most important problem to be solved in the Silistra case study is to develop a consistent approach to regional development planning and policymaking in Bulgaria.

The more specific aims and goals of the project are the following.

A strategic policy for regional development should be created together with the necessary system of models for this purpose. These models should shed light on the importance of the interdependencies between regional subsystems and give an indication of how different regional subsystem models can be coordinated.

An important problem to be solved in the general analysis is to generate consistent scenarios for population development in different regions. The total number of regions of which Silistra is one is 28. This analysis should include a study of migration scenarios and their relation to economic policies in the different regions.

An important problem in the regional context is sectoral specialization of the regional economies. This involves policies for the selection of agricultural, industrial and service sectors in the country and its different regions. This analysis should take into account an efficient use of resources such as labor, investments and natural resources like water and land.

For the Silistra region as such, the most important problem is to devise efficient land use and locational policies and its consequences for the development of settlement and service systems. This study should include an analysis of the principles of administration and settlements.

Silistra is a region of great importance for agricultural production and is expected to be a center of agriculture also in the future. This means that methods for strategic agricultural policies must be developed and adapted to the region. The current policy problems include efficient land use, crop and livestock structures and the use of water and energy.

The industry of Silistra is currently not large but a general expansion of manufacturing industry can be foreseen for Bulgaria and should also be reflected in industrial policies for the Silistra region.

The development of agriculture and manufacturing industry in different parts of the region are highly dependent upon regional water resource development. To this end, it has been requested that water resource development policies should be an important part of the study.

The design of new settlement systems, changes in location patterns will inevitably lead to requirements for new transportation and communication capacity in the region. This involves the analysis of the relation to other regions in Bulgaria as well as designs of new transportation strategies for the region as such. Included in this are better forecasts of transportation demands as well as development of efficient transportation investment policies.

Finally, the Silistra region has up to now been able to avoid many of the environmental problems of other, densely populated regions of the country. Industrialization and change of agricultural policies as well as water resource development can easily lead to environmental deterioration. It is requested that the development of methods of strategic economic policy for the regions should take environmental protection into proper account. In connection with this environmental study it is also necessary to analyze the relation between general development of the economic capacity of the region, environmental standards, patterns of diseases and efficient health care policies.

The general aims of the Silistra region development can be given a precise formulation (in accordance with the viewpoint of local decisionmakers) in the following way:

a) to maximize the rate of regional growth (in general terms) taking into account agricultural, as well as industrial and service sectors;
b) to keep regional agriculture on a level no less than the existing one in terms of national production;
c) to reach the national structure of industrial development;
d) to decrease outmigration from the region as well as intraregional rural-urban migration; and
e) to maximize the growth of the average wage rate for the region as a whole.

Taking into account the necessity to address all these goals, an elaboration of different approaches began in 1978.

THE CHOICE OF SYSTEMS ANALYSIS APPROACH

Regional systems analysis is an application of systems analysis to policy making in a dynamic and spatial perspective. Space can be handled in essentially two ways. We can either analyze the problem in continuous space as proposed by Martin Beckmann, Tonu Puu, Walter Isard and Edwin Mills, inter alia. The other principle is to subdivide the total space (for instance the nation) into a discrete set of regions. We have in our development of a systems analysis approach to regional development generally chosen the discrete, regional approach to spatial analysis. In most cases we have also chosen to handle time as a discrete set of time periods.

The policymaking problems are mostly in regional development analysis of a long-term nature. This means that uncertainties are a rule rather than an exception. Furthermore, we cannot expect these uncertainties to be well-structured in the sense that one can apply stochastic theory to the handling of them. It is rather the case that the uncertainties are of a more fundamental and ill-structured nature. For a region, the development of certain crucial national or international parameters (like the price of oil) is impossible to forecast in a more or less reliable way. We have found development scenarios for such external important parameters to be a much more promising approach.

Principles of Regional Decomposition

In a purely theoretical general equilibrium analysis of the kind proposed by Debreu (1959)* each decision variable, for instance the quantity to be produced, is indicated by time, decision maker, type of commodity and region. To prove the existence of a solution to such an interregional equilibrium problem, even with an infinitely large number of consumers and producers, is not impossible in a static situation. However, this approach requires a large number of simplifying and not very realistic assumptions about convexity of preference and production sets. Such assumptions are normally not valid in the real world.

