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Contents

Nondifferentiable and Nonsmooth optimization

Yuri M. Ermoliev
Evgeni A. Nurminski
Andrzej P. Wierzbicki*

Nondifferentiable or nonsmooth optimization—a branch of mathematics no more than 15 to 20 years old, represents an area of central importance to the development of methodological tools for systems analysis. Two meetings have been held at IIASA on this topic and a small group of scholars is engaged in research in this field at the Institute. In the following contribution the authors try to provide an insight into this complex matter.

The problem of choosing the best way of doing things—the best design of a technical device, the best decision or strategy in a developing situation—is as old as human civilization and has always attracted the analytical attention of mathematicians. One of the simplest representations of this problem is to minimize (or maximize) a mathematically expressed function that relates the goal of the decision maker to factors that he can influence or decide on. These factors are naturally constrained, which limits possible decisions. More complicated approaches allow the inclusion of, for example, random aspects of uncertainty, dynamic aspects of situations developing in time, multiobjective aspects and many (possibly conflicting) goal, game-theoretical formulations of conflict, or collaboration between many decision makers. The development of computers has made it possible to solve more and more complicated models of this general type and has stimulated the development of a branch of applied mathematics called mathematical programming or optimization. The use of the systems analytical approach to complex problems of modern society was not only based on optimization as one of its fundamental tools, but also has stimulated further development of optimization theory.

Systems analysis problems are usually complex—they are multiobjective, dynamic, have many uncertainties and, above all, have a large number of variables represented by a mathematical model. Of paramount importance in systems analysis is the vexing question of how to build models that represent

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*Dr. Yuri Ermoliev, USSR, Head of the Department of Mathematical Methods of Operations Research at the Institute of Cybernetics, Ukrainian Academy of Sciences since 1969, joined IIASA's System and Decision Sciences Area in October 1978 to undertake research on methods of stochastic and nondifferentiable optimization.
Dr. Evgeni Nurminski, USSR, joined IIASA's System and Decision Sciences Area in July 1978 to work on nondifferentiable optimization. He is senior research scholar at the Institute of Cybernetics of the Ukrainian Academy of Sciences in Kiev.
Prof. Andrzej Wierzbicki, Poland, Dean of the Faculty of Electronic Engineering of the Technical University of Warsaw, joined IIASA's System and Decision Sciences Area in October 1978, to do research on optimization theory and applications, including multiobjective optimization and decision making, augmented Lagrange Functions, and nondifferentiable optimization.

Nondifferentiable and Nonsmooth optimization

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the most pertinent features of a real-life problem, but that are not too complicated to be solved in a reasonable time on a computer with existing solution techniques. This question illustrates both the value of optimization theory in systems analysis and the challenges of systems analysis applications to optimization theory. A systems analyst must be aware of which types of mathematical models are less or more difficult to handle for further optimization and which solution techniques exist for a given class of models. The optimization specialists' involvement in all phases of the research is therefore necessary: from the initial model formulation to the final solution stage.

Optimization helps, but...

Very often the solution of optimization problems for a given system provides a deep insight into the interaction of the many factors involved and the many constraints imposed on the decisions. Naturally, a mathematical model of a systems analytical problem always remains a model and cannot replace human judgment in actual decision making. Optimization techniques help to eliminate decisions that are not optimal for any of the goals considered and reduce the number of possible alternatives to be further analyzed and decided on. On the other hand, the wide range of models used in systems analysis provides the mathematician with the challenging question of revising existing theoretical tools and checking whether axioms underlying a given mathematical theory are really compatible with the needs of systems analysis applications.

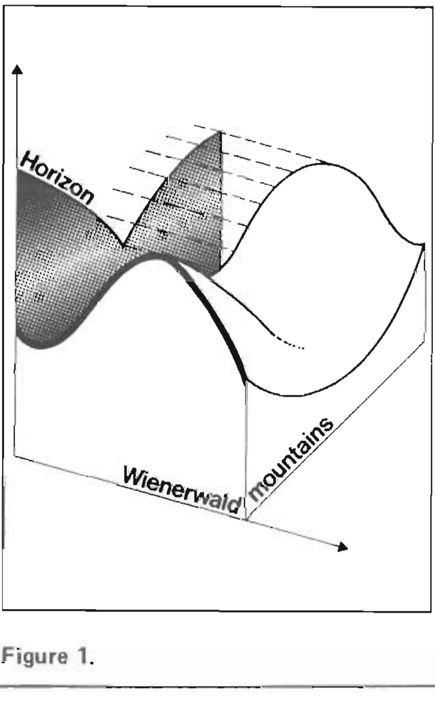

Figure 1.

