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IIASA Conference '80

Applied Systems Analysis: From Problem through Research to Use

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Cover

The front cover shows the Laxenburg Conference Center, which has been created through reconstruction of the former Imperial Theater and Dining Pavilion at Schloss Laxenburg. Its completion marks the final stage of restoration of the complex of buildings renovated for IIASA by the Austrian Government together with the Provinces of Lower Austria and Vienna.
(Photographer: Helmar Denkl.)

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IIASA REPORTS

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VOLUME 3 (1981)

IIASA CONFERENCE '80
APPLIED SYSTEMS ANALYSIS:
FROM PROBLEM THROUGH RESEARCH TO USE

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
Laxenburg, Austria

FOREWORD

According to the Charter of the International Institute for Applied Systems Analysis (IIASA)

> The Conference of the Institute is the major forum for providing broad scientific and technical advice to the Council and the Director; for encouraging the programmes of the Institute and linking them with the research efforts of other national and international institutions; and for fostering understanding of the work of the Institute.

IIASA Conference '80, which took place 19–22 May 1980 in the new Laxenburg Conference Center, was the second such meeting in the life of the Institute, the first having taken place in 1976. Since this meeting occurred during the Institute's eighth year, it celebrated the growing maturity of the research program by centering its attention on the theme Applied Systems Analysis: From Problem through Research to Use.

Under the patronage of Dr. Rudolf Kirchschläger, Federal President of the Republic of Austria, this Conference also marked the inauguration of the magnificent new Laxenburg Conference Center, an extension of Schloss Laxenburg, renovated and made available for the use of the Institute and other scientific, educational, and cultural organizations by the Austrian Federal Government, the Province of Lower Austria, and the City of Vienna. In view of the importance of this facility for the future of the Institute, the Conference Area was inaugurated with statements from Hubert Pfoch, First President of the Vienna Provincial Assembly, speaking for the Mayor of the City of Vienna, Mr. Andreas Maurer, Governor of the Province of Lower Austria, and Dr. Kirchschläger.

In order to carry out the threefold objectives of the Charter, the Conference included presentations of IIASA work both in summary and in detail; descriptions of IIASA's linkages to other international and national institutions; discussions of uses of IIASA work; and various informal interactions, both critical and explanatory, between attendees and members of the IIASA staff. In order to include these elements, the program was organized as follows.

Dr. Hertha Firnberg, Minister of Science and Research of the Federal Republic of Austria, opened the Conference. Academician Jermen M. Gvishiani, Chairman of the IIASA Council, then offered an introductory overview of IIASA; and Dr. Roger E. Levien, Director of IIASA, presented a summary of IIASA's research program and a perspective of its future. At the banquet after the opening session, Professor Howard Raiffa, the Director of the Institute during its first years, spoke about the importance and potential of the Institute.

The second day of the Conference was devoted to talks by the eight research leaders of the Institute, who gave overviews of work going on under their leadership.

The third day began with seven parallel consultative sessions, chaired by distinguished leaders from among the attendees, devoted to:

- Actual experiences of use, described by persons from the countries sponsoring IIASA's work.
- A general discussion among the attendees of lessons gained so far from experience of use, the potentials for further use, and how IIASA's work can be shaped to be useful.
- Discussion of problems of use from national points of view.
- Identifying principles for IIASA to follow as it seeks to ensure that its work is used.

The third day concluded with parallel sessions that afforded the conferees an opportunity to interact with members of the IIASA staff on a variety of subjects chosen from IIASA research activities.

The fourth and final day of the Conference began with short summary reports to all of the conferees by the chairmen of the seven consultative sessions of the previous morning.

The Conference closed with a summary of the important themes of the Conference given by Dr. Levien and a closing statement by Academician Gvishiani.

These Proceedings constitute a record of all of the presentations to the plenary sessions and summarize the more informal and detailed consultative sessions. In this way, the volume provides within a modest compass both an overview of the IIASA research activities and the responses of the conferees.

We hope that by presenting this information about the Institute's accomplishments and activities these Proceedings will help to extend the community of those who contribute to and benefit from IIASA's work and thereby help to fulfill the Charter's goal of achieving results that "benefit all mankind."

Jermen M. Gvishiani, *Chairman*
IIASA Council

Roger E. Levien, *Director*
IIASA

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Inauguration of the Laxenburg Conference Center

Mr. Hubert Pfoch
First President of the Vienna Provincial Assembly

Leopold Gratz, Provincial Governor and Mayor of the City of Vienna, has asked me in his absence to extend his sincere greetings to all participants at *IIASA Conference '80.*

IIASA Conference '80 marks the inauguration of the recently renovated Laxenburg Conference Center. The existence of this beautiful Center provides IIASA with facilities here in Laxenburg to hold its meetings and also offers other institutes additional conference facilities from which to choose in the Vienna area.

The availability of the Center's large and skillfully designed meeting rooms and of all essential conference facilities, the attractiveness of Schloss Laxenburg and its park, as well as the Center's proximity to the international city of Vienna are features that lead us to anticipate a large demand for the services of the Center.

The renovation of the Dining Rooms and the Theater Wing, both of which serve as the Conference Center, represents the final stages in the plans to use again the premises of Schloss Laxenburg. The success of this project demonstrates what can be accomplished when several territorial authorities cooperate toward achieving a common goal.

In 1962, Franz Jonas, then Mayor of Vienna, and Leopold Figl, then Provincial Governor of Lower Austria, agreed to cooperate in renovating Schloss Laxenburg, which was heavily damaged during the Second World War, and in developing the park around the Schloss as a recreation area. The Schloss Laxenburg Betriebsgesellschaft (management company) was set up and agreement was reached about the division of costs between the two provinces.

In the years that followed, the park was developed; a recreation center, including a restaurant, a swimming pool, and camping and other facilities was created; and renovation work began on the Schloss.

In 1972, when Laxenburg was made IIASA's home, the federal government joined the cooperative effort. It was decided to renovate the entire Schloss area with costs at a ratio of 60 percent of the costs being met by the federal government, 20 percent by the City of Vienna, and 20 percent by the Province of Lower Austria. By 1973 the first renovated rooms were put at the disposal of IIASA. By 1976 all renovation had been completed except for that of the Conference Center.

I believe that all efforts to provide IIASA with favorable working conditions have proven successful. The Schloss offers the seclusion in which creativity can flourish, while at the same time it is only a short traveling distance from the infrastructure of a major city.

The City of Vienna looks with keen interest at the research activities of IIASA, especially on its work on global food and energy problems. We believe that IIASA can contribute greatly to the practical application of scientific theories.

It is my personal hope that the work of the Institute will be characterized by the spirit of cooperation that has typified the period of renovation and restoration of Schloss Laxenburg. Collaboration of scholars from all countries is needed to tackle today's pressing global problems.

I hope that the participants will make full use of the Laxenburg Conference Center and that *IIASA Conference '80* will be a success.

Mr. Andreas Maurer
Provincial Governor of the Province of Lower Austria

It is a pleasure to join you today in celebrating the opening of the second IIASA Conference as well as the completion and inauguration of the new Laxenburg Conference Center. The first IIASA Conference took place in 1976 on the premises of the Hofburg Palace in Vienna; now, however, IIASA can invite conference participants to its own house, so to speak, to discuss world problems. The Schloss Dining Rooms and Theater Wing, erected in 1753, have been renovated to serve as a modern conference center, thanks to the cooperation of the Institute, the federal government, the Provinces of Vienna and Lower Austria, and the Local Administration of Laxenburg, whose mayor, Dr. H.C. Rauch-Höpfner, has always supported this undertaking enthusiastically.

I am especially proud of the Center. The magnificent Schloss, once the setting for many splendid festivities and political events of world note, has again taken on an important function.

The Schloss Laxenburg Betriebsgesellschaft (management company), set up in 1962 by the Provinces of Vienna and Lower Austria, has been a major factor in the success of this project that has made Laxenburg, a jewel on the outskirts of Vienna, more beautiful and attractive than ever.

We are proud that Laxenburg was chosen as the seat of IIASA, which, with its scientific member organizations in 17 nations, literally spans the world. Being host to such an institution is of particular importance to a federal province that has no university of its own and which, albeit involuntarily, might therefore have to play a lesser role in the field of science.

Our aim has been to make the scientists coming to IIASA from all over the world feel at home here in Lower Austria, and we shall continue to pursue this in the future.

Those of you who arrived earlier for the Conference witnessed Austria's celebration of two anniversaries. Thirty-five years have passed since the end of the Second World War and the restoration of the Republic of Austria. And it was a quarter of a century ago that the Austrian State Treaty was signed and that Leopold Figl, the distinguished son of Lower Austria, announced from the balcony of Schloss Belvedere in Vienna to a jubilant crowd, that "Austria is free!"

The signing of the Austrian State Treaty attracted attention throughout the world and was regarded as the beginning of détente, a policy that also led to the founding of IIASA.

It is thought that currently the policy of détente is in a critical state. This is of particular concern to a small neutral nation like Austria and to the Province of Lower Austria that suffered greatly during the war and the difficult post-war period.

We should exert every possible effort to overcome this critical state. As representatives of the scientific community, you may be called upon to exercise your influence in the interest of détente, for now – more than ever – our future is guided, not only by the views of politicians and the military, but also by scientists. The solution of the global problems is a requisite for peace, security, and mutual understanding throughout the world. IIASA's research activities, which deal with such wide-ranging issues as energy, food and agriculture, population growth, technology transfer, and resources and environment, illustrate that today's scientists do play a major role in détente.

In this spirit, I join the others in wishing the participants of the second IIASA Conference every success. I hope that the new Laxenburg Conference Center will be host to many important conferences on subjects relating to the world at large.

Dr. Rudolf Kirchschläger
Federal President of the Republic of Austria

It is with delight that I recall the month of October 1972, when the Charter of the International Institute for Applied Systems Analysis was signed, and when, in talks before and after the event, Austria was considered the future residence of the Institute. When IIASA finally decided in favor of Schloss Laxenburg, we, the Austrians, were overjoyed: there was a strong determination on the part of the federal government, as well as on that of the Provincial Governors of Vienna and Lower Austria, to spare no effort in creating an environment for the Institute that was both pleasant and conducive to its work, its members, and the conferences it would convene.

I repeat here with pleasure a statement that I made earlier in 1972 and 1973 in my former capacity as Foreign Minister of Austria: our aim in having IIASA located in Austria was not motivated only by a desire to host an ever-increasing number of international institutions and organizations. Rather, it stems from our interest in IIASA's research, and, above all, in our desire to have scientific life in Austria inspired. Clearly, these expectations and hopes have found ample fulfillment.

IIASA Conference '80 also marks the formal opening of the Laxenburg Conference Center, housed in the former Theater Wing and Dining Rooms of Schloss Laxenburg. This inauguration is both a proof that our promises have been fulfilled and a sign of Austria's appreciation of the Institute. The loving care and the financial support needed to successfully blend the traditional architecture with modern technology are possible only if the future user is held in high regard. This was the guiding force for the efforts undertaken by the federal government and the Provinces of Vienna and Lower Austria in establishing the Laxenburg Conference Center.

I would like to express my appreciation to the federal government of Austria, represented by Dr. Hertha Firnberg, Minister of Science and Research, to the Province of Vienna and its Governor, Mr. Leopold Gratz, to the Province of Lower Austria and its Governor, Mr. Andreas Maurer. The cooperation of these bodies has enhanced the image of Austria as a nation dedicated to scientific achievement.

The problems now facing the world are no less severe than those it was confronted with when the Institute was founded. Cooperation worldwide is needed in order to understand and to solve these problems. IIASA's findings are useful tools for those – not only the two great powers – entrusted with decisions about how the world can avoid catastrophes in the future and about how a more peaceful life can be created in the future.

May I take this occasion to extend my best wishes to IIASA and to express the hope that its research will yield valuable insights into global problems.

It is my hope that the new Laxenburg Conference Center will provide IIASA with additional means for carrying out its complex tasks and that you will view the Center as a sincere token of Austria's esteem for IIASA. It is my hope that the Laxenburg Conference Center will operate successfully.

