System and Decision Sciences at IIASA 1973-1980

Andrzej Wierzbicki
Peyton Young

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INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 LAXENBURG, AUSTRIA

FOREWORD

In October 1981, the International Institute for Applied Systems Analysis (IIASA) marked the ninth anniversary of the signing of its Charter, and by the middle of 1981 it had completed its first eight years of research activity.

We believe that the time has now come to assess the past achievements of the Institute and to outline future research directions. The successes we have had in the last eight years should be shared with those outside the Institute who are interested in its work – scientists, advisors, and decision makers – people who should also help IIASA shape its future plans.

With this aim in mind, Andrzej Wierzbicki and Peyton Young have prepared a report on the activities of the System and Decision Sciences Area (formerly known as the Methodology Project), which reviews past work, discusses current research, and suggests several new directions.

We hope that this report will lead to a greater understanding of the work being carried out at IIASA within the System and Decision Sciences Area, and will extend the international network of persons and institutions both collaborating with IIASA and making use of its research.

ROGER E. LEVIEN
Director
International Institute for
Applied Systems Analysis

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CONTENTS

OVERVIEW

From its earliest beginnings as the Methodology Project, the System and Decision Sciences (SDS) Area has fulfilled two main tasks at IIASA: providing methodological assistance to workers in other research areas, and carrying out fundamental research on new methods and models for use in applied systems analysis. From 1976 to 1979 the Area also included the former Computer Science Project; this group now performs a service function under the title "Computer Communications Services", and its history and objectives are described elsewhere.

Over the past seven years, the System and Decision Sciences Area has studied a wide range of topics, including economic theory, econometric modeling, mathematical demography, optimization methods, control theory and hierarchical systems, game theory, and decision sciences. The emphasis of the research changes from year to year, but the central objective of the Area has always been to maintain a strong core group working on economic theory and optimization methods, fields in which new results may be applied immediately in other parts of the Institute.

Because of the need to cover such a wide variety of topics with a relatively small staff, the Area has always tried to recruit people with a broad range of interests in theoretical and applied subjects, rather than specialists in any particular field. The scientific staff is drawn largely from IIASA's seventeen National Member Organization countries, and this results in much fruitful collaboration between researchers of widely differing disciplines and backgrounds. In addition, the Area encourages scientists from all over the world to visit IIASA to participate in the research program for periods of about a month. These policies, combined with a long history of successful conferences, workshops, and collaborative ventures, ensure that the Area will be open to new influences and new ideas, and should remain at the forefront of methodological research for many years to come.

BRIEF HISTORY

George Dantzig (October 1973 to July 1974)

George Dantzig, who was the original architect and first leader of the group, established several general themes that have continued to play a major role in the Area's research: mathematical programming methods and applications, decision theory, economics, and control theory. The scientists working in each of these four fields in the first year of the group's existence are listed below.

Mathematical Programming	Decision Theory	Economics	Control Theory
George Dantzig David Bell Carlos Winkler	Howard Raiffa Jean-Pierre Ponssard	Tjalling Koopmans	Yuri Rozanov

The methodological work in mathematical programming was principally concerned with different methods of solving large-scale linear programming problems by decomposition, and developing improved methods for integer programming. Applications included the development of an energy planning model in collaboration with the IIASA Energy Project, and the use of dynamic programming to determine optimal forest management policies jointly with the Ecology Project.

The work in decision theory included the development of a comprehensive theory of decision making with multiple objectives, the analysis of multiperson decision making using game theory, and selected topics in decision making under uncertainty. In economics the major topic of interest was the optimal allocation of resources over time, including the implications of different discounting procedures and the choice of time horizon. The group also spent some time studying control problems.

During this period, the System and Decision Sciences Area (or as it was then, the Methodology Project) sponsored two Conferences on Global

Modeling which had as their objective a comprehensive review and critique of global models, in particular the Mesarovic–Pestel and Bariloche models.

Tjalling Koopmans (July to December 1974) and William Jewell (January to June 1975)

Under the leadership of Tjalling Koopmans, and his successor, William Jewell, work continued on mathematical programming methods and decision analysis. Several topics received increased emphasis: control theory and dynamic systems, and statistical estimation (see below).

Mathematical Programming	Decision Theory	Control Theory	Statistical Estimation
David Bell	Jacques Gros	John Casti	Abdelmonem Afifi
Yuri Evtushenko	Ralph Keeney	Hans-Richard Grümm	William Jewell
Ralph Keeney	Tjalling Koopmans	Ramon Mehra	
Hiroshi Konno		Yuri Rozanov	
William Orchard-Hays			

A particularly fruitful collaboration began with the Ecology Project, headed by C.S. Holling, who used the term "resilience" to describe the kind of stability to external shocks exhibited by ecological systems. Members of the SDS Area became interested in trying to define this concept more rigorously using the language of dynamic systems theory. It was also shown how the same general approach might give insights into the qualitative behavior of other systems such as climate and economic growth.

The theory of multiobjective decision making developed by Ralph Keeney and Howard Raiffa was used in several applied case studies, including a study of salmon management in the Skeena River Basin in Canada, water resource development in the Tisza River Basin in Hungary, and an ecological study of a common pest, the spruce budworm. These and other uses, as well as new theoretical methods, were presented in a major workshop held in 1975, bringing together scientists with interests in multiple objective decision making from both East and West.

Michel Balinski (September 1975 to January 1978)

Michel Balinski served as Area Chairman from mid-1975 until the end of 1977. During this period, the scope of work in economic modeling was broadened and research into several new topics was begun. The new fields included problems in fair division, statistical forecasting techniques, and methods for nonsmooth optimization.

Economic Modeling	Fair Division	Statistical Forecasting	Optimization
Brian Arthur	Michel Balinski	Johannes Ledolter	Spartak Chebotarev
Harold Barnett	Bengt Hansson		Claude Lemarechal
Lars Bergman	Peyton Young		Robert Mifflin
Anthony Fisher			William Orchard-Hays
Pradeep Mitra			Anatoli Propoi
Morris Norman			Igor Zimin

One of the projects of the economic modeling group was to develop a simple macroeconomic model to analyze long-term growth alternatives in industrialized economies; this model was used by the Energy Project to construct different scenarios of future energy demands and supplies. Another energy-related study involved the construction of a general equilibrium model designed to forecast the effect of rapidly increasing energy prices on small open economies that depend heavily on imported energy sources. Increased emphasis was placed on problems of resource scarcity. Empirical and theoretical studies were made of the different ways in which resource scarcity can be measured and how resource scarcity may produce economic change. Finally, a new study was undertaken on the complex interconnections between demographic, social, and economic variables affecting economic development; this produced a case study analyzing population growth and economic development in Bangladesh.

A second new area of interest was problems of conflict resolution and fair division. This included a study of the different procedures that may be employed to reach a group consensus despite conflicting individual preferences, and a systematic analysis of the methods used to allocate political representation among political parties and geographical regions in different countries – this is a classic problem of fair division complicated by the indivisible nature of the things to be divided.

Yet another topic was the study of statistical forecasting techniques and multivariate time series analysis.

In optimization, two principal topics were pursued: methods for dealing with large-scale systems, and nondifferentiable optimization techniques. A new technique called "polyhedral dynamics" was developed to study the connective structure of large-scale processes. Another approach was to decompose certain types of large-scale systems using dynamic linear programming techniques combined with a generalized gradient method. Finally, a large-scale mathematical programming software system (SESAME), developed at the National Bureau of Economic Research and installed at Pisa, was transferred and adapted for use at IIASA by William Orchard-Hays.