An example of such revisions of basic assumptions is the development of a recent branch of mathematical programming. The branch, today called "nonsmooth" and/or "nondifferentiable" optimization, first attracted serious attention in the early 1960s from mathematicians working on applied optimization models in economics and other fields. Up to that time, the use of smooth or differentiable functions (functions that do not show any jumps or sharp corners in their graphs) in real models was believed to be sufficient. Moreover, it was also believed that if a model contains some ill-behaved functions, classical optimization methods could be applied in order to optimize it. Recent research shows that both of these widely held beliefs are not true in models of many important fields.

The Wienerwald near IIASA provides a good example of the nondifferentiability arising in a real system. No matter how smooth the mountains and valleys

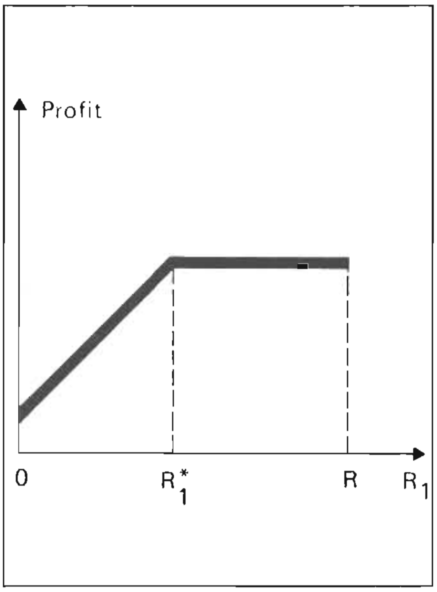

Figure 2a.

of the Wienerwald might be, when projected on a horizon their image appears to have sharp angles and turns (Figure 1). To represent it therefore requires a nondifferentiable mathematical function. As another less visual or obvious example, consider a system consisting of two subsystems each of which is described by a linear programming model and both of which share one common resource. The objective function in each subsystem is a nondifferentiable function of the amount of allocated resource (see Figure 2a). Let R_1, R_2 denote the amounts of the common resource $R = R_1 + R_2$ allocated to subsystems 1 and 2. If R_1 exceeds a critical value R_1^*, then a further increase of the allocated resource does not result in any further growth of the objective function; this subsystem cannot profitably use more than this critical amount because of other limitations. The same is true for R_2 and R_2^* in the second subsystem.

Suppose the total output of the subsystems corresponds to the sum of their objective functions. Then the total profit as a function of resource distribution (Figure 2b, c) is nondifferentiable. Suppose, conversely, that the total output corresponds to the minimal output from the two subsystems (the "worst case" analysis); then the function has another shape (Figure 2d), but is still nondifferentiable. This example is only a small indication of the problems arising in, for example, equilibrium analysis of economic systems and the linkage of

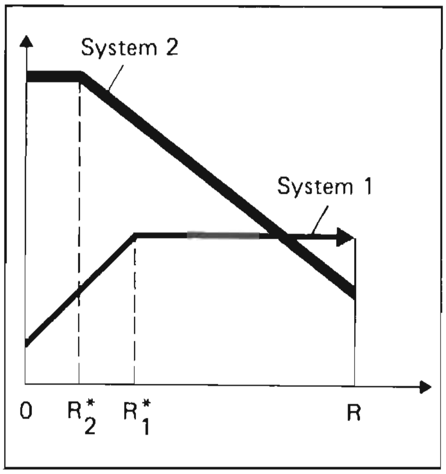

Figure 2b.

models of national economies in an international system. For all these problems, the nondifferentiability of the resulting functions, criteria, objectives and constraints is a fundamental internal property and must be considered to be the rule and not the exception.

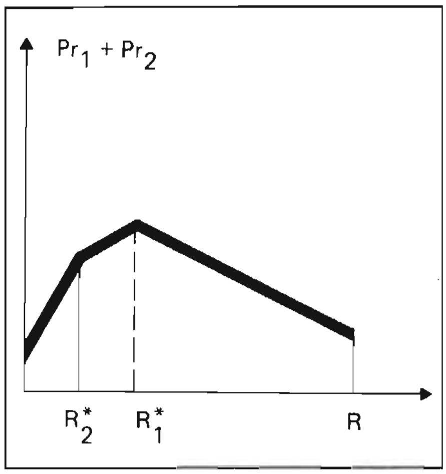

Figure 2c.