Opening session of the Conference

OPENING OF THE CONFERENCE

Dr. Hertha Firnberg
Minister of Science and Research of the Republic of Austria

I wish to convey to you my pleasure with today's events: the inauguration of the Laxenburg Conference Center and the holding of *IIASA Conference '80* in the Center, which is made up of the Theater Wing and Dining Rooms of Schloss Laxenburg.

It is an honor for me to open *IIASA Conference '80*, which provides the scientific community with the opportunity to review the progress of IIASA in studying global problems.

It is particularly gratifying for me to observe the many ways IIASA's presence in Austria has enriched scientific activities in Austria.

As the member of the Austrian Federal Cabinet responsible for scientific policy, I have observed the growth of the Institute over the years. I assure you unreservedly that IIASA's scientific work is fully known and highly regarded by prominent representatives of Austrian universities and extramural research.

Undoubtedly, IIASA's scientific achievements result from its collaboration with its National Member Organizations (NMOs). This cooperation in turn facilitates a continuous exchange of information and views between IIASA scientists and the scientific communities in the NMO countries.

This embedding of information about IIASA's scientific activities in the worldwide information and communication network exhibits in my view the systems characteristic that makes IIASA unique. It is this characteristic that – as set forth in the IIASA Charter – distinguishes the Institute from almost all other international and national research institutions.

This information and communication network is not made up merely of modern computer and telecommunications facilities. I believe there are also organizational and sociological factors at work, such as the explicit policy of continually bringing in new scientists and fresh viewpoints as well as nontechnical but highly functional, interpersonal and informal mechanisms of communication, which are presently receiving more and more attention from modern sociology of science.

The proper functioning of worldwide communication for scientific exchange is indispensable, and it is a requisite for achievements in the global political and scientific fields. The 1979 United Nations Conference on Science and Technology for Development pointed out clearly the difficulties of and underscored the need for global communication in these fields.

In this light, the inauguration of the Laxenburg Conference Center by the Federal President of Austria is an important event. It has provided IIASA with a means for contributing more widely to the international dialogue of politics and science.

I would like to extend to the participants of *IIASA Conference '80* my sincere wishes for success in their consultations. I believe that the results of your work are not only scientifically and politically significant but also contribute to global political stability.

The recent festival days in Austria, commemorating the twenty-fifth anniversary of the signing of the Austrian State Treaty and thus the beginning of détente, have – in the talks among foreign ministers, and in particular those of the two great powers, the USA and the Soviet Union – instilled new hope for peace in the world. Scientists as well as those responsible for scientific research policy, should see the events of these past few days as reason to ask: What can science and, in particular, an international scientific organization like IIASA, contribute to furthering the policy of détente? I believe that, in times of international tension, the presence of institutions like IIASA and the availability of a functioning worldwide communications network – that, fittingly, is furnished by interdisciplinary science – are requisites for the continued existence of mankind. During a crisis, the logic of political, economic, and scientific progress in the world is not one-dimensional. From my numerous talks recently with Austrian and foreign scholars, I have been led to believe that science is indeed aware of its sociopolitical responsibility toward fostering progress and peaceful coexistence throughout the world.

This observation is reassuring. IIASA was, at the time of its founding, an expression of the favorable climate in the relations between East and West; in view of the importance and strength acquired by IIASA since then, one can expect a positive feedback to develop shortly. Because of international tension, both between East and West and North and South, the world's scientific community should take up its share of the burden and do everything in its power to support the forces that are actively engaged in a policy of détente.

It is my hope that you will continue to work toward the objectives set forth in Article II of the Charter – to make scientific research a tool of peace and a means of communication among peoples.

WORLD PROBLEMS: INTERRELATIONS AND INTERDEPENDENCE

Jermen M. Gvishiani
Chairman of the Council of the International Institute for Applied Systems Analysis

The opening of the second IIASA Conference provides us with an opportunity to sum up the results of another important stage in IIASA's development. It is also an appropriate occasion to acknowledge the importance of another event taking place this month. Proudly, the Austrian people are celebrating the twenty-fifth anniversary of the signing of the Austrian State Treaty, which established the independent and democratic Republic of Austria. Both the State Treaty and the permanent neutrality adopted voluntarily by the Austrian parliament have helped relax international tensions and have fostered peace and international cooperation.

This is the basis of our belief in an even greater role for IIASA, as a seed of détente planted in the fertile soil of Austria, in facilitating wide international cooperation – cooperation aimed at solving many of the problems facing mankind today.

According to the Institute's Charter, the holding of an IIASA Conference can be regarded as a milestone of the Institute's progress: it provides an opportunity for both the Institute and the world scientific community to review the accomplishments of the Institute's research activities and to plan future research directions.

Those who participated in the first IIASA Conference held in 1976 at Vienna's Hofburg Palace may recall the hope and confidence expressed at that time that IIASA would be able to live up to its goal of contributing to international scientific cooperation. The belief in IIASA then could be traced to the first, though modest, successes of its research. These first successful steps confirmed the feasibility of the ideals of IIASA's founders, ideals based on a common desire to use the potential of international scientific cooperation, realized through a new form of interdisciplinary systems approach to solving the urgent problems faced by humanity.

Four years have passed since the first IIASA Conference, a rather long period in the Institute's life, representing more than half of its existence. The second IIASA Conference marks the end of the second phase of IIASA's development and gives us the opportunity to ask whether – after almost eight years of practical research experience – our hopes of establishing an institute with an international and interdisciplinary systems approach were justified.

The answer to this question is undoubtedly yes. This way of attacking the pressing problems faced by mankind – creating IIASA – has justified itself. Everyone engaged in analyzing similar problems understands that internationality and interdisciplinarity are key concepts in their understanding and successful solution. These concepts, realized through the practical activity and smooth functioning of the Institute, are constantly being developed and strengthened.

It is only the *international* character of the Institute's research that can ensure compatibility of views on the substance of global problems, an essential prerequisite for their solution. A true internationality in approach can only be achieved if there is a wide spectrum of conditions present in IIASA's everyday activities: from the purely quantitative factor of broad national and geographical representation in the Institute itself, which generates a wide variety of viewpoints on each problem, to the goodwill and sincere desire for effective cooperation in the effort to create on our planet favorable conditions for all peoples and nations, irrespective of race, political conviction, and national social and economic order. IIASA's international character is most effective in a favorable climate: in the climate of peace – peace defined not as the absence of military activity, but as a state in which international relations are characterized by détente, the limitation and reduction of armaments, the growth of mutual trust, and the development of cooperation in the economic, scientific, technical, and cultural fields.

The *interdisciplinary* approach has established itself as the methodological basis of IIASA's analytical and research activities. Systems research has emerged recently as a new science, still in its formative stages, which employs comprehensive studies of complex natural and social processes. Scientists are now able to accept the challenge of synthesizing the abundant theoretical and experimental material accumulated in scientific disciplines, as well as of elaborating new techniques and approaches of interdisciplinary analysis for dealing with the complexity of modern problems.

Until recently, specialization has been the dominating trend in the development of science. However, modern problems cannot be squeezed into the frameworks of individual branches of science; they call for interdisciplinary approaches and criteria. These problems are not formulated as a specific outcome and logical consequence of the prior development of scientific knowledge, but rather as the set of objectives posed to science as a whole by the development of civilization.

Global studies are the new *problématique* of scientific research. The very nature of global problems – their transnational and transdisciplinary features – requires new forms of creative interaction and wide collaboration that will allow us to mobilize the achievements of world science for integration in attacking problems unprecedented in scale and complexity. The purpose of such collaboration is the effective utilization of the planet's scientific potential, the experience amassed by all the scientific disciplines. The degree to which world science can fulfill its age-old mission of attaining human knowledge depends on how flexibly world science responds to the needs of human development.

Integration of world scientific achievements for this historical purpose can take various forms; one form (however modest, but we believe very effective) is IIASA, an international, interdisciplinary institute concerned with pressing problems that affect the entire globe. Naturally our confidence in the success of the endeavor is not based just on the principles of internationality and interdisciplinarity in IIASA's activities. It is confirmed today by the results of the Institute's research.

The interest of the world scientific community in the Institute's activities, the responses to IIASA's publications, and the desire for cooperation with the Institute indicate that IIASA is now firmly established among the world research institutions and has gained the reputation of a serious scientific center whose unique character – both existing and potential – is not yet fully realized and used. In this sense we may say that the atmosphere that reigned in the halls of the Hofburg Palace in 1976, of hope and confidence in IIASA's future successes, is also justified here, though on a different, more substantial basis: the solid foundation of significant research results achieved by the Institute so far.

It is appropriate to examine some general experience that IIASA has gained during its brief existence. It is obvious that the early years had to be years of constant searching – there were successes as well as some failures. The initial search process led inevitably to a wide spectrum of activities being undertaken by the Institute. This was sometimes looked upon – not without reason – as a fragmentation of IIASA's research program that seemed unwise given the Institute's limited resources. In retrospect we see that this testing of IIASA's abilities on many specific tasks requiring systems methodology was a valuable experience that helped in the search for a proper role for IIASA as a participant in the attack on humanity's pressing problems. In my opinion, this search for the correct role is not finished; it is a healthy feature of the dynamics of IIASA's development.

This search has singled out a class of *global problems,* the solution of which will influence the destiny of all humanity. At the same time, *universal problems* – problems that can be solved within the boundaries of individual nations – are the object of serious study at IIASA because their common features, the methodologies and techniques of their solution in differing socioeconomic conditions, are of interest to many national organizations. The Energy Systems Program, which is concluding its first phase by publishing the books on *Energy in a Finite World**, and the Food and Agriculture Program are working on the global class of problems; managing water resources, the quality of water, the health-care system, the demography and migration of populations, and regional planning are examples of areas in which universal problems exist.

I consider this combination of different classes of problems in IIASA's research program not only justified but also necessary. An opinion expressed sometimes is that analyzing local systems, or micro systems (such as urban systems, large enterprises, individual sectors of industry) is not worth while because the prospects for gaining experience that will be useful in the subsequent transition to the studies of more complex systems at the global scale are not good. However, I believe that, in trying to solve global problems, isolating them from everyday human cares and deeds will lead to abstraction both in formulation and solution. The global problématique has begun to puzzle men of science, public figures, and all those who care about the fate of humanity, as the generalized result of humanity's progress realized through local systems – systems where man's vision is confined to a geographically limited area or region, and where planning horizons are rarely beyond the threshold of immediate needs.

There is another reason for not isolating global problems: our increased understanding of their essence, the resulting knowledge, and our ever-increasing global concern should, even at this early stage, be transformed into purposeful actions in our everyday lives, no matter how limited the geographic or time scope of these actions may be. This transformation is likely to be very complex, and serious research is required on the necessary social and structural changes, such as reshaping economic orders and lifestyles as well as the current system of human values.

Therefore we consider it useful that the Institute's program of in-house research harmonizes global issues with universal problems of a largely national, regional, or indus-

*Energy Systems Program Group of the International Institute for Applied Systems Analysis, Wolf Häfele, Program Leader (1981) *Energy in a Finite World*: Volume 1. *Paths to a Sustainable Future*; Volume 2. *A Global Systems Analysis.* Cambridge, Massachusetts: Ballinger.

trial character. Investigating the interplay and interdependence of these two aspects helps to solve the problems more rationally.

What I have said so far is not intended to belittle the significance of the global problématique. On the contrary, the dynamics of IIASA's research plans reflects a raising of the Institute's aspirations to address significant international problems, of which issues of global development represent the major focal point.

The emergence of global studies in the 1970s, largely stimulated by the activities of the Club of Rome, reflected the growing concern of those who, having realized the disproportions, conflicting objectives, and lack of long-term considerations in the world development process, called for an immediate start on the scientific analysis of the global problématique.

It has become obvious that the increase in world population, the dramatic growth of cities, and the transient character and increasing rate of processes of scientific and technological development lead not only to a greater intensity and scale of man's impact on his habitat, but also to a change in the character of man's interference in natural processes and, consequently, in the implications of that interference. Man's impact on nature has reached a level of intensity comparable with that of the natural forces themselves. There are the threats of irreversible changes in the earth's atmosphere, of upsetting the main mechanisms of life-support systems on our planet, of depletion of natural mineral resources, and of damaging the natural conditions of existence for generations to come.