A group of researchers from different countries was brought together at IIASA to stimulate development in nondifferentiable optimization. Existing approaches in this new field were compared and new theoretical algorithms created for solving difficult classes of optimization problems that involve nondifferentiable objective functions. These techniques were used by Claude Lemarechal and Robert Mifflin in the world food trade model developed in the Food and Agriculture Program. These and other developments were reported in a Task Force meeting on Nondifferentiable Optimization, held in December 1977, which involved leading researchers in optimization from both eastern and western countries.

Peter de Janosi (February 1978 to June 1979)

The period between the beginning of 1978 and the middle of 1979 saw an increasing emphasis on economic modeling under the leadership of Peter de Janosi, and work on optimization also flourished.

Economic Modeling	Optimization
Clopper Almon	Spartak Chebotarev
Brian Arthur	James Curry
Lars Bergman	Yuri Ermolev
Lawrence Klein	Markku Kallio
Pradeep Mitra	Evgeni Nurminski
Douglas Nyhus	William Orchard-Hays
Fumiko Seo	Anatoli Propoi
Peyton Young	Andrzej Wierzbicki
	Igor Zimin

During this period, the economic modeling group started work on an international system of dynamic input–output models with nonlinear feedbacks, using the INFORUM models developed by Clopper Almon at the University of Maryland.

The group also worked on the incorporation of sophisticated demographic methods into economic theory. This approach was used to make a comprehensive theoretical analysis of the economics of risks to life, e.g., the potential costs of nuclear hazards, the benefits of improved safety standards in industry, and the possible returns of medical research designed to eliminate specific diseases. Building on previous work on the relationship between demographic development and economic growth, the career implications for the growing numbers of young people entering professional labor markets were analyzed. Finally, the economic modeling group held a Task Force meeting on Long-Term Economic Planning, which involved participants from both centrally planned and market economies.

The optimization group continued to develop new algorithms for large-scale and nonsmooth systems. Dynamic linear programming methods were used in a large-scale model of the Finnish forest industry, constructed as part of a study carried out in collaboration with the Finnish Forest Research Institute.

Research on nondifferentiable optimization (NDO) continued to thrive, the results including the development of NDO methods for a broad class of weakly convex functions, a study of the use of augmented Lagrange functions in NDO, a study of second-order approximations to nondifferentiable problems, and the application of NDO concepts to the problem of linking optimization models. Several NDO algorithms were used to solve equilibrium problems in international agricultural trade and were also used to study resource allocation in health-care systems. These and other developments were reported in a second international Task Force meeting on Nondifferentiable Optimization, held in 1978.

CURRENT AND FUTURE RESEARCH DIRECTIONS

In June 1979, Andrzej Wierzbicki became Chairman of the Area; in November 1979, Peyton Young became Deputy Chairman. During the second half of 1979 and throughout 1980 the work of the System and Decision Sciences Area fell into three main categories: economic modeling, decision theory, and optimization; there was also a certain amount of individual research on other topics.

Economic Modeling	Decision Theory	Optimization	Other
Bert Hickman	Andrzej Wierzbicki	Michael Dempster	Andrzej Lewandowski
Robert Coen	Fumiko Seo	Yuri Ermolev	Ingolf Ståhl
András Pór	Giandomenico Majone	Markku Kallio	
Lars Bergman	Michael Thompson	Evgeni Nurminski	
Clopper Almon		William Orchard-Hays	
Douglas Nyhus		Tyrrell Rockafellar	
Brian Arthur		Roger Wets	
Harold Barnett		Andrzej Wierzbicki	
Gerhardus van Muiswinkel			
Peyton Young			
Werner Güth			

Economic Modeling

The work in economics falls into four main categories: macroeconomic modeling, connections between economic and demographic theory, measures of resource scarcity, and public economics.

The work in macroeconomic modeling is concerned with the analysis of specific issues common to many countries, such as how changes in the age distribution of the population are likely to affect economic growth and other economic indicators; how constraints on natural resources may affect long-term economic growth; and the best methods of planning future economic growth and structural change in the face of highly uncertain international markets.

During 1980 a macroeconomic model of the United States was developed in cooperation with Stanford and Northwestern Universities by Bert Hickman and Robert Coen. The model was designed to study the dynamic relationships between actual and potential growth under different policy scenarios, and considers aggregate energy demand and supply, capital formation, productivity, energy use, and investments. The same basic structure may be used to model other market economies, and SDS has been collaborating with the Manpower Task of the Human Settlements and Services Area in applying the model to analyses of population change and labor market problems. IIASA has also made significant contributions in the further development of multisectoral general equilibrium growth models. This type of model can be adapted to study a great variety of structural issues, such as the effects of foreign trade and energy policies on particular economic sectors. The multisectoral model of a small open economy, developed by Lars Bergman, was used to prepare for the recent national referendum on the future use of nuclear energy in Sweden; the model is also being applied to Bulgaria and Hungary. András Pór has developed new and improved algorithms for the practical implementation of such models and these have also been applied to similar models used by the Human Settlements and Services Area and the Regional Development Task.

A topic receiving increasing emphasis is the modeling of international trade, which is especially appropriate bearing in mind IIASA's desire to promote greater international cooperation. A system of input–output models of national economies originally developed by Clopper Almon and the Inter-Industry Forecasting Project at the University of Maryland has been expanded at IIASA by Douglas Nyhus to create a linked system that provides an empirical framework for analyzing national policy decisions in terms of their impacts on other nations.

This work marks the beginning of a wider study of both theoretical and practical issues in international trade. Another ambitious objective is to develop a model that could be used to study the major factors affecting global economic growth and the distribution of wealth at a level aggregated enough to be easily maintained and understood. The model would consider such factors as overall demographic change, rates of capital accumulation, the availability of natural resources, technical progress, and growth of output in each of several aggregate world regions, with special attention paid to the roles of trade, capital flows, foreign aid, and migration in these processes. A conference on Global Economic Modeling was organized by Bert Hickman and Robert Coen and held in July 1980; the feasibility of the proposed model was one of the main topics under discussion.

A second area of interest in the economics group is the study of dynamic interactions between demographic and economic variables: this is largely the province of Brian Arthur. Recent contributions include the development of a method for measuring the economic impacts of risks to life and the expected benefits of new cures or safety measures, and a technique for studying the effects of population bulges on the career prospects of individuals in particular professions. Current research is using functional analysis to trace the complex ripple effects arising from specific demographic shifts such as new medical cures or changing fertility patterns.

Harold Barnett and Gerhardus van Muiswinkel are working on a third topic in economic analysis: a study of resource scarcity and economic growth. The project is funded in part by the U.S. National Academy of Sciences. The objective is to try to improve current concepts, measures, and understanding of resource scarcity. The study will consider not only the simple physical withdrawal of reserves, but also related factors which have become important in recent years, such as the need for environmental protection, the existence of cartels, the element of political risk, and the increasing availability of sea-bed resources.

The fourth topic, public economics and decision theory, includes several areas of research. One of these, pursued by Peyton Young, is concerned with problems of fair division, and is particularly relevant to economic planning and the allocation of resources. The objective is to develop practical methods to encourage a group of individuals representing different interests to agree on a given allocation of resources or costs by proposing appropriate incentives. Potential uses include allocating resources in centrally planned economies, planning the location and scale of public goods, and determining optimal prices and output in regulated industries. Some of these ideas have been applied to the problem of allocating the costs of a shared water supply system in Sweden among the municipalities taking part in the scheme. This project was carried out in cooperation with the Resources and Environment Area. A related piece of work by Werner Güth involves the use of game theory to study the effects of ownership and control of various resources on the market for other resources and how these factors affect rates of extraction and relative prices.

Decision Theory

The second main class of research in the System and Decision Sciences Area is the study of decision processes and hierarchical structures; this builds

on the Area's traditional interest in problems of multiple or conflicting objectives. The aim of this research is to demonstrate the influence of institutional structure on the decision-making process: how the organizational structure of a decision-making body balances conflicting objectives, how different structures may impede or improve information flow, how rapidly they can adapt to changing conditions, and how well they resolve competing interests.