Some Mathematics

The problems of nondifferentiable optimization also need specific solution methods, which have become the next steps in the development of mathematical programming. Although the simplest example given above can be solved in a straightforward manner, for more complicated problems the methods of classical smooth optimization are not likely to succeed. For nondifferentiable functions, the rate of decrease in a given direction at one point can differ greatly from the rate computed at a neighboring point. Thus, a linear or quadratic approximation of the function (which is typically employed in the methods of traditional smooth optimization) will differ significantly from the function itself.

Consider, for instance, the nondifferentiable function

$$f(x) = \min_{i=1,\dots,N} \frac{x_i}{c_i}$$

which might describe the number of cars that may be assembled from given quantities of different kinds of parts, x_i, and the corresponding required quantities of the parts per unit, c_i (a car needs four wheels, etc.). A possible strategy for increasing f(x) is to change the variables x_i by some trial amounts or variations. If the function f(x) were smooth, and if the variations were small enough, half of all attempts would result in an increase of the objective. In the nondifferentiable case, however, this is not so. In this example, at the point $x_i = c_i$, for all i, only simultaneous increases of all variables would improve the objective function. It is useful to notice that such an increase is a single choice among 2^N possibilities. For N = 100, one has to find this choice among more than 10^{30} variants. In modeling real situations, N can be in the thousands, and the interaction among different variables becomes much more complicated.

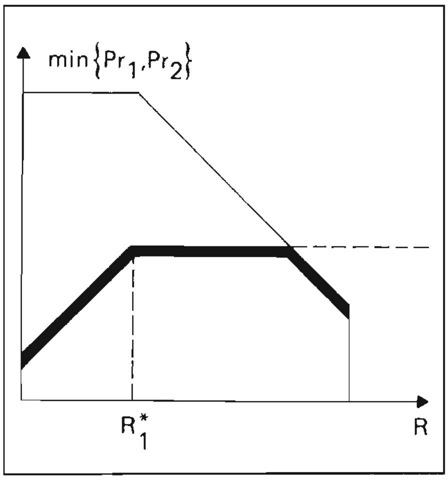

Figure 2d.

The consideration of objective or constraint functions that have jumps or corners severely complicates the handling of models, so until recently they have been generally avoided. However, the growing need for solving large-scale models in planning, resource allocation, and economic equilibrium analysis led to the recognition by mathematicians throughout the world of the need for solutions to nondifferentiable optimization problems.

First Results

The earliest promising results were obtained by a group at the Institute of Cybernetics of the Ukrainian Academy of Sciences in Kiev, where this work started in 1963-64. For possibilities for review of these results and further developments, see Shor [8]. The monograph by Ermoliev [2] covers a range of results in nondifferentiable optimization where stochastic factors are also involved. Many efficient methods were also developed by a group of mathematicians in Leningrad led by Prof. V.F. Demyanov [1]. Starting from another point, Dr. P. Wolfe in the U.S. obtained similar results at a later date; several other scholars also contributed to this field [6,9].

These explorations proceeded independently, and many scientists did not know about the results obtained by other groups. To remedy this situation and to encourage cooperation, IIASA's System and Decision Sciences Area, under the leadership of Prof. M. Balinski, initiated a series of activities in nondifferentiable optimization in 1977. Principal among them were the establishment of a small group of researchers at IIASA and the organization of meetings of the leading researchers from other institutions around the world. Since that time, IIASA has become known as a worldwide coordinating center for research in nonsmooth optimization. Two meetings on this subject were held at IIASA in 1977 and 1978. They were highly profitable and gave outstanding researchers an opportunity to become familiar with the work of other scientists from all over the world.

First Applications

The research in nonsmooth and nondifferentiable optimization at IIASA has been directed both towards basic mathematical questions and applied issues. The basic research has concentrated on broadening the class of functions for which a generalized notion of derivative can be defined, sufficient and necessary conditions of optimality can be specified, and an optimization technique can be used. The class of convex functions has been broadened to include semiconvex, semismooth, and weakly convex functions [6,7]; correspondingly, many nondifferentiable optimization techniques have been developed. The first applications of these techniques at IIASA were related to a large-scale equilibrium model of international trade of agricultural products [4]. Other applications in systems analysis have been made by Ermoliev [3].

In addition to large-scale programming, present applications of nondifferentiable and nonsmooth optimization include integer programming, game theory and minimax solutions, and stochastic optimization. The main theoretical tools are extensions of convex analysis and generalized Lagrange function theory, among others. Future development in this field will be directed to broadening the range of applications and gathering computational experience, as well as to furthering the development of theoretical concepts and tools.