The extension of this approach to realistic transportation-communication technologies and situations of growth and development has never been possible as an extension of the basic static theory. To cope with policymaking problems in such a dynamic, interdependent regional production and consumption system, decomposition and simplification is necessary. Simplification through decomposition and structuring of the regional development problems has been proposed by many analysts in the market- and plan-oriented economies. Some prominent names in this field are Walter Isard, Vasilii Leontief, Abel Aganbegyan and Alexander Granberg. Common to the approaches of these scientists is simplification through linearization of technologies for production, transportation, and consumption of commodities. With linearization it is mostly possible to solve problems with hundreds of regions and a rather large number of production sectors and different categories of households.

Two types of criticisms can be raised against the linearized approach proposed by Leontief and others. The first criticism concerns economies of scale in production and transportation of commodities. Economies of scale in production leads to non-linearities, which however, for sufficiently large regions are of limited importance. Leontief and similar world regional modelers can thus claim that linearization is of no real importance for their regional policy problems. In a national regional problem formulation one must however take this criticism seriously. The regions which form a part of a nation are normally rather small and economies of scale cannot be disregarded in the model formulation.

Furthermore, transportation and communication are phenomena which cannot, according to modern transportation-communication theory, be linearized but are non-linear on any scale of aggregation. It can, in fact, be argued that the higher the level of aggregation, the more non-linear it becomes.

From this point of view our approach to regional systems analysis has not been limited to simplification or linearization but in the cases where the linearization was justified, it was widely used.

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*Debreu, G., Theory of Value, Cowles Foundation Monograph 17. New York: John Wiley and Sons Inc., 1959.

We have rather chosen to simplify the long-term regional policymaking problems through decomposition of the total problems into a set of interlinked models. These submodels are linear, non-linear, integer or real-valued in accordance with the best formulation of the problem and the technologies and behaviors reflected by the models.

Decomposition and Structuring of the Regional Policy System

In decomposing a regional policy problem, there are basically two principles.

A. A procedure based on successively constraining policy actions from an international through a national, down to the regional level. (Top-down approach).

B. Another approach is to start with the planning of the individual region, aggregating those plans up to a national level, and then confronting the regional and national aggregates with the world markets. (Bottom-up approach).

At the same time, a third approach can be mentioned which is in fact the further development of A with respect to mutual regional interdependence.

It has often been assumed that these approaches are related to different institutional frameworks. This is only partially true. It is true that international organizations tend to prefer the interdependency approach. It is also true that planning in some fairly decentralized countries like the Scandinavian, has been more oriented to the "bottom-up" approach. In reality, the scale of the region is more important for the choice of approach. A relatively large region cannot disregard the impact of its policies on other regions and even on the nation as a whole. In such a case, it is fairly natural to use the interdependency approach in which the policies of the large regions are considered simultaneously in its natural context. In the case of small regions, one can safely disregard the effect of each one of the small regions on other, larger regions and the nation as a whole. In these cases causality tends to go in a one-way direction. International and national technological and market development determine the action possibilities for the regions, while it can be safely assumed that the actions taken in any single region will not influence national and international development to any significant degree.

Since the Silistra region is relatively small, the first two approaches ("top-down" and "bottom-up") were used to date in the IIASA study.

METHOD A: THE TOP-DOWN APPROACH TO REGIONAL SYSTEMS ANALYSIS

Silistra is, in comparison with Bulgaria as a whole, very small both in terms of employment and production. This means that decisions taken at a national level and international level on development of technology and trade patterns will be important constraints for the decision maker of the Silistra region. This implies that it becomes extremely important to predict the development at the national level and its regional consequences in order to use these development tendencies as external constraints.

It must be stressed that the construction of such national and international scenarios do not necessarily have to be developed by central research organizations. In theory, and very often in practice, such scenarios can be developed within the region. Economies of scale in gathering and processing of information, however, provide strong economic arguments for having the national and international development scenarios centrally produced.

This is also the reason why models for analysis of sectoral development have been constructed in cooperation with central research institutes in Sofia.