Global problems involve such powerful and complex phenomena that they will, for a long time, influence various aspects of life in countries and regions – and in the world as a whole. They will cause a reappraisal of long-established categories and build up forces acting for a sharp turn in some deep-rooted trends of development. The challenge of global development is to find socially, economically, technically, and politically feasible paths toward a world system of more than twice the present population: a system with a sustainable balance between man's activity and the biosphere, between society and nature, a system that is resilient to natural and human-induced shocks, and which provides an equitable distribution of sustenance and well-being.

IIASA is already meeting this challenge. Its Energy Systems Program has shown that paths to sustainability exist for the global energy system; the Food and Agriculture Program is establishing their feasibility for the global food system. The Institute is initiating a long-term effort toward meeting this challenge by reviewing our current understanding of the critical issues of population growth, urbanization development, energy, food, mineral and water resources, environment and climate, technology and industrial development, and economic growth.

Future success in studies of the global problématique and the long-term development of economic systems depends, however, on further advances in some areas. First it is necessary to develop a deep and fundamentally new understanding of the influence of selected development strategies on social and material reproduction structures. The focus in developing such understanding should be on the interaction and interdependence of various reproduction structures, with all their complexity, in the national and world context.

Second, new tools are required that allow for development modeling in the broad sense of the word. The methods of mathematics, cybernetics, systems theory, and logic employed today for systems analysis of socioeconomic processes are not adequate for solving these problems (although this does not preclude their application as elements in the algorithmic systems of solving development models). So far we have only embryos of the tools in various mathematical disciplines – game theory, topology, differential geometry as a whole, the neoclassical variational calculus, etc. The results obtained by applying these methods give some hope, but they are still too general to be adequate for the detailed modeling essential for any fully applied theory.

The third objective is to build up data suitable for long-term analysis, and for global modeling in particular. At present we put too much weight on traditional economic indicators and are naive in our belief that higher rates of growth of these indicators testify to more effective development. However, growth and development are not identical concepts, especially if such a dynamic, contradictory, and at the same time independent process as the contemporary world economy is considered.

Summarizing these points, I should like to repeat that there is a strong interrelationship and interdependence between the future development of the globe and the everyday activity of each human being on a local scale with geographically and temporally limited horizons. Our degree of understanding of this interrelationship and interdependence will continue to increase both with an improving vision of the global problématique and with an extension of our capability to look beyond our usual horizons at everyday requirements. New dimensional characteristics (spatial and temporal) of the factors involved, as well as their interrelationship and interdependence, call for a new methodology, or as it is often defined at the Institute, a new craft of systems analysis.

The theme of the Conference indicates that the application of this craft is equally important in all three aspects of the process of applied systems analysis: from formulation of the *problem*, through approaches and methodologies of *research*, to *use* of the research results. Relatively more attention is given at this Conference to the use aspect of this process, which is sufficiently complex in itself to justify a special and very important branch of research.

The uniqueness of the Institute lies not only in its conception or in the form of its realization but also extends to the process of its research and embraces the use of its results. However, in my opinion the most important of these results, at least, come in the form of a *vision* felt by researchers as an outcome of deep, concentrated analysis directed to long-term aspects of development but indispensable for intelligent and wise actions in everyday life. The process of transferring this vision is difficult, lengthy, and delicate. There is no assurance that it will grow simpler as our vision becomes closer to perfection.

Our confidence in the success of IIASA's endeavors is also based on the fact that the Institute is not alone in meeting the challenge of the contemporary world. Over the years, it has developed strong ties to organized and specialized agencies of the United Nations. Joint projects and cooperation are going on with the United Nations Educational, Scientific and Cultural Organization, the United Nations Environment Programme, the Economic Commission for Europe, the World Health Organization, the World Meteorological Organization, the Food and Agriculture Organization, and others. A very close relationship has been established with our UN neighbors here in Vienna: the International Atomic Energy Agency, and the United Nations Industrial Development Organization. Joint work is being pursued along the lines of mutual interests with other international – regional and nongovernmental – organizations. Many of these international organizations are represented at the Conference, as well as many national research institutions. Together they constitute an impressive network of research establishments whose potential for attacking world problems is difficult to overestimate.

We are particularly satisfied that during recent years this network has been joined by industrial organizations, who are also represented at the Conference. This extension of collaborative links has a special importance for IIASA, not only because it brings additional much-needed resources for research, but also because it brings new insights, both in problem formulation and in the practical implementation of research findings. Of course the degree to which this network is extended is, in a way, an indirect measure of the practical applicability of the Institute's research.

The most effective use of the already-formed infrastructure to develop collaborative research, and its expansion to amplify IIASA's research efforts, are topics of permanent concern to the Director and to my distinguished colleagues on the Council of the Institute. I take this opportunity to thank the IIASA Council members, the Institute's Director, Roger Levien, the research leaders, and all the IIASA scientists for their tireless efforts, devotion, enthusiasm, and initiative in meeting IIASA's objectives and in creating the IIASA working spirit.

We believe that this Conference will give new impulse to the work of the Institute and will strengthen its ties with the international scientific community and decision makers.

The objectives of IIASA and its collaborating international and national research organizations are very human in their essence. We strive to promote deeper vision of actual, real processes of development for mankind, a vision that is free of subjectivity and national egocentrism. Our goal is to achieve objectivity in evaluating ongoing processes and in supplying independent expert assessment of future development alternatives to those who inevitably concentrate their efforts on current problems, the complexity of which demands all their abilities.

We hope that the practically tested IIASA experience and the spirit of its efforts will gradually become dominant in our complicated world torn by contradictions and conflicts. We aspire to put studies of the future in a more important place on the agenda of contemporary international problems. Despite the severity of recent events and the attention they draw, there are forces in the world that aim to foresee new problems that will become critical for mankind. Nothing can justify lack of special efforts in this direction, which is of paramount importance for the inhabitants of our planet. This is the special mission of scientists, their special social responsibility.

The fact that an institute such as IIASA exists and evolves in Austria is highly symptomatic. We have ample grounds to affirm that, owing to the efforts of the Austrian government and the Austrian people, who have so hospitably accepted our organization, and owing to the growing conviction of our founders of the necessity of developing international cooperation in solving pressing problems of the contemporary world, we can look to the future of IIASA with confidence.

Having the privilege of your presence at the Conference, Mr. President, and that of many honorable guests representing the Austrian Republic, I cannot but express, in conclusion, the deep gratitude of the Council and National Member Organizations of IIASA to the Austrian public and government for everything they have done to support the successful activity of the Institute.

APPLIED SYSTEMS ANALYSIS: FROM PROBLEM THROUGH RESEARCH TO USE

Roger E. Levien
Director of the International Institute for Applied Systems Analysis

The first IIASA Conference was held in May 1976, approximately three years after the first scientists began work at the Institute; now, four more years have passed, and the Institute has seven years of experience behind it. In these seven years, IIASA has grown from 1 to 100 senior scientists and its budget has risen to about 140 million Austrian schillings, or somewhat over US$ 10 million.

At the first IIASA Conference, the Institute demonstrated that the founders' conception of an international but nongovernmental institution concerned with today's pressing problems was feasible; at the second IIASA Conference we address the question of the actual and potential usefulness of the Institute's research: Can IIASA's work contribute to a wiser resolution of problems of international importance? What can be done to improve IIASA's usefulness and use?

With this goal in mind we have chosen as our theme Applied Systems Analysis: From Problem through Research to Use.

My purpose is to introduce this theme by considering three questions:

- What *problems* does IIASA address, and how have they evolved since its inception in 1972?
- What are the distinguishing characteristics of IIASA's *research*?
- What *use* is made of IIASA's results, and by whom?

In their papers, my colleagues give more detail of each of the substantive issues that I shall raise here. My purpose is to present a broad view of IIASA's activities that will suffice for those who cannot go further and that will serve as a framework and background for those who read the more detailed papers.

Everyone with experience in applied systems analysis knows that the simple linear sequence: *from* problem *through* research *to* use rarely, if ever, occurs. Instead, there are usually loops back from research to an improved perception of the problem and from use back to revised research needs and to further redefinition of the problem. These loops may be followed many times in a constant interplay among problem, research, and use.

Having acknowledged this complex reality, however, I shall now discuss problem, research, and use at IIASA as though they followed one after the other rigidly. In discussing each, I shall begin where IIASA began – with the ideas of those who worked to create

IIASA as they expressed them in the Charter – and show how experience has given meaning to these aspirations.

PROBLEM

In the Preamble to the Charter, IIASA's founders identified in 1972 their concern for the complex problems of modern societies arising from the continued application of science and technology:

> . . . the spread and intensification of industry through the continued application of science and technology generates problems of an increasingly complex nature in modern societies . . .

These problems of modern society were manifest at the beginning of the 1970s when IIASA was established; events since then have only dramatized them further. Since IIASA's establishment, there have been: in 1973, the first oil crisis; in 1974, widespread food shortages; in 1975, recognition of the carbon dioxide threat to our climate; and, more recently, a general economic malaise characterized by slowed growth and increased inflation.

Categories

In identifying the problems of modern society that it should work on, the Institute found it useful to distinguish between two major categories: global and universal (Figure 1). *Global problems* cut across national boundaries and cannot be solved without joint action. Thus, they require joint analysis and are a proper subject for IIASA's concern. *Universal problems* lie within national boundaries and, therefore, are subject to national

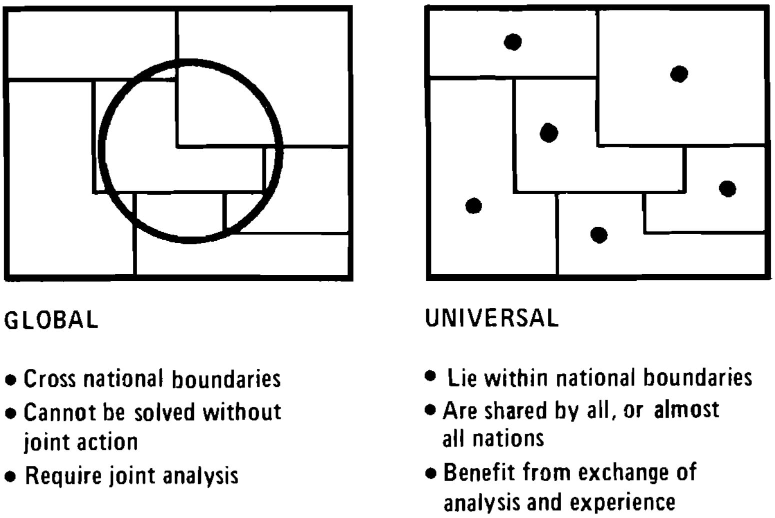

FIGURE 1 The problems of modern society.

authority. However, because all, or almost all, nations share them, their solution within nations can benefit from the exchange of analysis and experience among nations, especially among those that have different economic, social, political, or analytical approaches to their solution. Thus, IIASA concluded that it should address both global and universal problems.

Of course, most problem areas have aspects of both global and universal character; for example, there are both global population problems and universal population problems. Table 1 lists a number of problem areas in these two categories, with the universal problems broken into two subcategories, regional and national, depending on the level of decision making that is most immediately concerned.

This listing is not exhaustive, but rather illustrative. The italicized areas are ones in which IIASA has addressed problems (the Institute has been concerned with problems in other areas as well). Obviously, there are far too many problems of modern society in these areas for IIASA to work on them all at any single time. However, as we shall see later, there are beneficial interactions that come from examining more than one at a time.

TABLE 1 Some global and universal problem areas (the ones in which IIASA has done work are italicized).

	Universal	
Global	Regional	National
Population	*Water*	*Urbanization*
Food	*Environment*	*Health*
Energy	Industry	Economy
Industry		
Resources		
Ocean		
Climate		

Global Problem: Energy

The first research project that IIASA undertook in mid-1973, several months before the oil crisis in October, was in the area of energy. Professor Wolf Häfele of the Federal Republic of Germany had proposed such a project in mid-1972.