The research on nondifferentiable and nonsmooth optimization represents an unusual blend of methodology and application. The work will, if successful, not only assist analysts in providing better guidance for decision makers, but will also enrich the stock of basic mathematical knowledge. Moreover, this area of inquiry provides particularly effective grounds for cooperation between researchers in IIASA's National Member Organization countries.

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Energy Modeling for the Long Term - and with a Global Perspective

Paul S. Basile*

The ability to know the future is a rare talent. Even some facility for making reasonably accurate projections can enhance the effectiveness of decision-making; it can turn planning schemes from hopeful guesswork into confident road maps.

But future-study, regrettably, is not easy. None of us is a prophet or forecaster. We see the future as complex, and largely unknown—at least unknown to most of us to any degree of relevant detail. The future intrigues, inspires and occasionally frightens us. But, intelligently perceived, the future is found to be a motivator for mature actions. When understood, the future awakens, not frightens, us. And then we can take action. In the words of the sage comic-strip character Pogo, "Why do we stand here confronted by insurmountable opportunities"? Responsible action today requires an informed perception of tomorrow—an intelligent assessment of the real uncertainties and the possible outcomes in the future. To an enterprise, or an office, or a project, or to anyone raising a family, this is not a novelty. When society operates educational institutions, or when a family raises children, it acts (or should act) responsibly, with an informed perception of the future.

The energy studies at IIASA were motivated by the belief that informed perceptions of the long-term future of our energy systems are essential for responsible energy planning today. For this purpose, a set of tools have been developed.

These tools support the Energy Systems Program, a research program which focuses its attention on what has been called the energy *transition*—the slow, but profound shift from the present energy system to a future sustainable one. The Program's primary considerations are long-term ones, spanning a horizon of 15 to 50 years from now. Within this period, the Program's findings indicate, many characteristics of the coming energy transition will be seen and felt.

To be sure, long-term considerations rarely find place in the thinking and planning of those who must make investment decisions today. Yet, as energy systems are becoming increasingly interdependent and increasingly massive, the resulting inherent inertia or "braking distance" necessitates a long-term view, lest governments, businesses, investors arrive at the crux of the energy transition having done too little, too late. The big decisions in a shrinking world have big, and long lasting implications. Long-term views *are* in order; IIASA's energy study was conceived with this in mind.

The modeling is, in a very real sense, the *synthesis* of the several tasks within the Energy Systems Program. The intent is to bring the elements together in order to identify overall energy strategies for the long-term, and to evaluate the possibilities for the integration of such strategies into the economy, the environment, and the society. The complexity of the energy transition demands careful analysis of all of the interrelationships. Such analysis could be seen as the central purpose and strength of energy modeling.

Purpose and Goals of Energy Modeling

The general purposes of computer modeling may be three-fold. First, and perhaps foremost, the real value of models is in the *insight*, not the numbers, that they provide. Models should be designed for gaining insight and understanding, not (necessarily) for mathematical sophistication; informal "mental models", indeed, are essential prerequisites to formal mathematical models.

Second, computer models provide results which should be reproducible from basic logic; model results, once seen, should be obvious. Modeling does not, after all, replace careful thinking—it seeks to enhance it.

Finally, computer models are useful in that they provide calculational consistency. For highly complex and quantitative subjects, modeling provides an essential accounting framework—a necessary classification scheme—to aid in the otherwise laborious if not impossible task of simultaneous calculations with hundreds or thousands of variables.

The objectives or goals of IIASA's particular set of energy models are perhaps four-fold:

- to study the long-term, dynamic (transitional), and strategic dimensions of regional and global energy systems;
- to explore the embedding of future energy systems and strategies into the economy, the environment, and society;
- to develop a global framework to enable the assessment of the global implications of long-term regional or national energy policies;
- to evaluate alternative strategies—to compare options—of a physical and technological kind, including their economic impacts.

With these several goals in mind, the energy models at IIASA have been developed.

The Set of Models

The energy modeling approach at IIASA is a highly iterative one (Figure 1). Initiating assumptions and judgments lead to calculations and results which feed back and modify those assumptions and judgments. Most of the feedbacks are manual; while the flow of information is mechanized, the impacts on one set of inputs from changes in another are not. An original assumption about the relative rate of penetration of gaseous fuels into residential markets (for example) is increased by the analyst as relative fuel prices (stemming from supplies) show an advantage for gas.

The energy modeling activity begins with scenario definitions (top of Figure 1).

In the IIASA energy research, two scenarios are selected—two plausible futures believed to span a reasonable-to-expect range. They are defined by "high" and "low" economic growth within regions, and consequent high and low energy demand growth. Population growth is also a scenario-defining parameter, although at present just one projection of population is used in IIASA energy studies. Other factors vary from scenario to scenario according to judgments about internal consistency.