During 1979, and especially at the Conference at Burgas (Bulgaria) in October 1979, an extensive cooperation on development of national sectoral models was set up. It was then agreed that the multi-sectoral model developed by Lars Bergman, the INFORUM model as developed by Almon and Nyhus, and the TURNPIKE model, developed by Ake Andersson should be used in an interactive fashion to generate sectoral growth scenarios. These three models have complementary features. The TURNPIKE model is a model that searches for the growth maximizing investments policy for an economy that is supposed to grow with an equilibrium between supply and demand during the whole growth process. The model requires input-output and investment coefficients to be determined outside the model. This is done in two stages. One stage by application of the method for estimation of capital output ratios developed by David Batten, Dino Martellato and Ake Andersson. Another procedure is to use the estimates of energy and labor input coefficients as determined by the MSG model, developed by Lars Bergman. The result of this interactive procedure is a development of investment and consumption patterns that can be used to feed the INFORUM model to generate a yearly trajectory for the different sectors. The outcome of this package of sectoral models is a set of price, production, investments and employment scenarios for the different sectors of the Bulgarian economy. The fusing of these different scenarios into a limited number of common planning scenarios for the sectoral development is evidently a political problem that must be solved by Bulgarian policy makers.

At the next stage of analysis the interregional location of employment, investments and production model (MIRROR model) is used. This model uses as initial information the national sectoral scenarios as well as local information about the regional population growth and regional employment policy. The principle of minimum information gain is used and in this case means a minimum of reorganization.

The accepted growth scenarios in terms of sectoral production and investments can be used as constraints on the aggregated regional development in the 28 Bulgarian regions, of which the Silistra region is one. The population development as projected by the HSS model adapted to Bulgaria can give labor supply scenarios for the 28 regions. Sectoral, national production and regional employment scenarios are then used as constraints on the interregional location model. The natural inertia to relocation of production is then built into the goal function of the model. The essential idea is to search for a location of production that can fulfill the sectoral production goals and the regional employment goals together with sectoral and regional resource constraints while at the same time, minimizing the restructuring of the Bulgarian economy. With this formulation we hope to generate fast economic growth from full employment, realistic resource use with the minimum of institutional frictions in the regional economies.

The allocation of activities with the help of the MIRROR model created the basis for the next step: the analysis of intraregional problems. For this purpose a model for intraregional dynamic location of indivisible units of production has been developed in cooperation with SDS. This model (often referred to as MALTOS) allocates indivisible areas of land to the different production sectors over a discrete set of time periods.

This model is a multi-objective quadratic integer programming model with a set of different evaluation criteria:

- o investment, demolition and operating costs (linear);
- o accessibility of sectors of production and consumption to other activities and prelocated resources (quadratic):
- o node congestion costs (quadratic); and
- o environmental synergism costs (quadratic).

In this model which can also be classified as a combinatorial synergistic design model, patterns of land use will be generated. Because of the non-convexity of this problem, the need for a large number of scenarios must be stressed more than in connection with any other model of this package. As a rule, we can expect to have many local optima, where each one of the local optima have fairly similar values of the goal function.

The results of MALTOS can be used to generate constraints for land use in the more detailed analysis of service location, agriculture location, detailed industry location, transportation behavior, etc.