His concern was with the transition that must occur in the next 50 years from an oil- and gas-based economy to one relying on sustainable sources of supply. Is this transition feasible? What alternative strategies are there? Professor Häfele reports on his team's findings in his paper, but I can sum up the conclusions in one phrase: It can be done. That is, there are technically and economically feasible paths from here to an energy-sustainable society, although the transition will take longer than 50 years. This was our first global problem analysis.

Global Problem: Food and Agriculture

In 1977 we began our second, on food and agriculture, under the leadership of Professor Ferenc Rabar from Hungary. Here the problem was somewhat different, for distribution, rather than production, appears to be the central issue of the global food system – as Professor Rabar describes in his paper – and understanding this exceedingly complex system must precede strategies. The Food and Agriculture Program is in midcourse, so conclusions are not yet available; but a global community of analytical groups has been created to share in the effort.

Our work on these two global problems, and our preliminary examination of several others, has brought us to an appreciation that a dramatic phenomenon underlies the problems that we see in several different sectors and places: during the 300-year period from roughly 1800 to about 2100 the world has been moving from one stable population level to another, one order of magnitude greater (Figure 2). That is, up to 1800 the

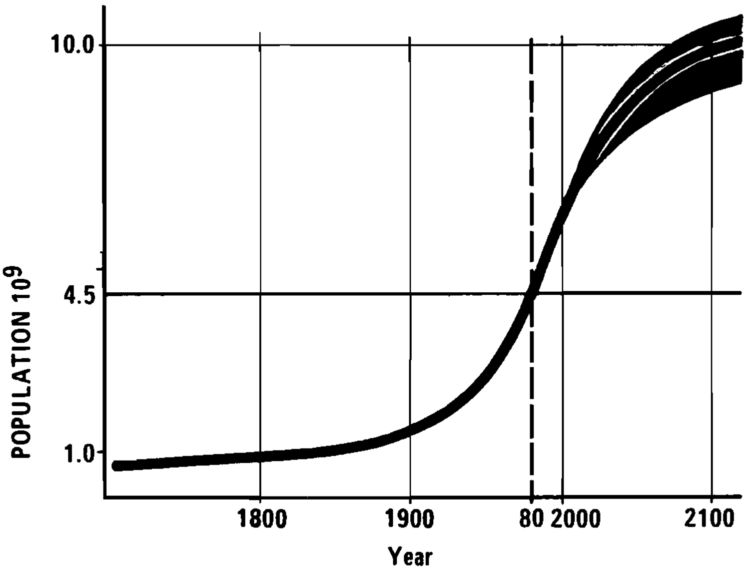

FIGURE 2 The population transition.

human population had never exceeded 1 billion and it existed in a long-term stable relationship with nature. After 2100, demographers suggest, the global population will again have reached a plateau of between 8 and 12 billion, say 10 billion.

This tenfold greater population must somehow establish a new, higher-level sustainable balance with nature. In 1980 we are roughly at the midpoint of the transition, with a population of 4.5 billion. And we are exploiting the world's nonrenewable resources to fuel our movement toward a larger population, exhausting the global endowment that thus will no longer be available to future generations.

Fundamental Global Problem: Transition

The fundamental global problem, then, is how to achieve a peaceful *transition* to a world of 8–10 billion that:

- Is in *sustainable* balance with natural resources.
- Has an *equitable* distribution of well-being – for 80 percent of these 10 billion people will be in the nations now called less-developed, and either considerable economic development will occur or conflicts between rich and poor will be unavoidable.
- Is *resilient* in the face of shocks – for there are bound to be natural and man-caused shocks (climate change or political change) and, unless the system can survive them, disaster will inevitably follow.

IIASA's Approach to Global Problems

With this extended appreciation of the global problem, we can return to IIASA's work – specifically to its approach to problems in this area. As Figure 3 indicates, we perceive the global system to comprise a number of sectors, some of which are shown,

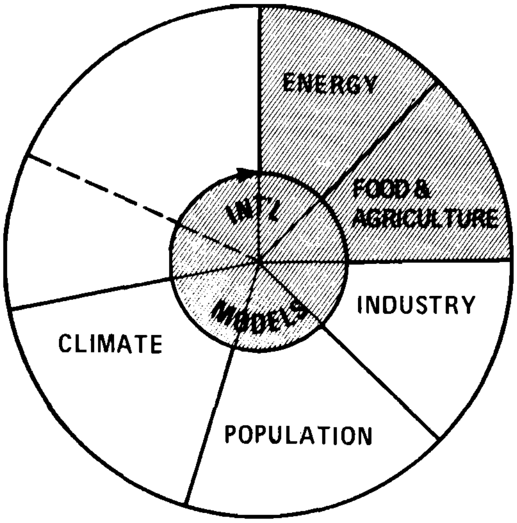

FIGURE 3 IIASA's approach to global problems.

linked through a variety of mechanisms. In recent years, efforts have been made to study the global system in all its complexity through multisectoral global models. While keeping a "watching brief" on such activities, our view has been that, before moving to that level of integration, much deeper knowledge of the individual sectors is necessary. Our global energy and food-and-agriculture studies (sectors shaded in the figure) have been the first steps along this path. In coming years, we will investigate additional sectors as resources become available. At the same time, we are carrying out certain studies of international linkages, especially economic linkages, that will provide the tools for analyzing the interactions of the individual sectors when this becomes appropriate. In all these cases, the question behind our studies is that of *transition*: What are the feasible paths from here to a world with a population of 10 billion?

Universal Problems: Regional

We now turn to universal problems, beginning with those at the smaller scale – the subnational region. A number of problems of modern societies on which IIASA began to work in 1973/74 take their most significant forms at the regional level. This is true, for example, of the problems of water supply, demand, and quality. There is no global water shortage – even in a world of 10 billion – but there are many regions that have water supply and quality problems.

Environmental and ecological problems also take their most dramatic form at the regional scale. IIASA has investigated the interactions among energy, agriculture, and the regional environment, as well as techniques for assessing the environmental consequences of new regional activities, within our Resources and Environment Area. Janusz Kindler describes some of this work in his paper in this volume.

Migration and urbanization are two other issues that are important at the regional scale and that have been on IIASA's agenda in the Human Settlements and Services Area. These studies are described by Andrei Rogers in these Proceedings. As in the global case, while working on these problems, we have come to appreciate that there is a common concern that lies behind them and that poses a significant challenge to regional planners and managers in general. It is shown in Figure 4; we call it the problem of integrated development.

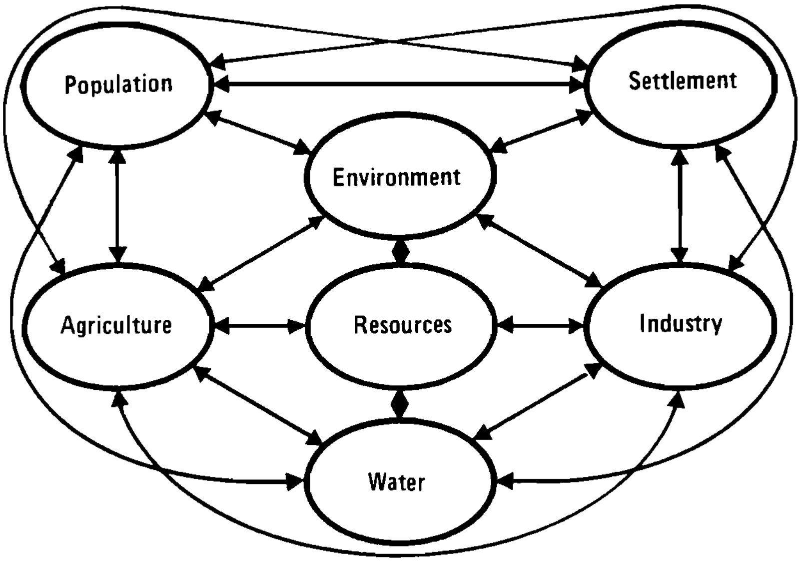

FIGURE 4 Integrated development.

If we consider, for illustration, the water system at the regional scale, we see that its development is interlinked with the development of agriculture, industry, settlements, and (of course) population in the region. There are also links to other resources and to the environment. And what is true for water is reciprocally true for the other sectors. Consequently, water-system analysis done in isolation from analysis of the other systems runs the danger of inadequacy or irrelevance. Similarly for planning and management.

Fundamental Regional Problem: Integration

The fundamental regional problem, then, is planning and managing the *integrated development* of regions having complex multisectoral structures so as to achieve high economic benefits while keeping the social costs low and the quality of life high. The instruments available and the resources and constraints differ widely from region to region. The problem of planning and managing integrated regional development appears in various guises in every economic and political setting. Solving the problem is a direct challenge to applied systems analysis.

IIASA's Approach to Regional Problems

The Institute's approach to this problem area has been somewhat different from its approach to the global problems. While many separate sectoral studies have been undertaken, as suggested by the shaded sectors in Figure 5, considerably more effort than in the global case has been devoted to the linkage among the sectors. There have been two interrelated means of doing this: The first is a series of case studies of regional development in which the integration of sectors has been stressed. The second is a linked set of models that provides the means for examining complex, but integrated, development paths for regions. Professor Murat Albegov describes this work in his paper.

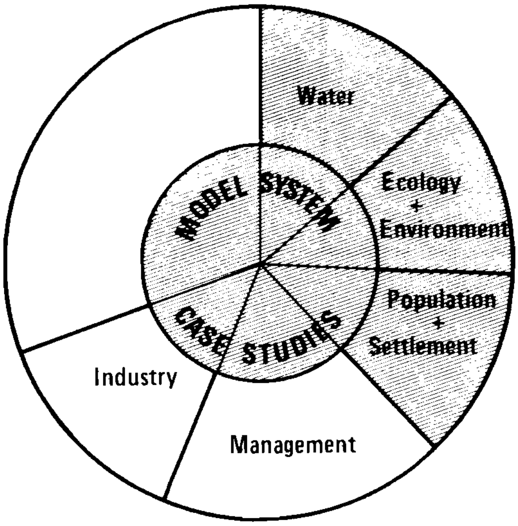

FIGURE 5 IIASA's approach to regional problems.

Universal Problems: National

Between the global and the regional scales stand the universal problems that arise with greatest cogency at the level of the national executive. Since its establishment, IIASA has investigated a number of such problems. For example, although the major focus of the Energy Systems Program has been the global scale, it is also engaged in an attempt to identify the consequences of the global prospect for specific nations. Agriculture, however, has been seen from the beginning as a national problem whose global form can only be understood through a linked series of national studies. Two issues that all national decision makers face are urbanization (and urban decline) and technological development. As noted above, urbanization has been the subject of studies in our Human Settlements and Services Area. The Management and Technology Area, whose work is described by Rolfe Tomlinson in these Proceedings, has been concerned with several aspects of technological development: innovation policies, risk management, scale, and new information technologies.

Fundamental National Problem: Interdependence

Again, through our work on this mixture of problems, we have come to recognize the centrality of one issue at the national level: interdependence (Figure 6). Nations have always exchanged with each other to some extent four basic entities: funds, goods, people, and knowledge. Thus, the fact of interdependence is not new. What has changed,

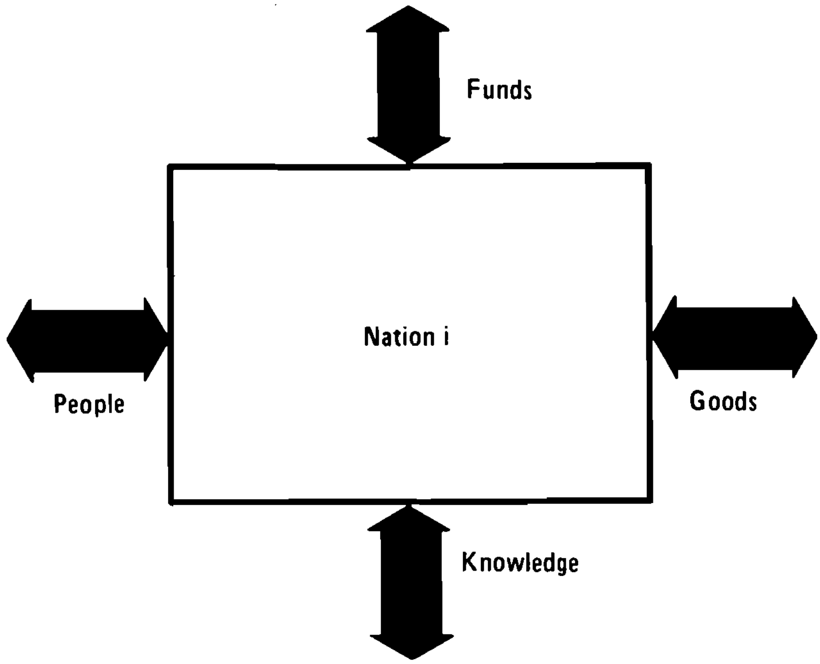

FIGURE 6 National interdependence.

however, is the scale and the rate of change of these exchanges. Shifts in raw material and energy prices, technological change, increasing labor costs, and entry of new countries into world markets have had rapid, significant impacts on nations that were often not prepared to deal with them. Interdependence carries with it now, not only mutual benefits, but also the capacity for unanticipated and unpleasant shocks to national systems. Nations must now learn to cope with this new dimension of interdependence.