The scenario projections of economic and population growth for each world region provide the basic inputs for detailed calculations of future final energy consumption consistent with the scenarios. An array of judgments about life-style developments, improvements in efficiencies of energy-using devices, and the rate of penetration of new and/or improved energy-using equipment aug-

*Paul Basile (USA) joined IIASA in June 1977 to work in the core group of the Energy Systems Program and in July 1978 was appointed Assistant Leader of the Program. Before joining IIASA, he worked with the MIT-based Workshop on Alternative Energy Strategies (WAES).

*MEDEE stands for Modele d'Evolution de la Demande d'Energie. It was developed at the University of Grenoble and adapted for use at IIASA.

*MESSAGE stands for Model for Energy Supply Systems and Their General Environment Impact and was developed at IIASA.

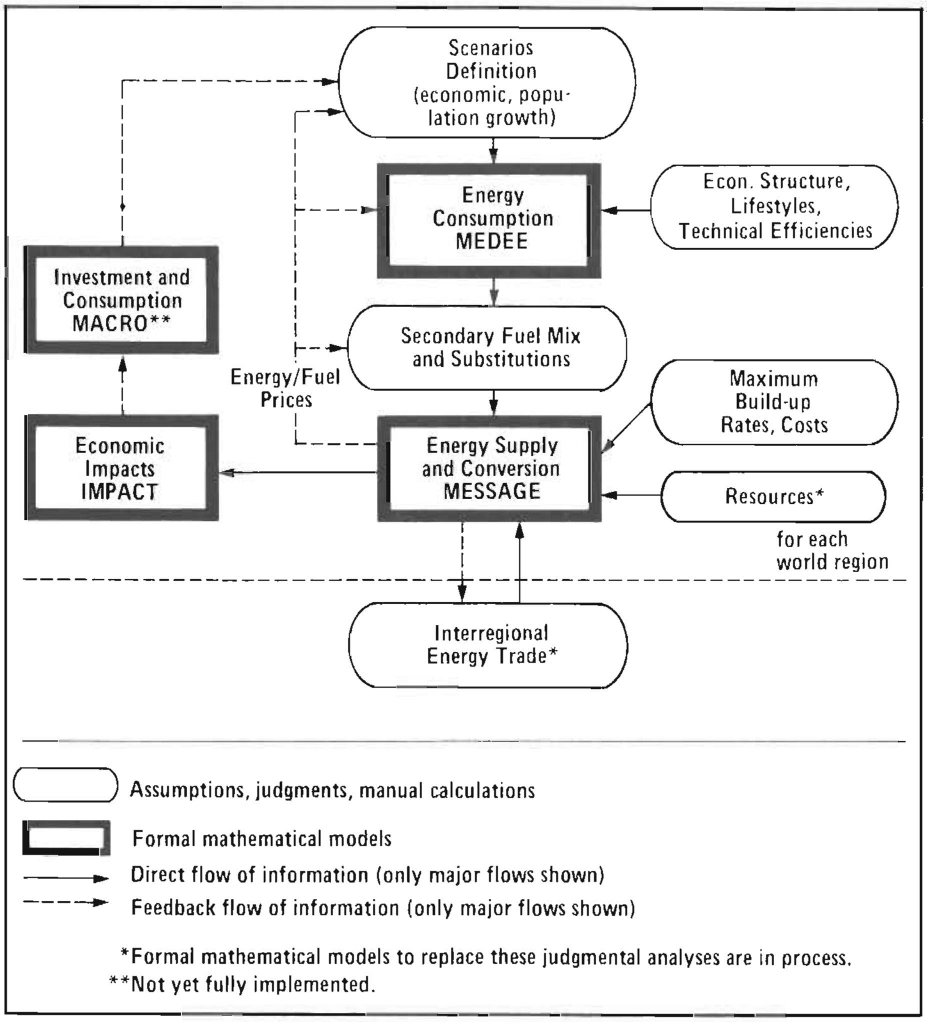


Figure 1. IIASA's Set of Energy Models: A Simplified Representation.

ment the disaggregated economic and demographic assumptions for each region. All of these details are meant to be consistent with the general scenario parameters and are recorded in a model called MEDEE* where calculations lead to estimates of final and (ultimately) secondary energy as input to the energy supply and conversion model MESSAGE*.