Recent advances include the use of a hierarchical approach to multiobjective decision analysis in regional planning (by Fumiko Seo) and a mathematical description (by Andrzej Wierzbicki) of the concept of "satisficing" in decision making. "Satisficing" represents the gray area between "satisfying" and "sufficing" as far as a decision maker is concerned, and up until now has existed only conceptually. The mathematical description of this concept is based on the analysis of a simple idealized organization composed of a manager and his staff. The manager is supposed to set targets, or aspiration levels, and then the staff must respond with a series of proposals. If the aspiration levels are too low, the staff may propose to exceed them; if the levels are too high, the staff suggests the closest possible approach: if the levels are exactly right, the staff proposes to meet them and does not attempt to have them altered. From this it is possible to obtain an axiom reflecting the rationality of staff proposals; this axiom may be incorporated into the general value theory for topological spaces. This somewhat abstract theory also has some practical applications, for example, when designing computer systems to be used interactively: the human judgement of the user (manager) is expressed in terms of aspiration levels, and a computerized optimization model (the staff) responds to these requirements by generating efficient alternatives. An interactive system based on this technique has been developed to analyze the possible development of the Finnish forestry industry, and tested successfully.

Giandomenico Majone and Michael Thompson are just starting a joint investigation of risk management with the Management and Technology Area. The study involves the use of both analytical and sociological methods to investigate the role of institutions in managing different types of risk.

Optimization

Optimization continues to play an important role in the work of the System and Decision Sciences Area. The optimization group not only provides expert methodological and mathematical assistance to other Areas and

Programs, but also forms an international center for research extending and developing new optimization techniques, such as large-scale and dynamic linear programming and methods for nondifferentiable and nonsmooth optimization.

The topics studied by the group therefore reflect both the growing needs of other Areas and Programs for techniques dealing with factors such as uncertainty, multiple objectives, and the effects of scale, and the desire to extend the theoretical basis of the subject through fundamental research.

Large-scale linear programming methods are being used to build models covering a wide spectrum of problems: the Energy Program's energy supply model, national food and agriculture models in the Food and Agriculture Program, and planning models for educational and manpower systems, health-care systems, and water resource management. In parallel with this applied research, the methodological research concentrates on such aspects as linking large-scale linear programming models, developing multiobjective linear programming methods, and including uncertainty in linear programming models.

Most of these methodological advances have been analyzed and tested on a planning model developed by the Area for the Finnish forestry industry. A new interactive method of multiobjective linear programming, in which the model responds to the user's stated aspiration levels for various objectives, has been developed, and used to produce a trajectory optimization in the Finnish forestry sector model. Other applications to regional planning and energy supply are in progress.

Active research continues on nonsmooth and nonconvex optimization techniques. Recent advances include a new saddle-point theorem for nonconvex and nonsmooth optimization problems, devised by Michael Dempster, and an algorithm of quadratic approximations to nonconvex optimization problems, developed by Andrzej Wierzbicki. A method of linking optimization models via nondifferentiable optimization has been worked out by Evgeni Nurminski, and has been used in such areas as health care, resource allocation, and linking energy supply models and economic models.

Stochastic optimization and its applications are receiving increasing attention in the System and Decision Sciences Area, partly in response to the needs of other groups working at IIASA. The main aims are to develop stochastic optimization algorithms – Yuri Ermolev and Roger Wets are paying particular attention to approximation techniques – and to investigate various applications, including stochastic programming models of hierarchical decision structures. A Workshop on Stochastic Optimization Techniques was held in December 1980.

Other Work

In addition to economics, decision theory, and optimization, the System and Decision Sciences Area covers a number of other topics, such as methods of building models and experimental gaming, that first arose in other Areas. Ingolf Ståhl has been involved in experimental gaming, a relatively new field in which real situations are modeled as "games" under experimental conditions, using a set of rules and objectives to simulate the behavior of the actual system. Planners and decision makers are invited to play "games" designed to illustrate the processes of planning and decision making in their particular field; this can cast some interesting light on the way in which decisions are actually taken. Gaming may also be used as a test of any proposed planning solution – if the "players" do not find the solution acceptable in an experimental setting, it will probably not be any more appealing in the real world. Members of the Area also try to act as constructive critics of the modeling work done in other parts of the Institute. Indeed, this has led to an exploratory study, by Andrzej Lewandowski, of how checks on model validity and consistency can be carried out systematically, using such techniques as parameter estimation, sensitivity analysis, and simulation.

RECENT PUBLICATIONS

Economic Modeling

The Economics of Risks to Life, by W. Brian Arthur (RR-79-16)

This paper examines the economic welfare implications of mortality change within a framework that both recognizes general equilibrium effects and incorporates full age-specific accounting. Two formal results are derived. Under a life-cycle welfare criterion, changes in the age-pattern of mortality, caused say by a medical breakthrough, should be assessed on the utility of additional life-years, production, and reproduction, less expected additional social costs of support. Loss of life at a specific age should be assessed on the opportunity costs of expected lost years of living and lost production and reproduction, less expected social support costs. From these results it is seen that current methods, in general, leave out an important social transfer term, that the valuation of life-risks is highly age-dependent, and that the degree of diminishing returns to consumption plays an important part in calculations of the economic cost of risks.

A Three Country Comparison of the Impact of Slower Growth on Three Industries Using Input–Output Analysis, by Douglas E. Nyhus (WP-79-21)

In the 1970s western Europe entered a period of reduced real growth. During the economic boom of the 1960s, nearly all industries were growing fast enough to allow employment to remain at least constant. However, in the 1970s western European industry experienced a recession from which it is now recovering, though output growth seems to be substantially below that achieved in the 1960s. Some industries have adapted to the reduced growth rates with relative ease while others have encountered severe adjustment difficulties. This report uses input–output analysis to compare the effects that slower growth has produced on three different industries in three western European countries.

A Global Economic Model, by Lawrence R. Klein (WP-79-76)

There are some problems which are best analyzed using large detailed models and others for which small simple models are more appropriate. An analysis of the world economy over long stretches of time is probably best tackled with a small model – one that captures the essence of some aspect of growth and general economic environment and that can handle a wide variety of problems. Much of the work will be done by scholars who are not economists and therefore it would be sensible to construct a model that is not data-intensive, that is easy to manage, and easy to apply to a limited range of issues. This report describes a first attempt to construct such a model.

An Input–Output Approach to the Analysis of Intercountry Differences in Per Capita Energy Consumption, by Lars Bergman, Claude Clemenz, and Alois Hölzl (WP-80-3)

Comparisons of energy consumption patterns in different countries can serve to identify inefficiencies in the use of energy in individual countries. However, measures

such as the use of energy per capita or per unit of GDP are not usually very good indicators of international differences in the efficiency of energy use. Factors such as climatic conditions, production methods, and consumption patterns may all affect the values of these parameters. Moreover, differences in these parameters may be caused not only by differences in the efficiency of energy utilization, but also by differences in the relative price of energy between countries.

In this study, input–output data for the Federal Republic of Germany, France, and the Netherlands are used to identify international differences in per capita energy consumption patterns which can be traced to differences in production methods and domestic consumption patterns. Such differences do exist: in particular, the technologies used in the three countries differed significantly in terms of energy intensity. However, when these results were combined with data on relative prices, the observed differences in energy intensities were in most cases quite consistent with the differences in relative prices. Thus, the observed differences between the three countries studied do not seem to reflect international differences in the efficiency of energy utilization.