On the one hand, nations must look to the outside world – to the global scale – to gain understanding of the dynamics of global development and its likely consequences for them. On the other hand, they must look inside – to the regional and sectoral scales – to support development paths that are consistent with national potential and goals and responsive to prospective global development.

Thus, the central problem of the national level to which IIASA can address its attention is the problem of *interdependence:* how to sustain consistent sectoral and regional development in a world characterized by increased interdependence and consequently greater uncertainty, increased vulnerability, and reduced controllability.

IIASA's approach (Figure 7) to this third problem area has been to combine sectoral studies – in energy, agriculture, urbanization, and technology – with the development of tools for studying international trade. But we can see that the capacity to study these national issues rests fundamentally on the capacity to investigate the global and regional correlates as well. At the national level the interactions among global transition, national interdependence, and regional integration become evident.

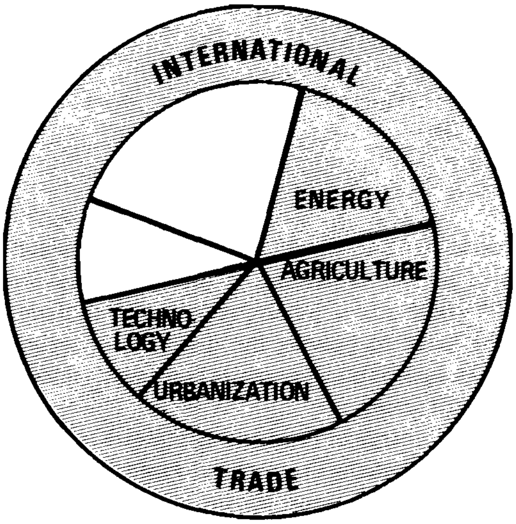

FIGURE 7 IIASA's approach to national problems.

RESEARCH

Referring once again to the Preamble to the IIASA Charter, we see that the founders had in mind that IIASA would address itself to improving methods of investigation and analysis:

> . . . present methods of investigation and analysis should be substantially improved to make them more adequate to predict, evaluate and manage the social and other repercussions of scientific and technological development . . .

What methods of investigation and analysis were available to IIASA when it began? Which of these were in need of improvement?

Many types of analysis have been applied in recent years to problems of modern societies within nations. Among them are operations research, cybernetics, policy analysis, mathematical ecology, economics and econometrics, and systems analysis. By dedicating IIASA to applied systems analysis, however, the founders clearly did not mean to limit the methods of investigation and analysis at its disposal. Rather, they intended the Institute to draw upon and to extend all available methods, to deploy them in various combinations, and to invent new ones to fill identified gaps.

Thus, applied systems analysis, as it has evolved at IIASA, is eclectic in its approach. All that I have said thus far has emphasized its fundamental orientation toward problems of modern society. In addition, four other features characterize it:

- It is realistic – tempering the course of theoretical development with the discipline of real data and real situations.
- It is methodological – disciplining the structure and path of analysis with precise quantitative and computational methods.
- It is interdisciplinary – bringing together in complex synthesis the diverse insights of specialized disciplines about a system.

• It is international – drawing together the talents, viewpoints, and approaches of many nations in examining complex issues.

Let us consider each of these characteristics in turn.

Realistic

Being realistic poses special problems to IIASA, which by its very nature and location is distant from the real problems of individual nations. It would be easy for the Institute to turn away from the "real" world into a lonely, ivory-tower solitude. For this very reason, special efforts must be made to provide the discipline of reality without losing the generality of results that an international organization must achieve. But reality assumes different meanings at different scales.

At the global scale it means that studies of energy or food and agriculture must be based on comprehensive global data. The Energy Systems Program has faced this problem by grouping the nations of the world into seven regions, shown in Figure 8, and using data for all seven in its analyses.

The Food and Agriculture Program has chosen a different approach. It has selected 25 nations that comprise 80 percent of the global food and agriculture system as its reality and uses comprehensive data about them.

At the national level, being realistic can also involve the strict discipline of a comprehensive comparison of the same phenomenon in a large number of countries. For example, internal migration among regions within IIASA's 17 National Member Organization (NMO) countries has been studied by the Human Settlements and Services Area under the leadership of Andrei Rogers, using the same research protocols, analytical tools, and computer programs for each country. No such data-rich comparative study of migration in these countries has ever before been carried out. Because of language and interpretation difficulties, each of these national studies has to be done by an individual or group in the country itself, with IIASA coordinating.

At the regional level, yet another form of realism becomes possible: case studies.

The Regional Development Task under the leadership of Murat Albegov is studying the problems of integrated regional development in four case-study regions in four different countries, two with market economies and two with planned economies; although even within these categories there are significant differences. The regions under study are the Upper Noteč Valley in Poland, the Silistra region in Bulgaria, the Skåne region in Sweden, and the Tuscany region in Italy. Here again, major reliance must be placed on national teams for the actual analysis, since only they can truly understand the local context. IIASA benefits, however, from the contact with a somewhat harsh reality in which to develop and test methods that will, we hope, have wide applicability. The regional groups, reciprocally, benefit from access through IIASA to experience elsewhere and new methods and approaches developed at IIASA.

Methodological

The methods that IIASA employs to give structure and consistency to its analyses also differ widely, although they generally – but not always – involve mathematical or computational models.

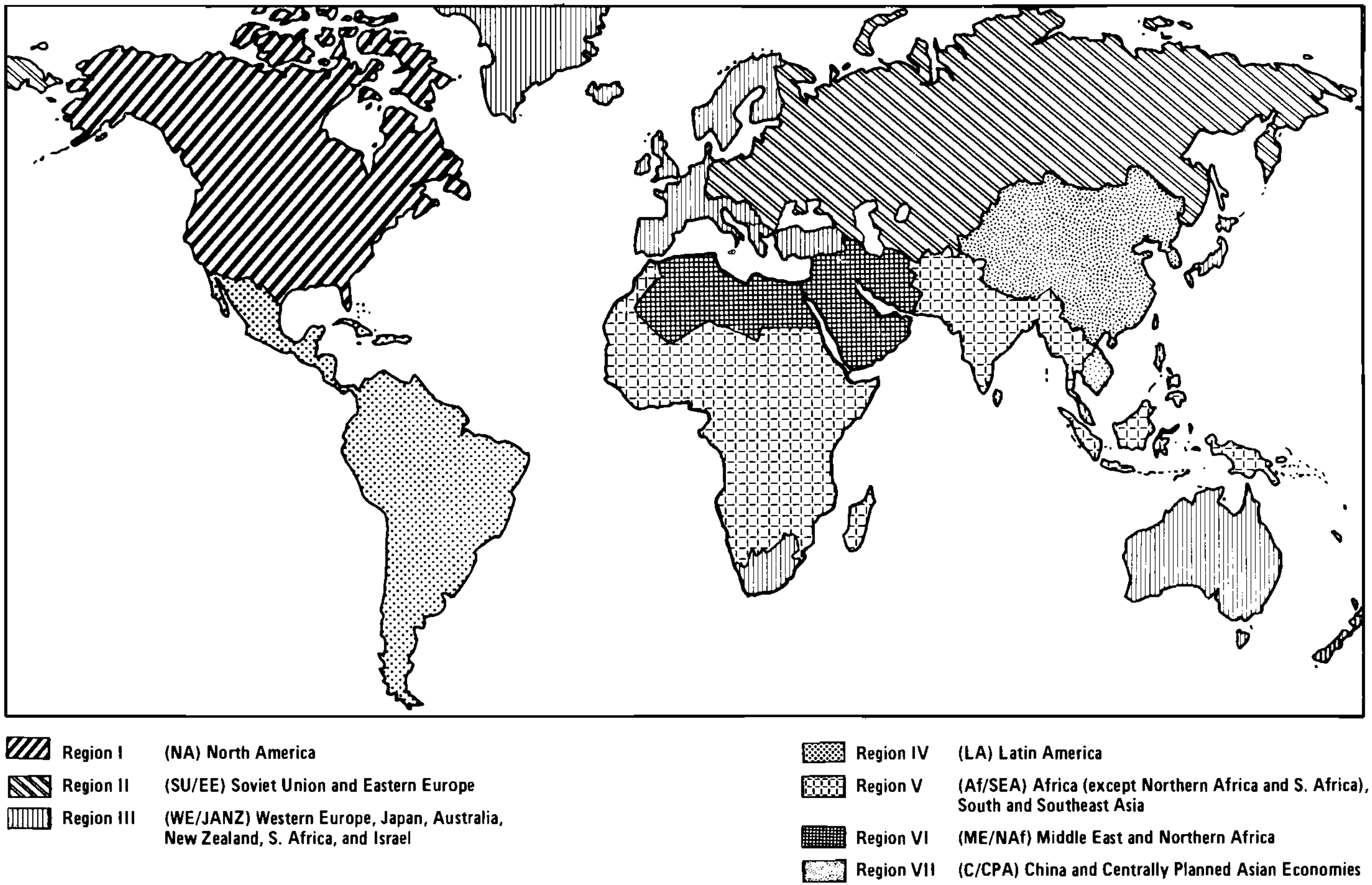

FIGURE 8 The seven IIASA world regions of the Energy Systems Program.

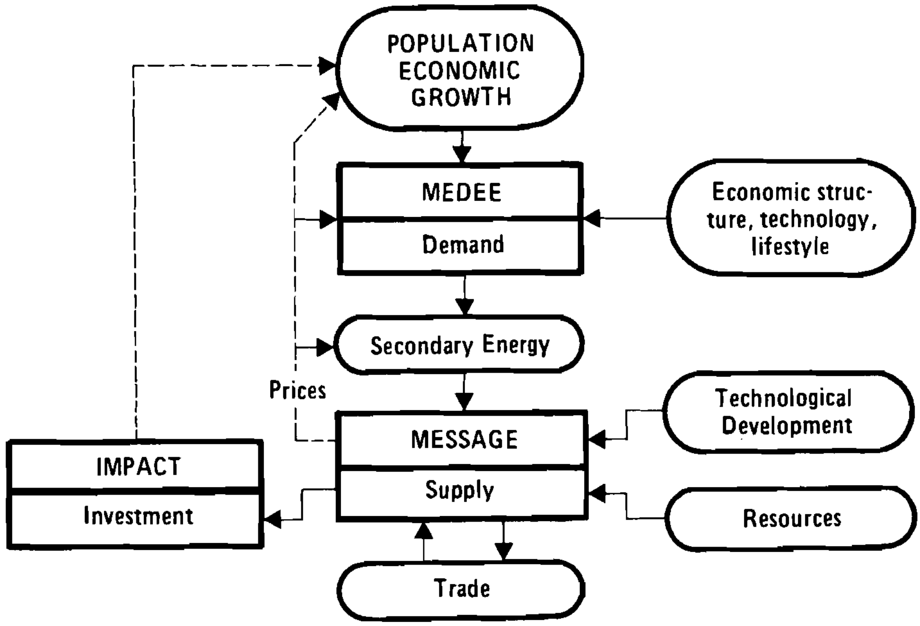

FIGURE 9 A simplified representation of IIASA's set of energy models. (MEDEE stands for Modèle d'Evolution de la Demande d'Energie. MESSAGE stands for Model for Energy Supply Systems Alternatives and their General Environmental Impact. IMPACT is the acronym representing a model that calculates the required direct and indirect (energy-related) costs of new energy facilities and that thus provides the basic information for assessing whether or not an economy can afford a given energy scenario.)