MESSAGE calculates the required supplies of primary fuels to meet the secondary energy demand, at lowest cost and within sometimes quite tight constraints on resource availabilities, technological development, and the rates of build-up of new energy facilities. Resource constraints are specified as maximum pools of oil, natural gas, coal and uranium available at specified costs. As prices rise, several high cost alternatives can compete. Limits on the maximum rate of build-up of energy facilities reflect the inherent lead times, as well as limitations of manpower, materials, etc. in a region.

Interregional energy trade considerations provide time profiles of imports and exports of fuels for each regional MESSAGE run. Relatively simple allocation rules distribute available exports of fuels (e.g. oil) from exporting regions (e.g., the Middle East) to competing importing regions (e.g., Western Europe and Africa). Allocations are done iteratively with MESSAGE runs so that a globally consistent balance is achieved.**

The addition of energy facilities required to meet the energy supply scenarios of MESSAGE have direct costs—capital, manpower, and materials costs. An IMPACT* model calculates the required direct and indirect costs of new energy facilities, and thus provides the basic information for assessing whether or not an economy can afford a given energy scenario. Exogenous assumptions about facility-specific size, material, and manpower requirements are made for IMPACT in order to calculate the direct and indirect (energy-related) requirements of a given energy strategy.

With IMPACT-calculated costs, we can begin to ask if energy will start to absorb unacceptably high shares of economic product. What forms of capital and financial aid will be required by developing countries? What level of non-energy exports are necessary to pay for large energy imports?

**This procedure will be formalized through use of a gaming model in the near future. The model, developed at the Siberian Power Institute of the Siberian Branch of the Soviet Academy of Sciences, is currently approximated through a series of calculations and assessments.

*IMPACT was developed at the Siberian Power Institute, and extended at IIASA.

Finally, a MACRO** economic model accepts exogenous assumptions about demographics, and institutional parameters such as productivity, taxes, trade, etc. and calculates investment and consumption rates consistent with the costs from IMPACT. This allows assessment of the magnitude of change in, for example, the capital/output ratio if and when energy becomes increasingly capital intensive. This in turn enables a recheck of the original GNP estimates for each region and a re-entering of the iterative process.

This last feedback is one toward which much of the energy modeling design and implementation work at IIASA has been leading. The critical question is: Can economies *afford* the capital or the time, to achieve energy strategies if, during the transition 15 to 50 years from now, energy becomes increasingly capital intensive?

Whither Now?

No client exists for global energy studies. No world-wide decision-maker exists. No one has requested, no one is looking for, no one knows exactly how to make use of global energy projections such as those produced by the Energy Systems Program at IIASA. How then can or should the methods and results of such studies be implemented?

There is, of course, no one answer to the question. Still, the global trends, the interactions among regions, the binding constraints in various regions that are seen in IIASA's energy studies, heavily impact or should impact the decisions and plans of each region and country. It is axiomatic that no man and no country is an island in these considerations. Narrow national interests peer into the future with tunnel vision. Our responses to international energy interrelationships have to date been primitive. The North-South dialogue was thought to explore (among other things) a common energy ground for producers and consumers. Yet, no one knows exactly what to do if the swing producers of the Arabian Peninsula cease to meet the oil shortfall stemming from Iranian production cutbacks.

Global energy analyses—as presented here and elsewhere—should find a way into the thinking of national energy policies throughout the world. Models—formal computer ones and mental ones—can and should play a role in the tough choices the world will surely face. IIASA's energy models, which will continue to be used for global and national perspectives and strategies, can offer an integrating device seldom available to energy planners and researchers. The models are readily available to those who have a need, and the recognition that these tools just might help to meet it.

**MACRO was developed at IIASA.

New Books from IIASA

Planning and Management in the USSR and USA

"The need for more effective planning and management on the global, national, and enterprise levels is becoming more evident as societies and economies become more complex and interdependent. Scientific study and discussion related to the improvement of planning and management has received increasing support in the recent past in many countries, notably in the Soviet Union and in the United States. Until very recently, however, there has been little systematic communication on these subjects between American and Soviet scholars and practitioners, and opportunities for exchange of information and to learn from each other's experiences were very limited.

"The system of economic management and control in the two countries is the product of different social systems. Planning in the USSR is organized and led centrally on a national level and includes all levels of territorial and economic administration in the Soviet Union. On the other hand, planning in the United States is not highly developed as a national government activity but is encouraged instead as a task for individual corporations or local governments. National integration of corporate and state and local government plans occurs through the working of the marketplace and the American political system. The federal government's management of the economy tends to be carried out primarily through fiscal and monetary policies, not through direct planning mechanisms.