A Quantitative General Equilibrium Model of the Swedish Economy, by Lars Bergman and András Pór (WP-80-4)

A quantitative general equilibrium model is useful for two main applications. The first includes work involving a time horizon two or more decades into the future. In such studies, a model of this type can highlight various features of future economic conditions by providing a number of resource allocations, each consistent with full equilibrium in both product and factor markets. The second application is concerned with comparisons between observed resource allocations and hypothetical equilibrium allocations.

In this report a quantitative general equilibrium model of an open economy is developed, and used to examine Swedish data. In addition to the foreign trade flows, the model includes the following procedure which is reiterated until a full equilibrium is reached. In the first step, technological coefficients and output prices are determined on the basis of initial factor prices. Then the excess demands on factor markets at product market equilibrium are determined. The initial factor prices are then adjusted and the process repeated.

The report also contains some preliminary results obtained with the model and a brief discussion of future directions of research in this field.

A Disaggregated Annual Model of Labor Supply and Unemployment, 1951–2000, by Robert M. Coen and Bert G. Hickman (WP-80-15)

The number of manhours available is one of the principal determinants of the potential output of an economy. Although this measure of labor supply may be strongly influenced by population developments, there are several economic and behavioral factors that rule out any simple relationship between population growth and increase in the number of manhours available. These include the willingness of individuals to join the labor force, the aggregate employment rate of those in the labor force, and the number of hours worked by each employee. In the United States, for example, the working-age population was 53 percent larger in 1977 than in 1947, yet total manhours worked increased by only 40 percent, and manhours worked in the private sector rose by only 27 percent.

This report presents an integrated empirical analysis of the links between population and labor supply. The factors affecting the size of the labor force, disaggregated by age and sex, the number of hours worked annually by each employee, and the unemployment rate are examined for the period following the second world war. The relations concerning these variables are designed for use in a new version of the Hickman–Coen annual growth model of the United States, but they also form a subsystem which jointly determines the supply of manhours, the unemployment rate that may be taken as representing a high level of employment, and the natural rate of unemployment. It is shown how the subsystem may be used to generate these variables, and conditional estimates of their values for the periods 1951–1977 and 1980–2000 are given.

The INFORUM–IIASA Trade Model: An Interim Report, by Douglas E. Nyhus (WP-80-24)

An initial version of the INFORUM–IIASA international trade model for linking national input–output models was completed several years ago. For many people, this model remains the most interesting part of the system of input–output models being developed jointly by the Inter-Industry Forecasting Project of the University of Maryland (INFORUM), IIASA, and several other institutions.

This report presents a brief overview of the system of models, a review of the international trade model, and a discussion of some of the results obtained from it. Possible methods of improving the model are suggested, and the problems encountered in transferring data from the national models to the international model are discussed.

Decision Theory

The Webster Method of Apportionment, by Michel Balinski and Peyton Young (WP-79-49)

The problem of U.S. Congressional apportionment is analyzed in this paper. The results indicate that a method ("Major Fractions") first proposed by Daniel Webster is fairest when judged on the basis of common sense, constitutional requirement, and precedent.

An Integrated Approach for Improving Decision-Making Processes, by Fumiko Seo (WP-79-54)

Decision-making processes generally involve multiple objectives which are noncommensurable and which are often in conflict with one another; decisions are also generally made under conditions of uncertainty. The decision-making process takes place in two stages: an analytical assessment followed by a value judgment. Optimization methods such as mathematical programming are often used in the analytical phase. The use of nested Lagrangian multipliers is one possible method of bridging the gap between the two phases of the decision-making process. This paper presents the basic theory of the nested Lagrangian multiplier (NLM) method and discusses some applications of this technique to integrated regional planning.

A Methodology for Environmental Systems Management: Dynamic Application of the Nested Lagrangian Multiplier Method, by Fumiko Seo and Masatoshi Sakawa (RR-80-12)

This report presents a method for solving multiobjective optimization problems. Special attention is paid to bridging the gap between procedures for obtaining Pareto-optimal solutions and the "best compromise" solution preferred by the decision maker. First, the main concepts of the utility approach are briefly reviewed from the point of view of multiobjective systems analysis, and some deficiencies in this approach are examined. Second, a new technique called the nested Lagrangian multiplier (or NLM) method is introduced, and compared with earlier methods adopting the utility approach. The theoretical background is also examined. Third, the use of the NLM method for environmental systems management in the Greater Osaka area is demonstrated. Finally, it is noted that using mathematical optimization methods in integrated planning would simultaneously provide optimal solutions for allocation as well as evaluation problems. The use of dual optimal solutions to provide evaluation factors is emphasized.

Evaluations for Industrial Land-Use Program Related to Water-Quality Management, by Fumiko Seo and Masatoshi Sakawa (WP-80-49)

This paper presents a hierarchical model used to analyze a regional land-use program based on water pollution control. The overall model is decomposed into both functional and regional subsystems. The method used to coordinate and evaluate the subsystems is based on multiattribute utility analysis combined directly with dual variables obtained from mathematical programming. Shadow prices are used to derive the component criterion ("utility") functions which provide a basis on which to compare widely differing attributes. Uncertainty based on judgmental probability distributions is explicitly taken into consideration in the upper layer of the decision-making system. This procedure is a modified dynamic version of the nested Lagrangian multiplier (NLM) method and the model is used to analyze a land-use program for the northern Senshu area in the Osaka prefecture of Japan.

Cost Allocation in Water Resources Development – A Case Study of Sweden, by Peyton Young, Norio Okada, and Tsuyoshi Hashimoto (RR-80-32)

Methods for allocating the joint costs of a water supply facility among the different users are systematically compared using basic principles from game theory and fair division. The analysis shows that some of the more widely used methods, including the separable cost–remaining benefits method, seem less satisfactory than a lesser-known game theoretic method based on the idea of the "core". A practical illustration is provided by considering various methods of allocating the costs of a joint water supply system in the Skåne region of southern Sweden among the municipalities participating in the scheme.

Optimization

Models of Dynamic Linear Programming, by Anatoli Propoi (WP-79-37)

This report presents a survey of dynamic linear programming models. The first part of the paper considers models which can be described as (specific) resource supply

models (these deal with energy supply, extraction of and exploration for mineral resources, water management systems, manpower and education, and agriculture). The second part of the paper describes economic models. Finally, the combination of these two types of model into an integrated system is discussed in the last part of the paper.

Experiments with the Reduced Gradient Method for Linear Programming, by Markku Kallio and William Orchard-Hays (WP-79-84)

This report deals with some methods for linear programming which generate a monotonically improving sequence of feasible solutions. Examples include the simplex method and the reduced gradient method. The SESAME linear programming system developed by Orchard-Hays is based on these concepts, and has already been implemented. This system resembles the reduced gradient method except that only a subset of nonbasic variables to be changed is considered at each iteration. Several modifications of this basic version are investigated in this report. These modifications are concerned with the choice of an initial basis and an initial solution, with strategies for finding a feasible solution, and with strategies for determining the direction of change for a feasible solution at each iteration.

Nondifferentiable Optimization Promotes Health Care, by David Hughes, Evgeni Nurminski, and Geoff Royston (WP-79-90)

The principal aim of health care research at IIASA has been to develop a family of submodels of national health care systems for use by health service planners. The modeling work involves the construction of linked submodels dealing with population, the prevalence of disease, and the need for, allocation, and supply of resources.

This report is the fruit of a collaboration between two research groups at IIASA. It describes how a health resource allocation model, constructed in the Health Care Systems Task of the Human Settlements and Services Area, may be solved by using nondifferentiable optimization techniques developed in the Optimization Task of the System and Decision Sciences Area.