Figure 9 shows a system of models developed to insure consistency in analyzing global energy alternatives. The rectangular boxes are separate models, one producing energy demand estimates (MEDEE), the second providing a corresponding supply (MESSAGE), and the third estimating the investment induced by the supply alternative (IMPACT). These have various inputs and interconnections, as shown in the diagram. In this example, the models serve principally to insure that the estimates of population and economic growth, induced energy demand, corresponding energy supply, and consequent investment are consistent with one another. The trade link at the bottom of the figure serves to assure their consistency with other regions. These models depend on the data that enter them, much of which is highly uncertain. Thus, they cannot be said to produce predictions; rather, they work out results consistent with certain assumptions and data.

Another kind of methodology has been developed by the Human Settlements and Services Area for the national level. It comprises a theoretical and a computational component. The theory concerns the propensity of different age groups to migrate: the migration that results from changing age compositions of the population in different regions and the consequent age and migration patterns in different regions. The computational part consists of programs that embody the theory and enable migration studies and projections to be done for real populations. This general method provides the common approach for the international comparative study mentioned earlier.

A third example is provided by the interlinked system of models for planning integrated regional development shown in Figure 10. Each of five important aspects of a region's development is represented as a submodel: industry, agriculture, water, population, and migration. Certain data and values are shared or flow among them: prices, wages, water demand and cost, and labor availability. A central integration model allocates

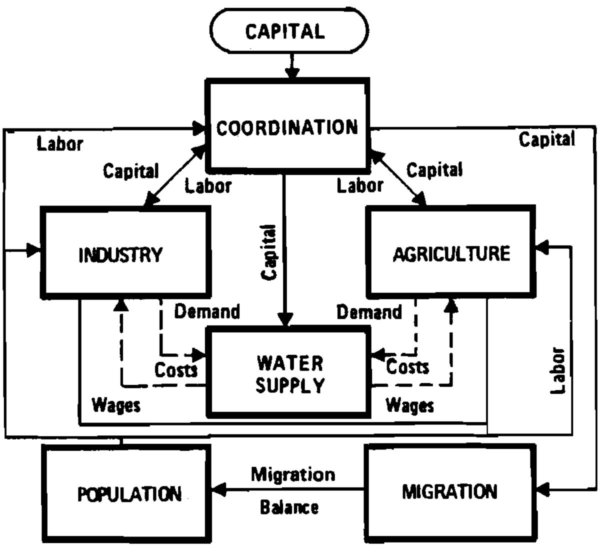

FIGURE 10 A system of models for regional development.

capital and labor among the sectors; the linked models work out the consequences of alternative allocations. The models are.a tool for planners and analysts to use in studying the results of different development strategies.

These models, as well as the others under development and use at IIASA, draw also upon the reservoir of methodological expertise provided by the System and Decision Sciences Area, whose work is described by Andrzej Wierzbicki in his paper in this volume.

Interdisciplinary

If we take as an example the model of regional development just described, we can see why IIASA's research is inherently interdisciplinary. In Figure 11, I have taken the skeletal structure of this system and listed next to each module the disciplines whose knowledge contributed to its preparation. Thus, the agriculture module draws upon agronomists for information about crops, geographers for data about soil and climate, engineers for agricultural technologies, and economists for cost and resource allocation questions. A similar picture can be drawn for each of the topics under investigation at IIASA.

If this exercise were repeated for all of IIASA's studies, certain clusters of disciplines would become evident. Table 2 shows the four most important disciplines for IIASA at this stage in its development. One group is concerned with the earth's natural resources; some, but not all, of the relevant disciplines are shown in the table. A second group is concerned with human resources, a sample of disciplines also being shown in this case. Technology and organizations, both the result of human effort, comprise the

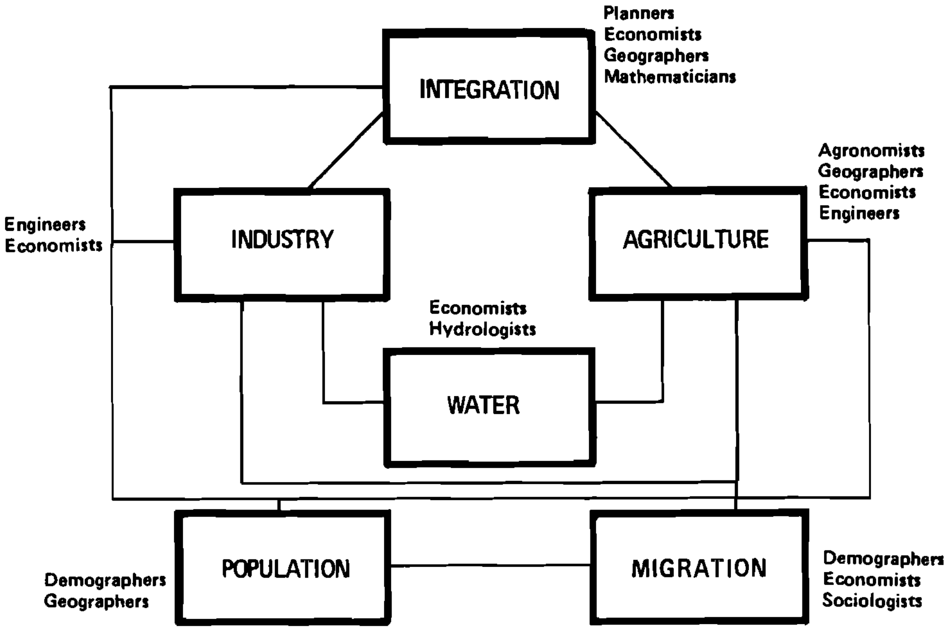

FIGURE 11 An example of the disciplines needed to prepare a system of models.

TABLE 2 The clusters of disciplines now needed by IIASA (specific disciplines are listed as examples).

Natural resources	Human resources	Technology/ organizations	Analytical methods
Hydrologists	Demographers	Engineers	Mathematicians
Geographers	Sociologists	Economists	Economists
Ecologists	Urban planners	Sociologists	Engineers
Economists	Economists	Psychologists	Operations researchers

third group. Analytical methods are the subject of the fourth group. While these four groups are quite highly aggregated, they suffice to span IIASA's current interests.

The identification of four basic groupings of disciplines germane to the Institute's research is reflected in its organization. There are four Research Areas, each concerned with one of the basic groupings:

Resources and Environment: *natural resources*
Human Settlements and Services: *human resources*
Management and Technology: *technology and organizations*
System and Decision Sciences: *analytical methods*

Figure 12 shows the Areas and their current principal interests.

By the standards of most research institutions, each of these Areas is itself interdisciplinary. Geologists, economists, and engineers interact in the Resources and Environment Area; demographers geographers, and economists in the Human Settlements and Services Area. But a further level of interdisciplinary integration is achieved when staffs

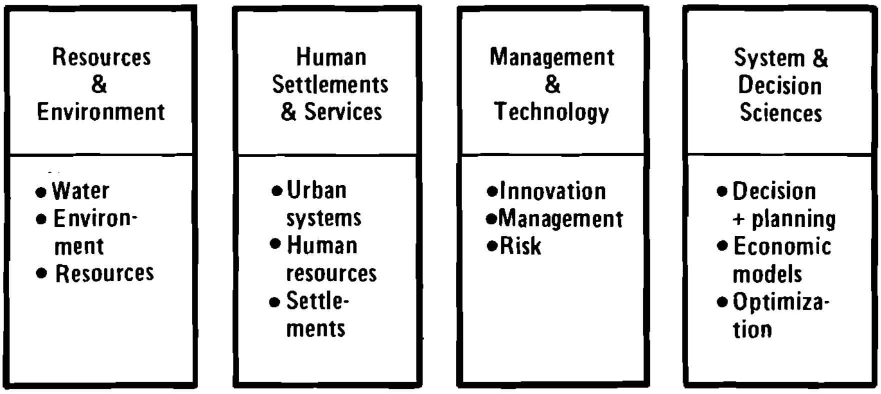

FIGURE 12 IIASA's four research areas.

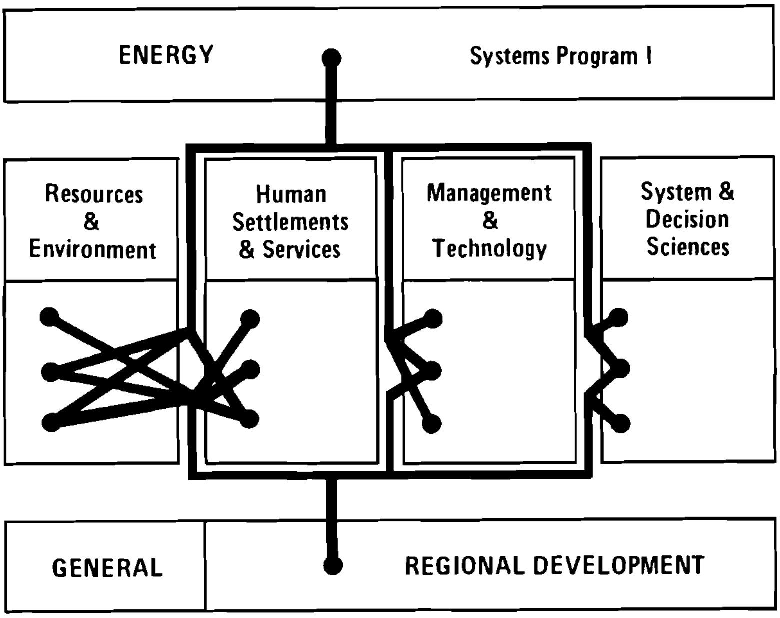

FIGURE 13 An example of cross-cutting linkages at IIASA.

from the Areas contribute to studies that cut across the Areas, as Figure 13 shows. The Energy Systems Program, for example, can call upon the Areas for assistance in resource or population projections, risk assessment, or economic modeling. The Regional Development activity can, at the same time, draw on area skills in water-system planning, migration studies, management techniques, or optimization.

International

What makes IIASA's research truly unique, however, is its international character. Most national institutions find the achievement of truly interdisciplinary and applied work difficult. The Institute adds to this challenge the necessity for its teams and collaborators to come from many nations, differing greatly in economic and political systems. While this poses difficulties, it also becomes a strength, because, as noted earlier, understanding of some issues can best be achieved by nationals of the country under study.

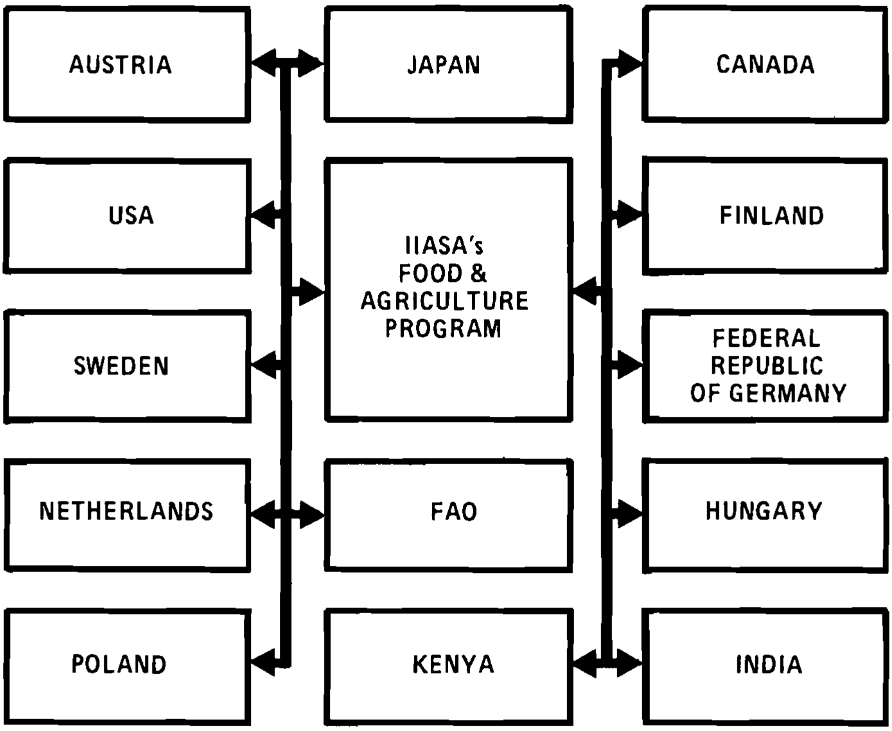

FIGURE 14 The international network of IIASA's Food and Agriculture Program. (FAO stands for the Food and Agriculture Organization of the United Nations.)