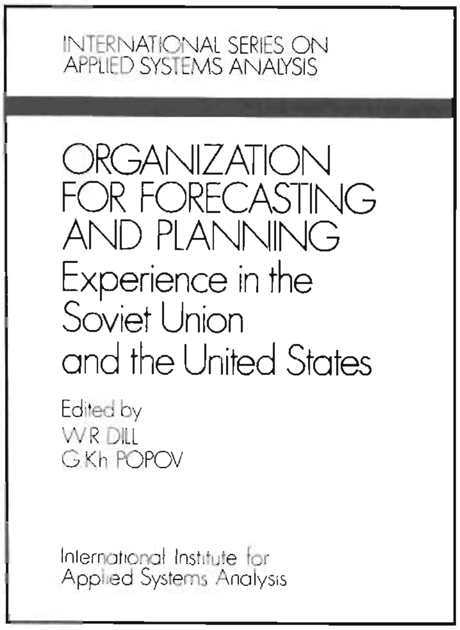
"It is impossible, of course, to apply mechanically one country's planning system, or even major elements of it, to the social system of another country. Nevertheless, acquaintance with the problems and practices of planning and forecasting in both the Soviet Union and the United States provides a rich basis for thinking about the fundamental economic and social problems that these practices are designed to address, and about how these practices might be improved.

"This book, prepared by a joint Soviet-American editorial board, is an effort by planning and management experts from both countries to describe their views of current planning and forecasting theory, practice, and problems. These authors analyze the patterns of development of planning and forecasting systems in each country and identify needs for and lines of further development. They identify planning and forecasting problems and practices common to both countries, and areas where joint research between the two countries might lead to greater effectiveness in the planning practices of each."

This excerpt from the Foreword by McGeorge Bundy and Jermen Gvishiani describes the latest volume on IIASA's International Series on Applied Systems Analysis. *Organization for Planning and Management: Experience in the Soviet Union and the United States*, edited by W.R. Dill, of New York University, and G.Kh. Popov, of Moscow State University, has just been published by John Wiley & Sons, Chichester, England. The fourth volume in the Series, this 267-page book is the outgrowth of a long-term cooperative effort sponsored by the Ford Foundation in the United States and the State Committee for Science and Technology in the Soviet Union, an effort initiated in 1970 by Mr. Bundy and Professor Gvishiani.

The book contains contributions ranging from basic descriptions of the planning processes in the Soviet Union to a paper on the Volzhski automobile plant at Togliatti on the one hand, and from an overview of planning in the American economy to, for example, a description of planning at the IBM corporation.

Organization for Planning and Management: Experience in the United States and the Soviet Union, edited by W.R. Dill and G.Kh. Popov, ISBN 0-471-99720-x, can be ordered from John Wiley & Sons, Ltd., Baffins Lane, Chichester, West Sussex PO19 1UD, England. The price is $29.50, or £12.75.



SARUM and MRI

In the field of global modeling, IIASA has assumed a monitoring role: whenever a major global model was completed, the Institute convened an international conference of scholars working in this field to discuss the assumptions, methodology, and findings of the model before its final publication. Unlike the first three such meetings, each of which dealt mainly with one specific model, the Fourth IIASA Global Modeling Symposium, held at Laxenburg in September 1976, was devoted to a comparison of two models: SARUM (Systems Analysis Research Unit Model, developed at the Department of the Environment of the United Kingdom), which is an attempt to display the world economic system and its use of natural resources; and MRI (Model of Relations to Industry, Poland), which aims at providing a basis for optimization in a centrally planned economy. The proceedings of this meeting SARUM and MRI, edited by G. Bruckmann, have just been published in the IIASA/Pergamon Press Proceedings Series.

As the full version of SARUM was published elsewhere, these proceedings contain only a summary which, nevertheless, should give sufficient insight into the functioning of the model and its main results. MRI, however, is published in full.

The methodology used for the construction of ten long-term normative models of development of Poland by a team of scientists from the Polish Academy of Sciences is described. The MRI system of models has a decentralized structure with a core model and a number of sectoral submodels, among which are industrial production, agriculture, personal and aggregate consumption, and regions of the country. The system takes into account the complex interactions between production, consumption, demography, environment, technological change, foreign trade, and so on. The existing decision and management structure as well as regional and international linkages is included. Using the MRI, 10-year forecasts of national development under optimum allocation of resources (maximizing GNP and other criteria) and alternative strategies were investigated.

Both models, SARUM and MRI, are intended to be used to test a wide range of scenarios and policy options. The proceedings also include papers reporting on other ongoing activities in the field of global modeling.