Some Theoretical Considerations on Linkage Problems, by Evgeni Nurminski (WP-79-117)

A new decomposition approach is proposed for solving large-scale linear programming problems. This paper outlines the theoretical basis of this approach and gives a small numerical example illustrating the method of solution. The algorithm is based on nondifferentiable optimization and the solution is obtained in a finite number of steps monotonically decreasing an objective function. At each step, a number of subproblems from the original large-scale problem is solved; the additional computations necessary to coordinate the solutions of these subproblems via the nondifferentiable optimization technique are much less time-consuming than the solution of the subproblems.

A Methodological Guide to Multiobjective Optimization, by Andrzej Wierzbicki (WP-79-122)

During the last few years there has been growing interest in the field of multiobjective optimization. There are many approaches and techniques associated with multiobjective decision making and optimization; however, not all approaches have been

developed to the same level, and the use of the resulting techniques is often based on tradition rather than on the suitability of a particular technique for solving a given problem. This report is a comparative evaluation of various approaches and techniques. The evaluation is based on a classification of the various problems which can arise in multiobjective decision making and optimization. The different approaches, methods, and techniques for solution are described briefly and then evaluated in terms of their suitability for solving various classes of problems.

The final part of the paper presents a broad description of a relatively new approach based on reference objective levels. This method has not yet been fully developed but in the future may be used to solve many classes of problems. Various theoretical and practical implications of this new approach are also discussed.

A Model for the Forest Sector, by Markku Kallio, Anatoli Propoi, and Risto Seppälä (WP-80-34)

This report describes a dynamic linear programming model for studying the long-range development of forestry and forest-based industries at both national and regional levels. An analysis of the Finnish forestry sector illustrates the use of the model and provides some numerical examples. The model is composed of two subsystems, the forestry subsystem and the industrial subsystem, which are linked to each other through the wood supply. The forestry submodel describes changes in the number and age distribution of trees of different species within the nation or its subregions. The industrial submodel considers various production activities, such as the saw-mill industry, the panel industry, and the pulp and paper industry, as well as activities involving the processing of primary products. A number of different technologies may be employed to produce any single product. Thus the production process may be described by a small Leontief model with substitution. Production is restricted not only by the supply of wood and the demand for wood products, but also by labor availability, production capacity, and financial resources. The production activities are grouped into units and investments are made within the financial resources of these units. Objective functions related to GNP, balance of payments, employment, wages, stumpage earnings, and industrial profit are formulated. It is suggested that end-point conditions for the dynamic optimization problem may be determined through an optimal solution of a stationary model for the whole forestry sector.

An Implementation of the Reference Point Approach for Multiobjective Optimization, by Markku Kallio, Andrzej Lewandowski, and William Orchard-Hays (WP-80-35)

This report studies the reference point approach used by Wierzbicki for multiobjective optimization. The method does not necessarily try to find an optimum under any utility function but rather to generate a sequence of efficient solutions which are interesting from the decision-maker's point of view. The user can interfere via suggestions of reference values for the vector of objectives. The optimization system is used to find the Pareto solution that is nearest to each reference objective.

The approach is expanded to include any information on the decision-maker's preferences which may accumulate during the interactive process. In this case a Pareto point is excluded from consideration if it is not optimal under any linear utility function consistent with the information obtained.

Numerical Experiments with Decomposition of Linear Programming on a Small Computer, by Evgeni Nurminski (WP-80-37)

This report presents the results of some numerical experiments on the effectiveness of a decomposition approach to solving large-scale linear programming problems. Decomposition may also be seen as a specific way of linking subproblems or submodels to reach a coordinated solution. One major advantage of this approach is that each subproblem may be solved separately, if necessary using a different computer located at a different institution in each case.

Other Work

The Accuracy of Population Projections, by Michael A. Stoto (WP-79-75)

Population projections are key elements in many planning or policy studies; unfortunately the projections are inherently inaccurate. This study of the errors in past population projections provides a means for constructing confidence intervals for future projections.

First of all a statistic is defined which measures projection errors independent of the size of the population and the length of the projection period. Examination of a sample of U.S. Census Bureau and UN projections indicates that the distribution of the error statistic is relatively stable. Finally, this information is used to construct confidence intervals for projections of the total population of the United States up to the year 2000.

Why a Population Converges to Stability, by W. Brian Arthur (RR-80-19)

A central theorem in mathematical demography states that the age distribution of a closed population with unchanging fertility and mortality behavior must converge to a fixed and stable form. Proofs rely on ready-made theorems borrowed from linear algebra or from asymptotic transform theory, particularly the Perron–Frobenius and the Tauberian theorems. But while these proofs are efficient and expedient, they give little insight into the mechanism that forces the age distribution to converge.

This report proposes a simple argument for convergence. An elementary device allows us to view the birth sequence as the product of an exponential sequence and a weighted smoothing process. Smoothing progressively damps out the peaks and hollows in the initial birth sequence; thus the birth sequence gradually becomes exponential, and this forces the age distribution to assume a fixed and final form.

A Gaming Experiment on Cost Allocation in Water Resources Development, by Ingolf Ståhl (WP-80-38)

This report describes a gaming experiment concerning the allocation of costs among participants in a joint water supply system. Six Swedish water planners participated. The aim of the experiment was to test some game theoretic models of cost allocation presented in IIASA report RR-80-32. The behavior of the players was partly at odds with that predicted by game theory, and this suggested some new ideas for future research.

RESEARCH SCHOLARS, 1980

Clopper Almon (USA) first worked at IIASA between July 1978 and July 1979 and returned for three months in the summer of 1980. He received his B.A. degree from Vanderbilt University in 1956, his M.A. in 1961 and his Ph.D. in economics from Harvard University in 1962. After working at Harvard University for four years he joined the University of Maryland, where he is currently Professor of Economics. At IIASA he is engaged on the development of a linked system of national input–output models.

W. Brian Arthur (UK) arrived at IIASA in March 1977. He received his B.Sc. in electrical engineering in 1966 from Queen's University, Belfast, his M.A. in mathematics in 1969 from the University of Michigan, his M.A. in economics and his Ph.D. in operations research in 1973 from the University of California at Berkeley, where he was an assistant research professor in economics from 1973 to 1974. He has been an Associate at the Population Council, New York, a Visiting Fellow at the Office of Population Research, Princeton University, and has served as a consultant with McKinsey and Company in Düsseldorf, the Arab Planning Institute in Kuwait, the Institute of Development Studies in Bangladesh, and the East–West Population Institute in Hawaii. His current research interests include economic planning and intergenerational processes in economics.

Isak Assa (Bulgaria) joined the System and Decision Sciences Area at IIASA in September 1980. He received his B.Sc. in electrical engineering from Kiev Technical University in 1967 and his Ph.D. from the University of Manchester Institute for Science and Technology (UK) in 1973. He has been working at the Institute for Social Management in Sofia since 1973; he is an associate professor and leader of a program on management simulation games as well as the Scientific Secretary of the Institute. His main research interests are the application of mathematical methods and techniques in economics and social management.

Harold Barnett (USA) first worked at IIASA for three months in 1976 and returned for a further three months at the beginning of 1980. He received his M.S. in economics in 1941 from the University of California at Berkeley, and his M.A. and Ph.D. in the same subject from Harvard University. From 1952 to 1955 he was Senior Economist at the RAND Corporation, and from 1955 to 1957 he was Director of Economic Growth Studies, Resources for the Future, Washington, D.C. He was Professor of Economics at Wayne State University, Detroit, from 1959 to 1963 and since 1963 he has been Professor of Economics at Washington University, St. Louis, Missouri. His main interests lie in the analysis and measurement of mineral resource scarcity.