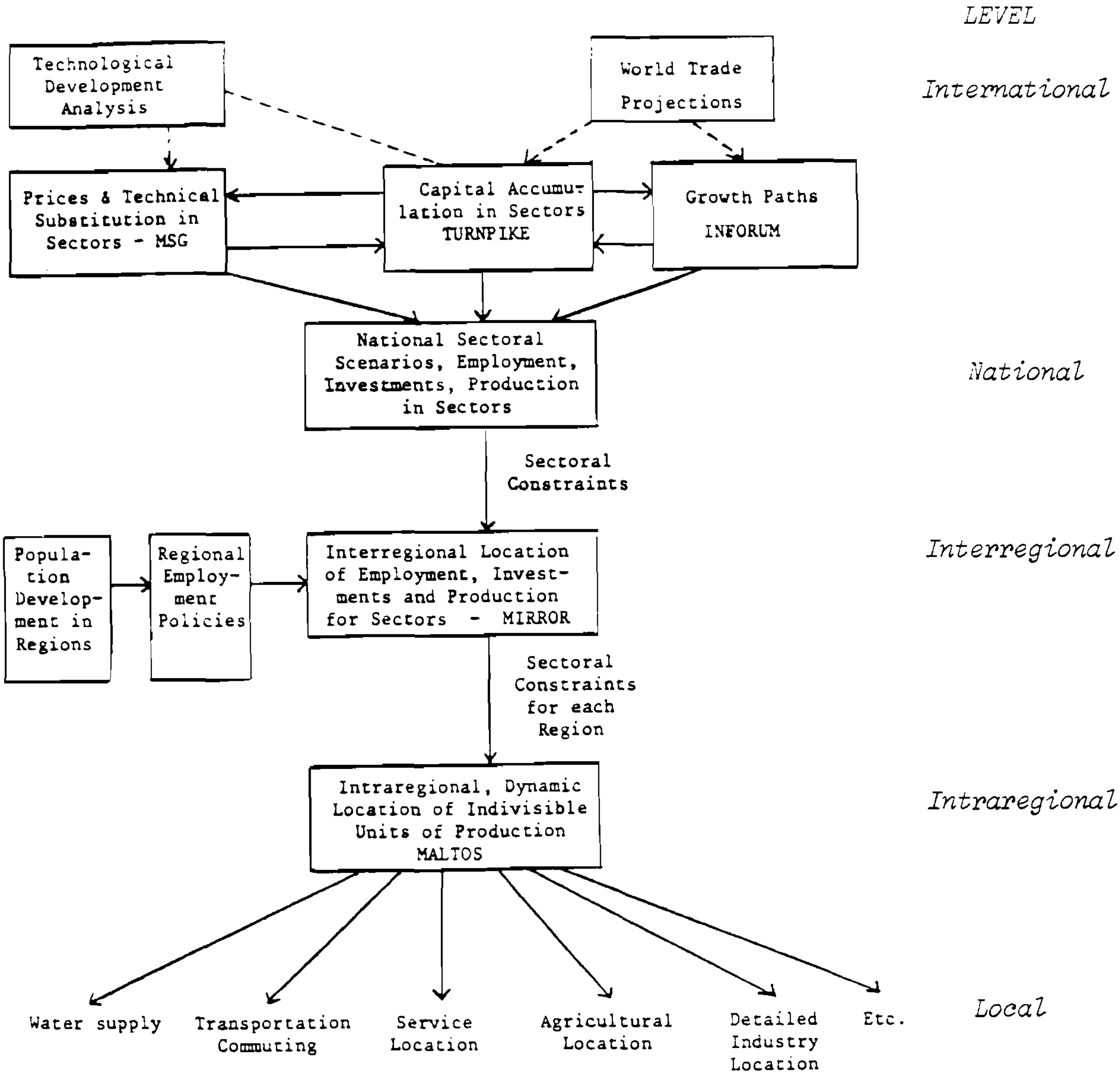

Figure 1. METHOD A: The Top-Down Approach to Regional Systems Analysis.

Results Obtained and Expected Activities

The models developed during 1978 and 1979 which are being transfered to Bulgaria are discussed in the following publications: WP-79-04, WP-79-9, WP-79-97, WP-79-111 (which refer to the MSG, INFORUM, TURNPIKE, MIRROR and MALTOS models). The work on their implementation in Bulgaria has begun, but it will be some time before results will be seen. The models on a national level will serve as scenario-producing for the Silistra case, as well as for other implementations as well. MIRROR and MALTOS are planned to be used in the framework of the Silistra Complex Project.

The main goal for the future is to gather initial information (by the Bulgarians) in order that the IIASA models should be made operational in Bulgaria (in this case IIASA scholars will be consulting in Bulgaria) and analyze the obtained results jointly. Work with realistic data will begin in the middle of 1980 and will go on for one year. The results of this work will be incorporated into the *Complex Project*.

METHOD B: THE BOTTOM-UP APPROACH TO REGIONAL SYSTEM ANALYSIS

This approach is based on the detailed description of the regional sectors of the economy where intrarregional problems are carefully examined and the coordination of the sectors will be done with respect to two overall resources: capital and labor force.

The general scheme of the system is shown in Figure 2. It includes the following models:

1. Generalized regional agricultural model (GRAM).
2. Generalized industrial growth and location model.
3. Regional transportation system model.
4. Regional water supply model.
5. Regional population and migration model.