SARUM and MRI: Description and Comparison of a World Model and a National Model, edited by G. Bruckmann, ISBN 0-08-023423-2, can be ordered from Pergamon Press, Headington Hill Hall, Oxford OX3 OBW, England. The price is $55.00.

News from IIASA

IIASA Publications

With the start of the new year, the Institute initiated a new publication program intended to ensure that the results of its work reach the appropriate audiences and that its publications satisfy high standards of quality, at the same time ensuring that research staff members receive the professional recognition and benefits that result from publication. We now have two major aperiodic categories of publications—reports and papers—which serve different purposes and reach different audiences, as well as two periodicals, The IIASA Record and OPTIONS (the Research Memorandum series has been discontinued). We have also continuing relations with two English-language commercial publishers: John Wiley & Sons, who publish The IIASA International Series on Applied Systems Analysis; and Pergamon Press, who publish the IIASA Proceedings Series. Other less formal communication media include newsletters and progress notes sent to selected audiences for particular research topics.

Reports

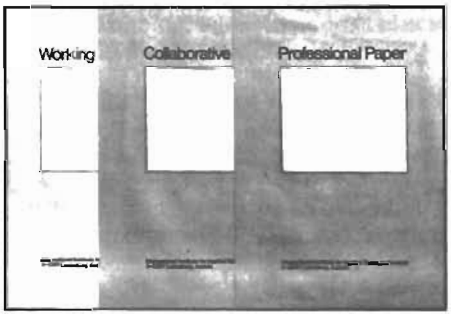
There are three types of reports, differing according to the audience they address.

- Research Reports, are a vehicle for disseminating the results of finished and reviewed IIASA work to the scientific and analytical communities for examination, incorporation in ongoing work, and application. Since the Institute encourages publication of its work in recognized journals, many Research Reports will be reprints from external journals. Others will be preprints from The IIASA Record, described below.
- Executive Reports, a new series, provide a means of communicating results of our studies to the decision-making and policy-making communities. These reports will clearly and concisely convey their message to these audiences, and they will often be prepared with the assistance of a professional writer.
- Status Reports, which generally have a limited distribution, report the progress, financial status, and accomplishments of our studies to sponsors, including our National Member Organizations, and other interested groups.

Papers

Papers are not considered by the Institute to be formal products of its studies. Again, there are three types:

- Working Papers, like the now-defunct Research Memorandum series, provide a means for the informal distribution of intermediate results to colleagues within and outside the Institute.
- Collaborative Papers, now less formal than the earlier series of the same name, report work accomplished by collaborators not on the Institute's staff, but done in conjunction with IIASA's overall research program.
- Professional Papers, which report work by IIASA staff that is not directly related to the research program, are published as a service to the scientific and professional staff.



The IIASA Record

The IIASA Record, a new formal publication, is a periodical compendium designed to convey the results of our work in concise form to our various audiences: National Member Organizations, Advisory and Liaison Committees, collaborating institutions, sponsors, and other interested groups and persons, including libraries. Research Reports not published in journals or books, selected sections of Executive and Status Reports, abstracts of journal articles and books, and reports on major conferences will be included. The IIASA Record, a journal-format publication, will be published as often as material permits, perhaps three or four times a year.

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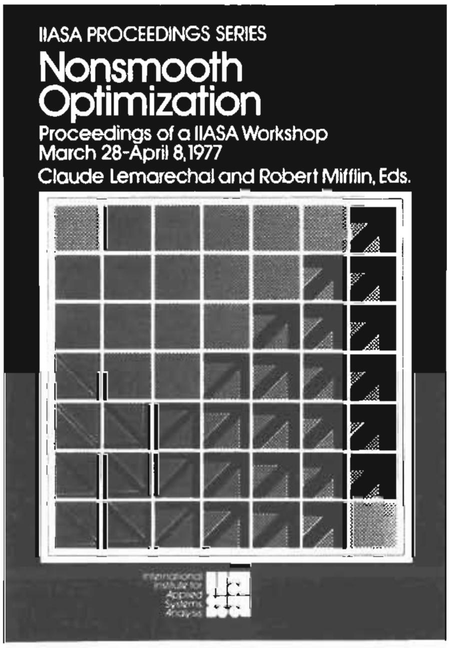

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Topical information on specific research areas is conveyed periodically through various newsletters and progress notes prepared for interested audiences. Although a relatively new medium of communication, we expect to produce such periodicals in many of our major areas of research. OPTIONS, a non-technical newsletter, is published quarterly as a means of conveying information about IIASA's activities and program to all those interested in the Institute's work; and is distributed free of charge to some 5000 individuals and organizations.

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