Lars Bergman (Sweden) worked with the System and Decision Sciences Area in August and September 1977, between August 1978 and July 1979, and between February

and April 1980. He received his Ph.D. in economics in 1977 from the Stockholm School of Economics. From 1970 to 1975 he was a research assistant and later a research scholar at the Economic Research Institute of the Stockholm School of Economics. From 1975 to 1976 he was a researcher at the Secretariat for Future Studies, Ministry of Education, Stockholm. Since 1976 he has been associated with the Stockholm School of Economics. He is interested in the use of multisector general equilibrium models for long-term forecasting and economic policy analysis.

Robert Coen (USA) arrived at IIASA in August 1979 and left in August 1980. He received his B.A. degree in economics in 1961 from Harvard University, his M.A. in economics in 1964 and Ph.D. in economics in 1967 from Northwestern University. From 1965 to 1971 he was Assistant Professor of Economics at Stanford University, from 1971 to 1975 he was Associate Professor of Economics at Northwestern University, and he has been Professor of Economics at the same university since 1975. His current research involves extending and refining a macroeconomic growth model of the United States.

Joel E. Cohen (USA) worked with the System and Decision Sciences Area at IIASA for three months during the summer of 1980. He received various degrees in population sciences, public health, and applied mathematics from Harvard University between 1965 and 1973, and was Associate Professor of Biology at the same university until 1974. He has served as a consultant to many organizations, including the RAND Corporation and the Computer Science and Engineering Board of the National Academy of Sciences. Since 1975 he has been Professor at the Rockefeller University, New York; in 1976 he was also Director of the American Association for the Advancement of Science. He has been Chairman of the Board of Directors of the Society for Industrial and Applied Mathematics (SIAM) since 1973. His main research interests lie in the application of statistical and mathematical techniques to biological systems.

Michael A.H. Dempster (Canada) started working at IIASA in September 1979. He studied mathematics at the University of Toronto, and received his Ph.D. in mathematics in 1965 from Carnegie–Mellon University, Pennsylvania. He was Ford Research Assistant and Teaching Assistant at the Carnegie–Mellon University (1961–1965), IBM Research Fellow at the University of Oxford, UK (1965–1966), and a Research Fellow at Nuffield College, University of Oxford (1966–1967). He has been a Fellow of Balliol College, Oxford, since 1967 and is Chairman of Oxford Systems Associates Limited. His research interests include optimization, stochastic systems, and economics.

Felix I. Ereshko (USSR) worked at IIASA in April and May 1980. He received his diploma in applied mathematics from the Moscow Institute of Physics and Technology in 1963 and his degree as Candidate of Science from the Computer Center of the USSR Academy of Sciences in 1969. He has been at the Computing Center since 1966, first as a research scholar, then as a senior research scholar, becoming head of the Laboratory of Mathematical Modeling and Decision Making for Water Resources Management and Planning Systems in 1977. He is also an associate professor in the Department of Control and Applied Mathematics at the Moscow Institute of Physics and Technology. His scientific

interests include the mathematical basis of systems analysis, and the use of hierarchical games in large-scale systems.

Yuri Ermolev (USSR), who has been at IIASA since October 1979, received his Ph.D. in mathematical sciences in 1963 and his Doctor of Mathematical Science degree in 1970. He is currently head of the Department of Mathematical Methods in Operations Research at the Institute of Cybernetics, Ukrainian Academy of Sciences, and is also a professor at the University of Kiev, and a member of the Ukrainian Academy of Sciences. His current interests include methods of nondifferentiable and stochastic optimization.

Werner Güth (FRG) worked at IIASA between February and August 1980. He received his Ph.D. in economics from the University of Münster in 1972, and then became an assistant professor at the same university. Between 1974 and 1975 he was a visiting scholar at Yale University and at the University of California, Berkeley. He received his D.Sc. (Habilitation) in economics in 1976 from the University of Münster, and is presently Professor of Economics at the University of Cologne. His research concentrates on models of economic competition and game theory.

Bert G. Hickman (USA) first came to IIASA in 1979, returning for one month in the summer of 1980 to chair a conference on international economic modeling. He received his B.Sc. in economics from the University of California in 1947, and his Ph.D. from the same university in 1951. Between 1953 and 1955 he worked for the Council of Economic Advisors, and from 1956 until 1965 he was with Brookings Institution. Since 1966 he has been a professor in the Department of Economics at the University of Stanford. His main interests lie in econometric modeling, including the linking of international economic models and the development of the Hickman–Coen annual growth model of the United States.

Markku Kallio (Finland) was at IIASA between July 1978 and August 1980. He received his Ph.D. in 1975 from the Graduate School of Business, Stanford University. During the period 1968–1972 he was with the A. Ahlström Corporation in Finland, and from 1975 to 1976 he worked at the European Institute for Advanced Studies in Management (E.I.A.S.M.) in Brussels. Since 1976 he has been with the Helsinki School of Economics. His main interests lie in large-scale linear programming.

Andrzej Lewandowski (Poland) arrived at IIASA in February 1980. He studied control engineering and mathematics at the Technical University of Warsaw from 1969 to 1971 and received his Ph.D. in control sciences in 1974 from the same university. Since 1975 he has been an assistant professor at the Institute of Automatic Control, Technical University of Warsaw. His current research interests include model validity and credibility and dynamic optimization methods.

Giandomenico Majone (Italy) worked with the System and Decision Sciences Area on risk management in July, August, and November 1980. He received his B.Sc. (Laurea) in political economy (1956) from the University of Padua, his M.S. in mathematics

(1960) from the Carnegie Institute of Technology, and his Ph.D. in statistics (1964) from the University of California at Berkeley. He was the recipient of a Fullbright fellowship to George Washington University in 1955. He has been on the faculty of the Mathematical Institute of the University of Rome since 1964, and from 1967 to 1968 was an associate professor with the Faculty of Business Administration at the University of British Columbia. He was a consultant for the National Planning Commission of Italy between 1969 and 1972. His research interests include the foundation of statistics, policy science, and the philosophy of science.

Gerhardus van Muiswinkel (Netherlands) joined IIASA in November 1979 to work on the Economic Mineral Scarcity Project. He graduated from the Free University of Amsterdam with a Masters degree in macroeconomics in 1977, and since March 1977 has been with the Foreign Economic Relations Department of the Ministry of Economic Affairs in the Hague. His current research is centered around the economic analysis of mineral scarcity.

Evgeni Nurminski (USSR), who has been at IIASA since July 1978, is a senior research scholar at the Institute of Cybernetics of the Ukrainian Academy of Sciences in Kiev. He received his Ph.D. in nonlinear and stochastic programming in 1973. He has been with the Institute of Cybernetics since 1973, first as a research scholar and then as a senior research scholar. He is working on methods for solving nonsmooth optimization problems.

Douglas Nyhus (USA) worked at IIASA for two years, from July 1978 to July 1980. He studied mathematics and economics at the Universities of Washington and Maryland and received his Ph.D. in economics in 1975 from the University of Maryland. He has been with the University of Maryland since 1971 and is associated with the Inter-Industry Forecasting Project. His current research project involves the international linkage of national input–output models.

András Pór (Hungary) joined SDS in January 1979. He obtained his degree from the Mathematical Faculty of the Eötvos Lorand University in Budapest in 1967 and before coming to IIASA was a member of the Systems Analysis group of the Institute of Economic Planning, Budapest. His main research interest is developing improved numerical methods for solving multisectoral general equilibrium models.

R. Tyrrell Rockafellar (USA) started working with the System and Decision Sciences Area in September 1980. He received his Ph.D. in mathematics in 1963 from Harvard University. He was a Fulbright Scholar at the University of Bonn (1957–1958), Assistant Professor at the University of Texas (1963–1965), Research Scholar at the Mathematical Institute at the University of Copenhagen (1964), and visiting Assistant Professor at Princeton University (1965–1966). He has been Professor of Mathematics at the University of Washington since 1966, and has also been Visiting Professor at the University of Grenoble, France (1973–1974), and the University of Colorado (1978). His scientific interests center on applications of convexity theory and nonsmooth analysis to problems in nonlinear networks, stochastic programming, and optimal control.