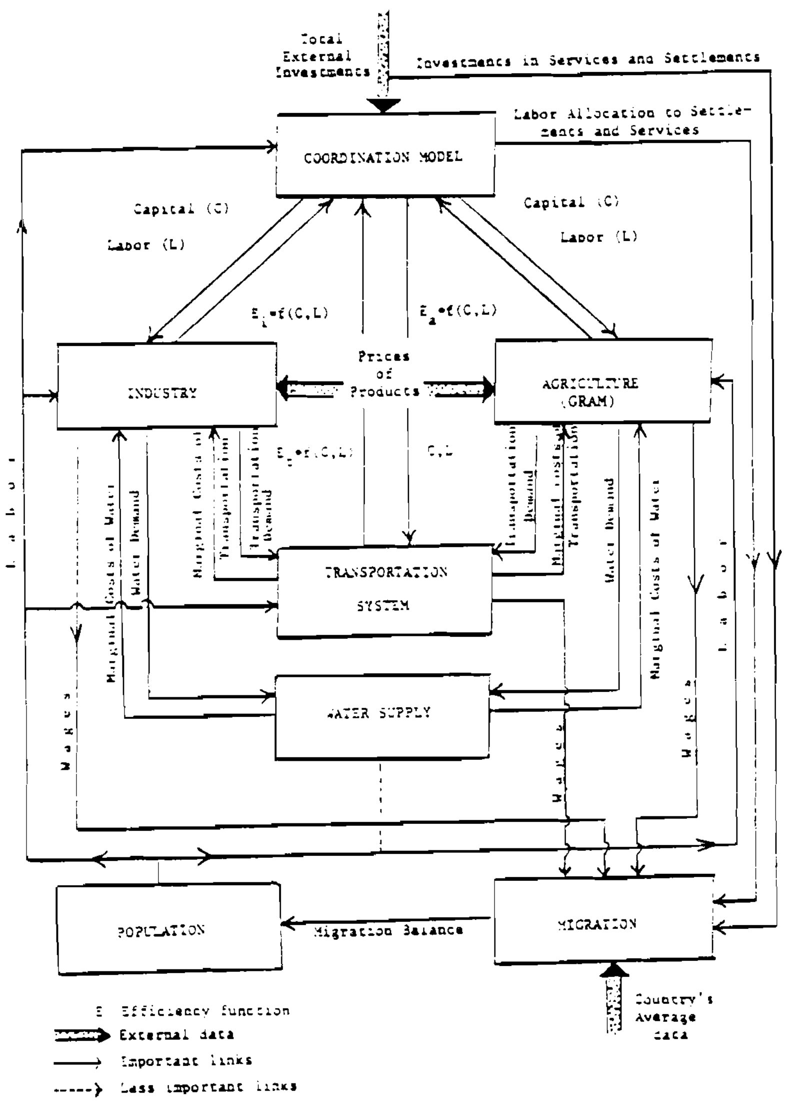

Figure 2. METHOD B: Bottom-Up Approach to Systems Analysis - First Version.

The principal purpose of the GRAM model is to achieve results that can be used for the formation of policy regarding future regional agricultural specialization. GRAM is strictly limited to solving agricultural problems but must also be able to include all significant feedbacks and results from other subsystems, such as water, industry and labor.

Although GRAM is a detailed model, it is essentially intended as a general model and as such must describe a variety of agricultural and technological conditions; for example, all aspects of land use, all possibilities for land improvement, and alternative animal-feed compositions.

The main characteristics of regional agricultural development that are included in the model are:

- -- regional agricultural specialization;
- -- crop and livestock production in disaggregated form;
- -- regional agricultural specialization;
- -- crop and livestock production in disaggregated form;
- -- land-use problems, with reference to irrigation, drainage, the use of pastures, and so on;
- -- alternative animal-feed compositions (protein, rough and green forage, etc.) for balanced animal-feed rations;
- -- crop-rotation conditions;
- -- possibilities for second crop productions; and
- -- availability of regional supplies of labor, capital investments, fertilizers, water, etc.

Next to the detailed description of "technological" issues the possibility of multi-objective analysis is foreseen. The implementation of the model is relatively simple because of a special generator elaborated by William Orchard-Hays.

The Regional Industrial Model

This model which is broad enough to cover many cases, was elaborated by a group of scholars in the Central Economic Mathematical Institute, Moscow.* The model has the following features of specialization:

1. It can be used for a one-product system and also for a multi-product system. For the latter, several products have to be aggregated and all inputs and outputs should be calculated with respect to the unit of aggregate product.
2. For each location the appropriate capacity and the technology for the production unit can be chosen.
3. Transportable and non-transportable products can be included in models. The latter may refer to, for example, intermediate products that are used at the point of production.