Figure 14 shows the international network of collaborating institutions working with the Food and Agriculture Program. In each of the countries shown there is a team dedicated to analyses of its national agricultural policy according to a common analytical framework developed and coordinated by IIASA; the Food and Agriculture Organization of the United Nations has a team collaborating on international linkage questions. As we shall see shortly, this international aspect contributes greatly to the linkage between research and use.

USE

We return once again to IIASA's Charter and note that the Institute's founders intended that its results "benefit all mankind" and, in particular, "the economic and social progress of peoples:"

> . . . science and technology, if wisely directed, can benefit all mankind . . . international cooperation between national institutions promotes cooperation between nations and so the economic and social progress of peoples . . .

This rather broad guidance is notable, because it did not limit the Institute, for example, to serving the developed countries alone, despite the composition of its founders; it opened a rather wide domain of prospective users: developed and developing nations and international organizations, industry and government, the scientific community and the general public, East and West, North and South.

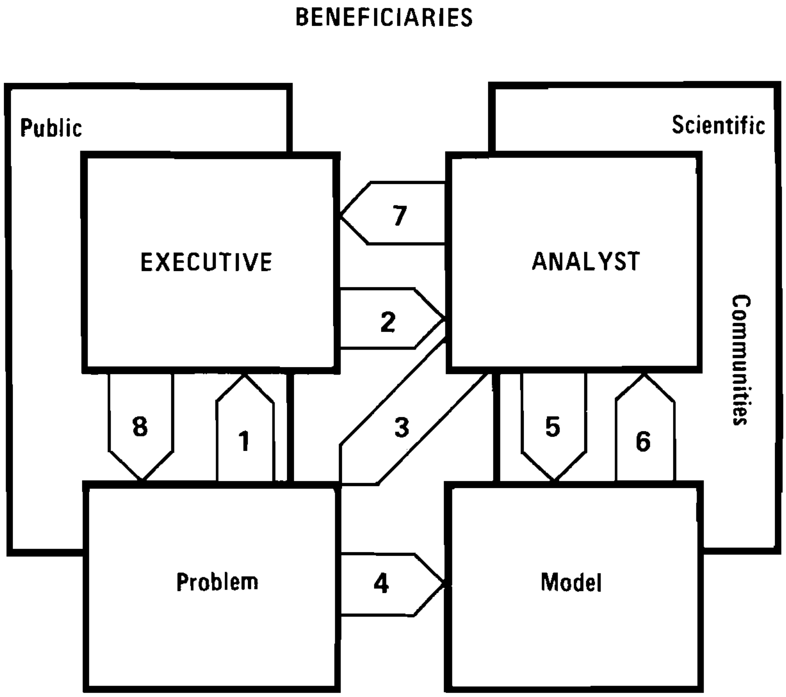

FIGURE 15 An idealized sequence from problem to use.

To appreciate the nature of prospective benefits and beneficiaries of IIASA's research, it is useful to consider the simple schematic of an idealized sequence from problem through research to use shown in Figure 15. It begins (1) with the recognition by an executive that he has a problem, which he communicates (2) to an analyst, who examines (3) the problem himself. This leads to the construction (4) of a model of the problem situation that is subjected to exploration and testing (5) by the analyst, producing results (6) from which conclusions are formulated and communicated (7) to the executive, who consequently acts (8) to resolve the problem. In the course of his analysis, the analyst draws heavily on the knowledge gathered by the scientific communities; the executive, for his part, responds to his perception of the public's needs and desires. Of course, this picture greatly oversimplifies the actual situation.

Understanding

Let us consider, first of all, the benefits that can be produced from this process. There are three broad categories. The first is enhanced *understanding* of the system, the problem, or possible policies.

A case in point is the Food and Agriculture Program, one of whose principal goals is to gain a better understanding of the interactions among national policies through the world market and their joint interactions with international policies. What is especially important in this case, however, is that the process of gaining this understanding engages an international community of researchers and research institutions sharing a common approach and analytical language. And, once this understanding is gained, it will be shared by analysts who advise executives in the world's key agricultural countries. While it is not sufficient, such shared understanding seems a necessary condition for a more successful and equitable solution of global food problems.

Methods

The second category of benefits is improved *methods* for analyzing, planning, and managing systems facing severe problems. A number of such methods have already been described, particularly those for planning integrated regional development, for analyzing energy prospects, and for studying interregional migration. Such methods are of value primarily to analysts and scientists, although some executives may come close to their use.

Strategies

The third category of benefits is *strategies* for responding to, resolving, mitigating, or solving problems. One outcome of IIASA's Energy Systems Program, for example, is

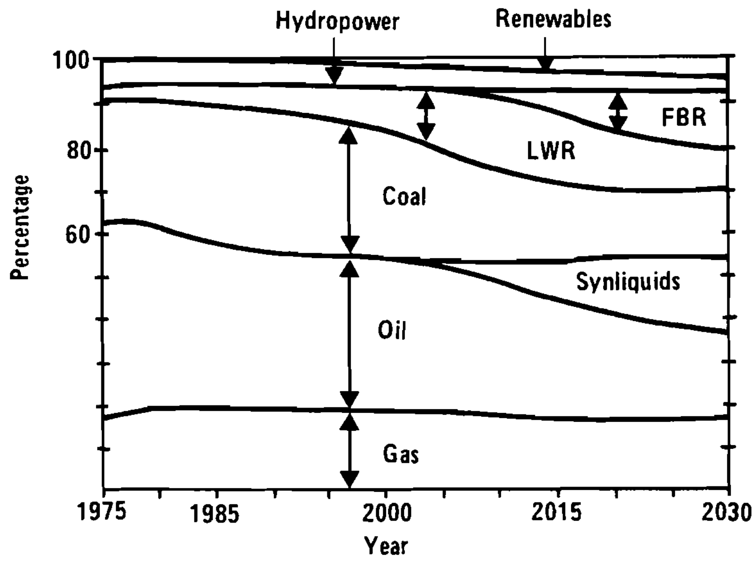

FIGURE 16 A feasible mix of energy sources from 1975 to 2030 for a high-growth world scenario. (FBR stands for fast breeder reactor; LWR for light water reactor.)

the identification in general terms of feasible strategies for meeting energy demands over the next 50 years (Figure 16). Although it is most important as a demonstration that at least one such strategy exists, the strategy illustrated here comprises a fairly detailed sequence of decisions. Such strategies are of principal interest to executives and the publics they serve.

CONCLUSION

These three categories of benefit -- understanding, methods, and strategies – can apply to any of the three levels of problems: global, national, and regional. They are of interest in differing intensities to the four major groups of beneficiaries: scientists, analysts, executives, and the public. And to return to an earlier point, they can be in developed or developing countries, National Member Organization (NMO) or non-NMO countries. Thus, the use of IIASA's research has many dimensions, as Table 3 shows. For example, it may be enhanced understanding of a global problem by the public in a developed country, or it may be methods for regional planning of value to executives and analysts in developing countries.

TABLE 3 The dimensions of the use of IIASA work.

Benefit	Problem	Beneficiary	Nation
Understanding	Global	Scientists	Developed, NMO[a]
Methods	National	Analysts	Developed, non-NMO[a]
Strategies	Regional	Executives	Developing
		Public	

[a]NMO stands for National Member Organization.

Although the theme of this Conference is Applied Systems Analysis: From Problem through Research to Use, its focus is on use. By familiarizing you with the full range of IIASA's research and the problems we are addressing, we hope to prepare the ground for a more intense discussion of use. We need your help in understanding the central question of use: *How can IIASA structure its problem formulation, its research, and its communications so as most effectively to "benefit all mankind" and to promote "the economic and social progress of peoples"?*

Banquet Address

IIASA, PAST AND FUTURE

Howard Raiffa
Founding Director of the International Institute for Applied Systems Analysis

In my farewell speech at IIASA in 1975, I said that, if an IIASA-type institution had not been created in 1968, to create such an institution in 1975 would be compelling. And I think there would have been a modest chance for a successful start in 1975. I say modest because so many little things can go wrong in protracted negotiations. The creation of any institution – especially an international one, especially one that is nongovernmental but requires the blessings of governments, especially one that tries to reach over the East–West divide – has only a modest chance of success, despite the best intentions. Now in 1980, I would claim, and practically all my scientific friends would concur, that there is more need for IIASA than there was in 1975 or 1968, and the tragedy is that in 1980 we could not create IIASA.

We have something precious here: something vastly different from other institutions. My hope is that we will not lose perspective, that we will continue to nurture IIASA, despite the troubling times in the world.

IIASA, being nongovernmental and multinational, should remain a fixed point within a turbulent sea. IIASA has a mission: to continue to be; to continue to look ahead and to anticipate the problems of the future; to identify the real problems of the globe; and not to get caught up in the hopefully ephemeral disputes of the superpowers.

I must confess that I am not sanguine about the future of the world. We seem to be in a world of confrontations. But technology marches on, and in 25 or 50 years, almost a blink of an eye in an evolutionary time scale, devastating damage can be done to the world. There just is not enough time to get our world house in order – to learn ways for more amicable and rational conflict resolutions.

It is ludicrous to think that any single institution like IIASA can solve these problems. But still, IIASA may make a difference. IIASA is now, at this very minute, making a difference. Just the very fact of our being here and having this Conference is important to the international scene. So let us not falter.

With regard to international idealism, I am enough of a realist to know that the world is governed by myriad political constraints. It is hard to move in any new direction without offending some politically effective blocking coalition. And yet there are times in world affairs when a window of opportunity opens for a brief period during which significant changes can be implemented. All too often these windows of opportunity open after a tragedy occurs – only to close again a short while thereafter, when a life-as-usual attitude begins once again. Here is where I think IIASA can play an effective role.

First, IIASA can try to anticipate the future and plan idealistic solutions. IIASA can paint a picture of "what-could-be-if-only" – if only people were more reasonable, more cooperative, more conciliatory, more visionary. Frankly, I think the extent to which IIASA can help in this way is small, but the payoff may be so large that it is well worth a continuing effort. A second way that IIASA can help, a way that I believe is far more likely, is in proving to the world's leaders that IIASA is a place where serious work is done, and where far more serious work can be done if the need arises. There are not many such places, and none that I know of that is so ideally postured among nations. IIASA is a place that is not bogged down in bureaucracy; it can react quickly when the window of opportunity opens, even if briefly.

IIASA is no longer an infant. It is still a young child in a vigorous growth stage. No longer will it grow vigorously in size, but it will grow in intellectual maturity and outreach. Is it developing well? What are the criteria for determining how well IIASA is doing? We could look at output measures: numbers of papers, books, and conferences; number of citations by others. However, I would like to talk about a more elusive quality: IIASA's effect on people who have been here.

I have asked many scientists who have been at IIASA for various lengths of time this question: "Looking back, was the time you spent at IIASA productive? Has it influenced your professional life?" Often the answer is "I did not stay long enough at IIASA to accomplish a major piece of research, but after leaving IIASA I continued to work on the research I started there, and I would not be doing what I am now doing if I had not been there."

For example, Nobel laureate Tjalling Koopmans made a major contribution to IIASA by inspiring many young scientists. He was, however, according to his account, not very productive in terms of scholarly papers written at the Institute – but he was exposed here to many new and exciting ideas, and he worked closely with specialists outside his field of expertise. He thus opened up new doors and is now working collaboratively and interactively in the USA with a broad array of experts on systems problems. In some loose – but I think accurate – way, Professor Koopmans moved his research focus from economic analysis to applied systems analysis.