Fumiko Seo (Japan), who worked at IIASA between April 1979 and May 1980, is currently an associate professor at the Kyoto Institute of Economic Research. She received her Ph.D. in economics from Tokyo University in 1967 and from 1973 to 1974 was an Honorary Research Fellow in the Department of Economics at Harvard University. Her research involves the methodological development of multicriteria decision analysis and its application to integrated regional planning and environmental systems management.

Anatoli Smyshlayev (USSR) worked at IIASA between August and December 1980. He graduated from the Moscow State University in economic cybernetics in 1969, and received his Ph.D. in mathematical economic models and techniques from Moscow State University in 1972. From 1972 to 1977 he was an associate professor at Moscow State University, and since 1977 he has been head of a laboratory in the Department of Economic Forecasting at the Central Economic–Mathematical Institute of the Academy of Sciences of the USSR. His main research interest is applied economic forecasting based on systems of econometric models.

Dennis Snower (USA) arrived at IIASA in May 1980. He received his M.A. in politics, philosophy, and economics in 1971 from New College, Oxford, and his Ph.D. in macroeconomic theory, international economics, and labor economics in 1975 from Princeton University. He is presently an assistant professor at the Institute of Advanced Studies in Vienna, on leave of absence from the University of Maryland. His main interests lie in input–output modeling and problems in intersectoral disequilibrium.

Ingolf Ståhl (Sweden) started working for the System and Decision Sciences Area in January 1980. He received his degrees in economics from the Stockholm School of Economics, where he has been Associate Professor of Managerial Economics since 1973. His research interests lie in experimental gaming and game theory.

Michael Thompson (UK) arrived at IIASA to work with SDS in July 1980. He received his Ph.D. in anthropology in 1976 from the University of London and is Senior Research Scientist with the Institute for Policy and Management Research, working in Bath, UK. He is also a lecturer in urban sociology at Portsmouth Polytechnic School of Architecture in the UK. He has published articles on aesthetics, the sociology of education, architecture, risk, ceremonial exchange systems, and the sociology of perception and is currently working on institutional aspects of risk management.

Roger Wets (USA) started work at IIASA in August 1980. He received his Ph.D. in engineering sciences from the University of California at Berkeley in 1966. He was a member of the applied mathematics division of the Boeing Scientific Research Laboratories, Seattle, in 1964. From 1970 to 1971 he was Professor of Applied Mathematics and Decision Sciences at the University of Chicago. In 1971 he was appointed Professor of Mathematics at the University of Kentucky, and since 1978 he has been head of the Department of Mathematics at the same university. Between 1965 and 1976 he held visiting appointments at the Universities in Louvain, Grenoble, Stanford, Cologne, Bonn,

and Berkeley. He was also a consultant to several industries and research organizations in the USA and elsewhere. He is the author of numerous publications and Editor of the SIAM Journal on Control and Optimization, as well as Associate Editor of several journals dealing with mathematics and operations research. His research interests include stochastic optimization theory and computational techniques, and the basis of mathematical optimization theory.

Andrzej Wierzbicki (Poland), who arrived at IIASA in October 1978, is a former Dean of the Faculty of Electronic Engineering in the Technical University of Warsaw and has been Chairman of the SDS Area since June 1979. He received his Ph.D. in automatic control in 1964 and his D.Sc. (Habilitation) in mathematical programming and optimization in 1968, both from the Technical University of Warsaw. He was a visiting professor at the University of Minnesota in 1969 and at Brown University in 1970. His research interests include optimization theory and its applications, multiobjective optimization and decision making, augmented Lagrange functions, and nondifferentiable optimization.

Peyton Young (USA) started working at IIASA in February 1976. He received his B.A. in mathematics in 1966 from Harvard University and his Ph.D. in mathematics in 1970 from the University of Michigan. Between 1971 and 1973 he was an assistant professor and from 1973 to 1978 an associate professor of mathematics at the Graduate School of the City University of New York. He has been an economic consultant with the United States National Water Commission and the Northeastern Illinois Planning Commission, and a Research Associate at the School of Organization and Management at Yale University. His research interests include public economics, game theory, and methods of fair division.

Ernö Zalai (Hungary) worked with the System and Decision Sciences Area for two months in the summer and autumn of 1980. He graduated from the Karl Marx University of Economics, Budapest, in 1966 with a degree in mathematics and economic planning, and he received his doctorate in 1968. Since then he has been working on the theory and applications of mathematical economic models at the Karl Marx University in the Department of National Economic Planning and Management; he is now head of the Planning Methodology Section within this Department. He spent the academic year 1971–1972 at Carnegie–Mellon University, Pittsburgh, sponsored by a post-doctoral Ford Foundation Scholarship, and in 1977 he was a visiting professor at Duquesne University, Pittsburgh. His research is based on the use of mathematical methods and models in economic planning.

SCIENTIFIC STAFF, 1973–1980

Scientist	Country	Period of service	Institute of origin	Remarks
1973				
A. Nomoto	Japan	June 1973	Osaka University	
R. Winkler	USA	July–Dec. 1973	Indiana University, Bloomington	
D.E. Bell	UK	Sept. 1973–Sept. 1975	Massachusetts Institute of Technology	
J.-P. Ponssard	France	Sept. 1973–Sept. 1974	Cesmap, Paris	
G.B. Dantzig	USA	Oct. 1973–May 1974	Stanford University	
Yu. Rozanov	USSR	Oct. 1973–May 1976	V.A. Steklov Institute of Mathematics, Moscow	
C. Winkler	Chile	Nov. 1973–July 1975	Stanford University	
G. Bruckmann	Austria	Nov. 1973–	University of Vienna	Part-time
1974				
T.C. Koopmans	USA	Jan.–Dec. 1974	Yale University	
J. Casti	USA	Jan. 1974–July 1976	University of Arizona, Tucson	
H. Konno	Japan	May–Nov. 1974	University of Tsukuba	
T.N. Srinivasan	India	May–July 1974	Indian Statistical Institute	
R.L. Keeney	USA	June 1974–Aug. 1976	Massachusetts Institute of Technology	Also with ENP
J.F. Shapiro	USA	June–Sept. 1974	Massachusetts Institute of Technology	
H. Strobel	GDR	June–Aug. 1974	Academy of Sciences, Berlin	
K.-H. Werler	GDR	June–Sept. 1974	Technical University of Magdeburg	
S. Chatterjee	USA	July–Aug. 1974	New York University	
J. Gros	USA	July 1974–June 1976	Harvard University	Also with ENP
T. Hansen	Norway	July–Aug. 1974	Norwegian School of Economics	

L. Zadeh	USA	July 1974	University of California, Berkeley	
J. Miller	USA	Aug. 1974	University of Louisville	
A.A. Afifi	USA	Sept. 1974–Aug. 1975	University of California, Los Angeles	Also with HSS
W.S. Jewell	USA	Sept. 1974–June 1975	University of California, Berkeley	
Yu. Evtushenko	USSR	Oct. 1974–Aug. 1975	Computing Center, Moscow	
F. Klix	GDR	Oct.–Nov. 1974	Central Institute for Cybernetics and Information Processes	
I. Zimin	USSR	Oct. 1974–Dec. 1978	Computing Center, Moscow	Also with ENP
H.-R. Grümm	Austria	Nov. 1974–Dec. 1978	University of Vienna	Also with ENP
1975				
R.K. Mehra	USA	March–Aug. 1975	Harvard University	
M. Peschel	GDR	March 1975	Academy of Sciences, Berlin	
W. Orchard-Hays	USA	May 1975–June 1979	National Bureau of Economic Research	Also with ENP
V. Sokolov	USSR	June–Dec. 1975	Soviet Committee for Systems Analysis	
W. Rödding	FRG	July–Oct. 1975	University of Dortmund	
H. Konno	Japan	Aug.–Nov. 1975	University of Tsukuba	
M.L. Balinski	USA	Sept. 1975–Jan. 1978	City University of New York	
H. Strobel	GDR	Sept. 1975	Academy of Sciences, Berlin	
A. Whinston	USA	Sept.–Dec. 1975	Purdue University	
1976				
D. Bunn	UK	Jan.–March 1976	London Graduate School of Business Studies	
J. Ledolter	USA	Feb. 1976–June 1977	University of Wisconsin, Madison	Also with FAP
M. Norman	USA	Feb. 1976–April 1977	Econometrica International, Santa Barbara	Also with ENP
P. Young	USA	Feb. 1976–	City University of New York	
V. Peterka	Czechoslovakia	May 1976–April 1977	Institute of Information Theory and Automation, Prague	Also with ENP