*Mednidski, V. (1978) Special Methods of Optimization Problem Solution. Nauka, Moscow (in Russian).

4. Local demand, and also demand of other regions can be included in the model (this extra-regional demand may be concentrated at points near the boundaries of the region under analysis
5. Elements of substitution in the process of pro-dunction and consumption can be introduced.

What is most important is that the system has been created (which would otherwise require many person-years). The linkage between IIASA (Laxenburg) and Moscow by a special computer line makes this package of programs accessible.

Regional Transportation System Model

The transportation system model designed by B. Mihailov was built for all 6 possible transport modes, all 139 projected nodes of the region and 17 types of loads according to the current aggregation of the loads. For that purpose, a transportation network including the existing and possible transportation modes has been designed.

The model was solved in two versions: a linear and a more complicated non-linear version, each of them on two levels: for each mode of transport and for the regional transportation system as a whole (see Figure 3).

At the level of each transportation mode in the region, a local optimization of development using an objective function of minimum total annual costs was performed in a way that for each possible set of traffic volumes, the optimal alternative to be included when optimizing development of the whole regional transportation system is identified. The chosen technological alternative belongs to a concrete traffic volume which is subject to distribution between the different transport modes at a regional level. Thus, the global optimization at a regional level was done on the basis of the preliminary optimization of individual transportation modes. Thus optimal development in a global sense is based on local efficiency. In this way, the minimum total costs for development of the regional transportation system were reached.

Regional Water Supply Model

The work on the Silistra water supply modeling was carried out by V. Chernyatin (IIASA) in close cooperation with the Sofia Institute for Water Projects (SIWP). That is one reason why the main purpose of the mathematical modeling was achieved, i.e. to determine an optimal and practical design of a water supply system.

The Silistra water supply model was basically developed at IIASA in 1979. By definition it is a linear programming model. The output of the model is:

1. Basic parameters of a water supply system; capacities of reservoirs and pumping stations, and discharge capacities of canals.
2. Within-year operational rules for all the water supply facilities.
3. Marginal costs (seasonal and mean-annual) of water for all considered areas.

In 1979 the Silistra water supply model was implemented on the computers in Pisa (IBM 365/170) and Sofia (ICL 1904). Being initially intended for Silistra, this model was generalized to cover the whole set of irrigation systems of the same type as "Silistra". The main elements of generalization here are:

-- many water inputs to the water supply system can be handled as well as
-- arbitrary configuration of the water supply system;
-- possibility of simulation of stream flows with within-year regulation of water;
-- possibility of physical connection with other water supply systems;
-- possibility of simultaneous numerical analysis of a number of water supply systems.

Population and Migration Models

The following approaches have been used here: to implement the HSS methodology (A. Rogers, RR-79-18) on population growth and to combine this with the results of the A. Andersson and Philipov study of the Silistra region migration. This approach is based on the requirement to combine projections of future regional population growth (including fixed fertility and mortality rates) with the results of migration policy which can to some extent be controlled.

The methodology of regional population projection was successfully implemented by D. Philipov and B. Mihailov. At the same time, the Andersson/Philipov study has shown that a logit-type model can be used for interregional migration prediction. In this model, the following factors of migration are important: the relative size of local population, quality of local services, mean wage, dwellings per person, distance from the capital.

A combination of these two models seems to be promising for local labor forecasts.

Results Obtained and Expected Activities

Four models of the "bottom-up" approach have now been applied to the Silistra case study: The water supply, GRAM, Transportation System, and Population and Migration models. The water supply model was not only run with real data, but important proposals were made to the Water Project Institute in Sofia about changes of the projected water supply system. These changes led to significant economic savings for the Bulgarians.

The GRAM model was generated at IIASA and is now being run in Sofia. The models of population and migration were tested with real data; first results have also been obtained using the regional transportation model.

The task for the future is twofold:

1. To obtain realistic results for every single model (to complete the calculations on GRAM, on the migration and transportation models).

2. Following the completion of the separate models, to include these into one system and to verify their practical usefulness; firstly for the simplified example, then for a full-fledged analysis of the Silistra case (completion date: 1981).

EFFORTS REQUIRED

The work at IIASA on the system of models for the Silistra region contributed to some extent to the decision of the Bulgarian government to approve a Complex Project for the development of this region. This Project includes more aspects than our work on the system of models: a social development project, a cultural project, an education project, etc., which makes the work at IIASA on the system of models even more important and necessary as a part of a general system for regional planning.

At present, the work on the system of models serves as a basis for the elaboration of the Complex Project. In this respect we have to collaborate with almost all of the 34 scientific and project groups in Bulgaria who work according to the accepted Coordinative Program.

In accordance with the joint working plan with Bulgaria, the following models are being worked on at IIASA: GRAM, population and migration, industry, transportation system, water resources, and health care models and the hierarchical regional system of models, described above. In this work, one scientist within the Regional Development Task is fully engaged and three scientists are working on these part time. Several scholars from other groups (SDS, HSS) are also participating in this work.

Taking into account the crucial stage of our work, where more intensive IIASA participation is needed for the adjustment of the individual models to the system of models (for the testing of the individual as well as the system of models, for the strengthening of the coordinative work with the Bulgarian scientists in Bulgaria) the level of involvement in 1980 should not decrease from that in 1979.

COLLABORATIONS

We work directly with the following Bulgarian institutions:

1. Institute for Social Management (the coordinating institute)
   Pionerski Put 21, Sofia.

2. Complex Research Design Institute for Territorial Development, Urbanization and Architecture (KNIPITUGA)
   Rakovsky 134, Sofia.

3. Institute for Complex Transportation Problems
   Ministry of Transport
   Levski 9, Sofia.

4. Bulgarian Academy of Sciences, Institute for Technical Cybernetics
   Acad. G. Bontschev street, Block IV, V Floor, Sofia.

5. Scientific Institute for Social Hygiene and Health Care Organization
   Dimitar Nestrorov street 15, Sofia.

6. ISA "Agrocomplekt" of the Ministry of Agriculture and Food Industry
   Sofia.

7. Bulgarian Academy of Sciences, Scientific Coordination Center for Environmental Protection
   Gargarin street 2, Sofia.

8. Institute of Agriculture, Economy and Organization
   Ministry of Agriculture
   Sofia.

9. Computer Information Center, Ministry of Agriculture
   Sofia.

10. Scientific Research Institute for Territorial Planning
    State Planning Committee
    Sofia.

11. Economic University "Karl Marx", Laboratory for Demogaphic Investigations
    Sofia.

12. State Planning Committee
    Sofia.

13. Research Institute for Construction
    Sofia.

14. Institute for Water Projects
    Sofia.

These institutes, jointly with the Silistra region authorities, are responsible for the preparation of information, model implementation and assessment of results (this is done jointly with the IIASA Regional Development Task).

Our Bulgarian counterparts depend on the kinds of output we produce. Three types of results are expected:

-- educational;
-- methodological; and
-- qualitative and quantitative policy recommen recommendations.

The first type of output is rather advanced: a number of models were elaborated at IIASA and transfered to Bulgaria and the meeting in Burgas (October 1979) was devoted to this. One of the models (water supply) was not only transfered to Bulgaria but special guidance for users was also prepared.

The methodological work is more important for high level policy makers in Bulgaria. We believe that some of our findings could be used by the following bodies:

- State Council of the People's Republic of Bulgaria (in particular, the Council of Management--Chairman: Prof. Emil Christov), supervising the work on the Silistra Complex Project;

- National Committee for Applied Systems Analysis and Management (Chairman: Prof. David Davidov), the main coordinator between IIASA and Bulgaria; develops and approves the research plans of all research institutes and approves their budgets;

- State Planning Committee (Deputy Chairman: Prof. Naidenov); in relation with its Institute for Territorial Planning working directly on the territorial distriburion of the production of social activities;

- Institute for Social Management (Director: Prof. Nicolov), main coordinative institute for all Bulgarian research and project institutes concerning both the Complex Project and the system of models for the Silistra Silistra region.

The third group of output (qualitative and quantitative policy recommendations) are very important, firstly for our main partner (the Silistra authority):

- Country People's Council of the Silistra Region (Chairman: D. Mihailov), the main user of the Complex Project and of the regional system of models provides all necessary data.

At the same time, some of the results can be used by separate project institutes (as was the case with the irrigation system) or by the State Planning Committee.

To summarize, it should be noted that our main partner on a scientific level is the Institute for Social Management and the main user of the results is the People's Council of the Silistra Region.