Scientific Staff *(continued)*

Scientist	Country	Period of service	Institute of origin	Remarks
F. Toueg	France	May 1976–Sept. 1977	University of Grenoble	
H.J. Barnett	USA	July–Sept. 1976	Washington University, St. Louis	
S. Chebotarev	USSR	July 1976–June 1978	Institute of Control Sciences, Moscow	
P. Jennergren	Denmark	July–Dec. 1976	Odense University	
A. Propoi	USSR	July 1976–Aug. 1979	Institute of Control Sciences, Moscow	
R. Mifflin	USA	Aug. 1976–Dec. 1977	Yale University	
C. Lemarechal	France	Sept. 1976–Nov. 1977	Institute de Recherche d'Informatique et d'Automatique, Yvelines	
A. Fisher	USA	Nov. 1976–Feb. 1977	University of Maryland	Also with REN
B. Hansson	Sweden	Nov. 1976–Aug. 1977	University of Lund	
1977				
W.B. Arthur	UK	March 1977–	The Population Council, New York	
P.K. Mitra	UK	April 1977–June 1978	University College, London	
A. Fisher	USA	July–Sept. 1977	University of Maryland	
P. de Janosi	USA	July 1977–June 1979	The Ford Foundation, New York	
L.V. Kantorovich	USSR	July–Aug. 1977	All-Union Institute for Systems Studies, Moscow	
L. Bergman	Sweden	Aug.–Sept. 1977	Stockholm School of Economics	
V.E. Krivonozhko	USSR	Aug.–Dec. 1977	All-Union Institute for Systems Studies, Moscow	
J. Waelbroeck	Belgium	Dec. 1977–Jan. 1978	Free University, Brussels	Also with FAP
1978				
B. Nouroutdinov	USSR	Feb.–March 1978	V.A. Steklov Institute of Mathematics, Moscow	

A. Umnov	USSR	Feb.–March 1978	Institute of Control Sciences, Moscow	Also with HSS
V.E. Krivonozhko	USSR	March–Dec. 1978	All-Union Institute for Systems Studies, Moscow	
L.R. Klein	USA	June–July 1978	University of Pennsylvania, Philadelphia	
C. Almon	USA	July 1978–July 1979	University of Maryland	
M. Kallio	Finland	July 1978–Aug. 1980	Helsinki School of Economics	
E.A. Nurminski	USSR	July 1978–	Institute of Cybernetics, Kiev	
D.E. Nyhus	USA	July 1978–July 1980	University of Maryland	
L. Bergman	Sweden	Aug. 1978–July 1979	Stockholm School of Economics	
J. Curry	USA	Aug. 1978–Aug. 1979	Xerox Palo Alto Research Center	
Yu. Ermolev	USSR	Oct.–Nov. 1978	Institute of Cybernetics, Kiev	
B. von Hohenbalken	Canada	Oct.–Nov. 1978	University of Alberta	
A. Wierzbicki	Poland	Oct. 1978–	Technical University of Warsaw	
S. Chebotarev	USSR	Nov. 1978–Jan. 1979	Institute of Control Sciences, Moscow	
1979				
A. Pór	Hungary	Jan. 1979–	Institute of Economic Planning, Budapest	
F. Seo	Japan	April 1979–May 1980	Kyoto Institute of Economic Research	
M.-E. Paté	USA	June–Aug. 1979	Massachusetts Institute of Technology	Also with MMT
M.A. Stoto	USA	June–Aug. 1979	Harvard University	
K. Tone	Japan	May–June 1979	Saitama University	
R. Coen	USA	Sept. 1979–Aug. 1980	Northwestern University, Illinois	
M.A.H. Dempster	Canada	Sept. 1979–	University of Oxford	
B. Hickman	USA	Sept. 1979	Stanford University	
Yu. Ermolev	USSR	Sept. 1979–	Institute of Cybernetics, Kiev	
G.M. van Muiswinkel	Netherlands	Nov. 1979–	Ministry of Economic Affairs, the Hague	

Scientific Staff *(continued)*

Scientist	Country	Period of service	Institute of origin	Remarks
1980				
H.J. Barnett	USA	Jan.–March 1980	Washington University, St. Louis	
I. Ståhl	Sweden	Jan. 1980–	Stockholm School of Economics	Also with MMT
L. Bergman	Sweden	Feb.–April 1980	Stockholm School of Economics	
W. Güth	FRG	Feb.–Aug. 1980	University of Cologne	Also with FAP
A. Lewandowski	Poland	Feb. 1980–	Technical University of Warsaw	
F. Ereshko	USSR	April–May 1980	Computing Center, Moscow	
C. Almon	USA	May–July 1980	University of Maryland	
D. Snower	USA	May–Sept. 1980	Institute for Advanced Studies, Vienna	
J. Cohen	USA	June–Aug. 1980	Rockefeller University, New York	
E. Zalai	Hungary	June, Oct. 1980	Karl Marx University of Economics, Budapest	Also with HSS
B. Hickman	USA	July 1980	Stanford University	
G. Majone	Italy	July, Aug., Nov. 1980	University of Rome	
M. Thompson	USA	July 1980–	Institute for Policy and Management Research, Bath, UK	
A. Smyshlayev	USSR	Aug.–Dec. 1980	Central Economic–Mathematical Institute, Moscow	
R. Wets	USA	Aug. 1980–	University of Kentucky	
R.T. Rockafellar	USA	Sept. 1980–Aug. 1981	University of Washington, Seattle	
I. Assa	Bulgaria	Oct. 1980–	Institute for Social Management, Sofia	Also with MMT

IIASA PUBLICATIONS, 1973–1980

C. Almon
The INFORUM–IIASA international system of input–output models (WP-79-22)
Path curves and plant buds: an introduction to the work of Lawrence Edwards (PP-79-5)
Linked input–output models for France, Germany, and Belgium [with D.E. Nyhus] (WP-80-22)

W.B. Arthur
Stochastic control for linear discrete-time distributed-lag models (RR-77-18)
An analytical survey of population and development in Bangladesh [with G. McNicoll] (PP-78-8)
Why a population converges to stability (WP-79-85)
Age and earnings in the labor market: implications of the 1980s' labor bulge (WP-79-118)
The economics of risks to life (RR-79-16)
Why a population converges to stability (RR-80-19)
The analysis of causal linkages in demographic theory (WP-80-110)

M.L. Balinski
A problem of fair division: apportioning the European Parliament [with H.P. Young] (RM-76-55)
The Jefferson method of apportionment [with H.P. Young] (PP-76-6)
Criteria for proportional representation [with H.P. Young] (RR-76-20)
On Huntington methods of apportionment [with H.P. Young] (RR-77-2)
Apportionment schemes and the quota method [with H.P. Young] (PP-77-3)
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