David Bell, a young colleague of mine at Harvard University, who spent two very productive years at IIASA, claims that he has added an international perspective to his thinking. I notice the same thing in myself. In recent years, I have served in the USA on several National Academy of Sciences committees dealing with topics on energy, the environment, the adverse impacts of chemicals, and natural hazards. I have been struck repeatedly by the narrow national perspective of most of my fellow committee members. They tend to view problems as US national problems and not as international ones. A period at IIASA would help them.

IIASA is a broadening experience, where one meets and works with people from different cultures and, what is far more "mind-stretching," from different disciplines. I have always felt that two mathematicians, one from the USSR and one from the USA, are closer together than a physicist and an economist from the same university. In most universities and research institutions one works with a very narrow segment of researchers. Disciplinary research, as compared to research in applied systems analysis, tends to focus on deep aspects of a relatively narrow part of a specific field. But the hallmark of applied systems analysis is synthesis and integration. It is not bound to any discipline and can be said to be nondisciplinary.

In early 1972, when France was vying with Austria for the location of the Institute, I asked Pierre Aigrain, one of the founders of IIASA, why France was so determined that the Institute be located there. He said that he could not speak for France, but he was clear in his own mind why he wanted the Institute. He said it would be good for French science and scientific education. Science tends to become excessively narrow, and it often drifts off into pure theoretical pursuits. A prestigious institute with an applied systems analysis focus would be a balancing force. I think Mr. Aigrain was right – IIASA benefits science, not only in France and Austria, but also in other countries.

The IIASA community is growing. There is a relatively constant number of scholars in residence at any one time, but the IIASA alumni are growing in numbers and influence. Their voices are not uniformly raised in support of IIASA, but mostly so. This is a force that should be harnessed.

From the perspective of a researcher working at IIASA, the most important matter is the research atmosphere and stimulation. And with our network of alumni it should prove easier over time to design and coordinate external research with IIASA as home base. This is happening now. It will happen more and more and it should be given increasing support. There should be a dynamic, synergistic interplay between internal and external research activities. For the most part, scientists come to IIASA for a limited period of time and our challenge is to achieve continuity over time while developing an institutional memory. Alumni who continue their involvement with IIASA through external research provide a partial solution to this problem.

This Conference, which is mandated by our Charter, is a step in the right direction, but many more creative steps have to be taken to develop continuing coordinated research across national and disciplinary boundaries.

IIASA is a unique institution. It has even greater potential than we have as yet developed. Since IIASA could not be created in 1980, let us nurture our growing child and provide it with meaningful experiences.

Informative sessions: Overviews of IIASA activities

Global issues

PUTTING THE RESULTS OF THE IIASA ENERGY SYSTEMS PROGRAM TO WORK

Wolf Häfele
Leader of the Energy Systems Program

INTRODUCTION

For the past seven years we at IIASA have been studying the energy problem. Quite early in the process, we learned that the "energy problem," though the subject of much discussion and debate, is indeed something that escapes easy definition. Is it a problem of prices, a problem of environment, resources, life-styles, technology or simply politics? To all these possibilities the answer is, undoubtedly, yes, all these aspects are part of the energy problem. And it is not too difficult to analyze any one aspect of the problem at a time; but when everything is taken together the problem becomes a difficult one, a complex one, a burning one. It is, in fact, a typical systems problem, a question of synthesis.

It is thus essential to organize one's thinking early in the game, to explore the problem's many aspects, and to organize them so that they can be dealt with scientifically. By this I do not mean to suggest that the energy problem should be considered an exclusively "scientific" problem. It contains moral aspects and political aspects that do not lend themselves immediately to scientific treatment in the rigorous sense of the term. But it is precisely because of these aspects, not in spite of them, that one should identify what can, and what cannot, be dealt with on a scientific basis. Making that distinction is not a trivial task. The early stages of the Energy Systems Program devoted much exploratory and interactive thinking to this question, and it took us some time to organize our thoughts to the point where we were confident we could approach the problem constructively.

Our decision was to concentrate on the natural-science aspects, on engineering and economic approaches, although we have always kept it clearly in mind that there is much, much more to the energy problem – the politics, the moral questions, etc. But our choice of perspective was based on the nature of the Institute. IIASA is an East–West institute, and it is expected to provide a service – a service to its National Member Organizations (NMOs) and ultimately to the whole world. In this case, the service takes the form of clarifying a factual basis upon which political issues may be settled. I say "may be settled," for of course no analysis can resolve all the difficulties with which we are faced. Still, to agree on some sort of factual basis would be extraordinary.

This concentration on the natural-science aspects of the energy problem means that the scenarios we developed – I shall elaborate on them later – necessarily anticipate a future of a relatively surprise-free nature, or, more concretely, of modest economic growth. In particular, we have decoupled the energy problem from the monetary problem by carrying out the analysis in constant US dollars.

The factual basis, then, is the platform on which political issues, such as setting environmental standards or determining development policies for nuclear power, can be settled. Figure 1 illustrates this idea. The balance-of-payments issue is used to caricature

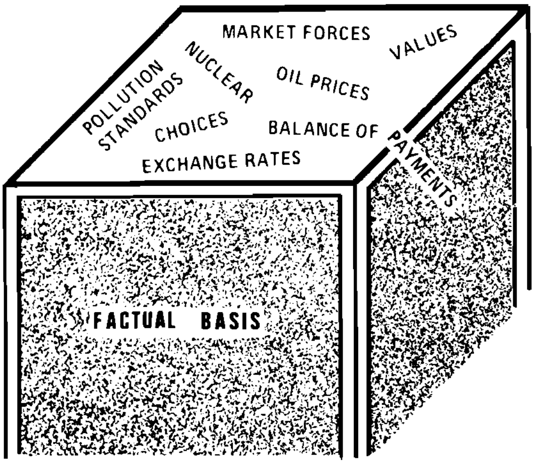

FIGURE 1 Providing a factual basis for energy policy.

what happens when wishes become a driving force independent of the supporting facts – attempted resolutions unsupported by the facts cannot survive long. We set out to provide a service by identifying the factual basis necessary for informed energy decisions. That is, we began by asking what *can* be accomplished, thus providing the essential background for addressing ourselves later to politics and other problems.

CHOOSING A TIME FRAME

A first and fundamental question in our study is the question of a time frame. Again the choice is not trivial. After some thinking, we decided on a time frame of 50 years for several reasons. When we started our investigations, a number of studies were already under way, the Workshop on Alternative Energy Strategies (WAES 1977), for example, and the work of the World Energy Conference (WEC 1978). It is reasonable and appropriate for these studies to approach the year 2000 from the front, so to speak. However, we chose to consider the question the other way around. That is, after the year 2000 a major transition must take place, a transition not only in terms of energy supply patterns but also in terms of the infrastructures underlying both supply and demand patterns. This will require time, and we are therefore led directly to the question of what happens after the year 2000. More specifically, will we be sufficiently prepared to master the more immediate transition around the year 2000 so that we are ready for the substantial

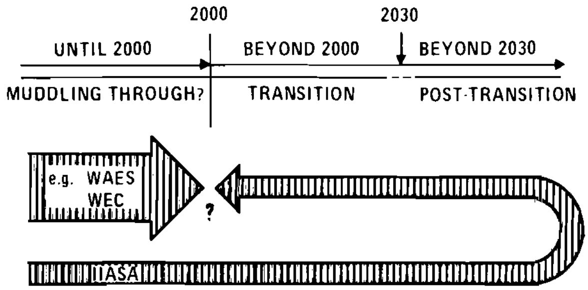

FIGURE 2 Time phases of energy and IIASA's approach to a global energy strategy. (WAES stands for the Workshop on Alternative Energy Strategies. WEC stands for the World Energy Conference.)

transition that will take place during the twenty-first century? Thus, our idea was to go far out into the future and to look back at the year 2000 through the year 2030. In a sense, the question mark shown in Figure 2 describes the spirit of our project appropriately. Now, as is shown in Figure 3, the year 2000 coincides with a very critical period in the evolution of the globe and its population. As Dr. Levien pointed out yesterday, there has been some sort of an equilibrium in the past, that is, only modest population growth, with a billion or so people around the year 1800. But our study period from 1980 to 2030 coincides with what is anticipated will be the steepest increase ever in the global population, with the projection for the year 2030 being on the order of 8 billion people.

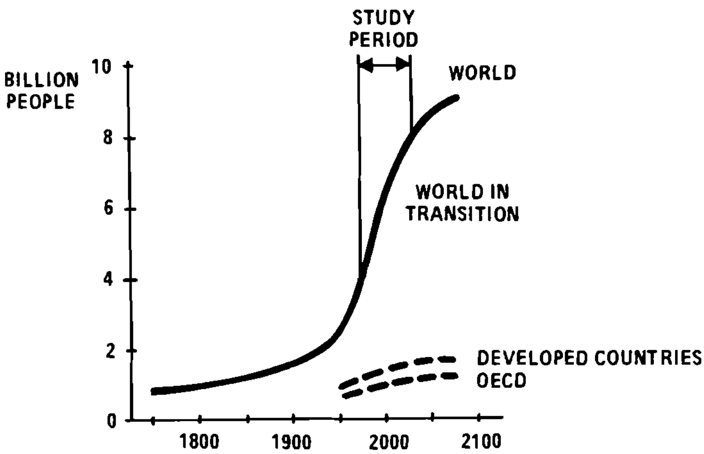

FIGURE 3 The past and future trends in world population. (OECD stands for the Organization for Economic Co-operation and Development.)

World population is the force ultimately driving the energy problem, and the growth pattern shown in Figure 3, therefore, only reinforces the importance of extending our analysis as far as 2030.

THE SEVEN IIASA WORLD REGIONS

As indicated in Figure 3, population growth will not be the same the world over. In the industrialized countries the population growth will be quite modest; thus, it is in the developing countries where most of the growth will occur. Because of this, we can expect shifts in political structures and accompanying shifts in the allocation of resources. It was therefore necessary to introduce some level of geographical disaggregation in our analysis.

We felt it would be inappropriate to consider, for example, the 153 member nations of the United Nations; in the end, we grouped the countries of the world into seven world regions chosen on the basis of national energy resources and economic structures but not on the basis of geographic proximity.

The regions are shown in Figure 4 and can be characterized briefly as follows. Region I (NA), North America, has a developed market economy and is rich in resources. Region II (SU/EE), the Soviet Union and Eastern Europe, is developed and rich in resources but differs from Region I in that it has a planned economy. Region III (WE/JANZ) is essentially the member countries of the Organization for Economic Co-operation and Development (OECD) minus North America and has a developed market economy but not many resources. Region IV (LA), Latin America, is a developing region with market economies and many resources. Region V (Af/SEA), Africa (except Northern Africa and South Africa) and South and Southeast Asia, is also a developing region with mostly market economies but not many resources. The countries of the Middle East and Northern Africa, Region VI (ME/NAf), are a special case since they are rich in oil and gas resources. And, finally, Region VII (C/CPA), China and the centrally planned Asian economies, is a developing region with centrally planned economies, but it is not so rich in resources.

Obviously aggregating all the countries of the world into only seven regions leaves us, at the end of the analysis, with the problem of translating our findings into various national frames of reference so that they address the concerns of energy analysts in different countries directly. We are in the midst of doing this now, and I shall discuss these efforts at the end of my talk.

THE CONCEPTUAL APPROACH

I have already stressed the necessity of conceptualizing. During the first IIASA Conference in 1976, I showed the diagram presented in Figure 5 which, in a sense, represents our thinking, or conception, at that time.

The diagram is meant to be read from the bottom, which corresponds to the present, to the top, which corresponds to the period after 2030. It represents the fact that at least a few long-term options are available. Specifically, we can count on coal as a source of energy, or on solar power, or on nuclear power. The immediate question then becomes, what are the conditions and features for exercising these options? In particular, how will energy demand evolve over the next decades? Or, how will the resource picture develop? In this area there is a strong tendency to consider the resources from a traditional perspective, and it may well be more appropriate to change substantially our attitudes toward resources and the associated, relevant infrastructure.

Given the basic features of demand development and resource characteristics, the idea was then to define and compose strategies for realizing the possible long-term

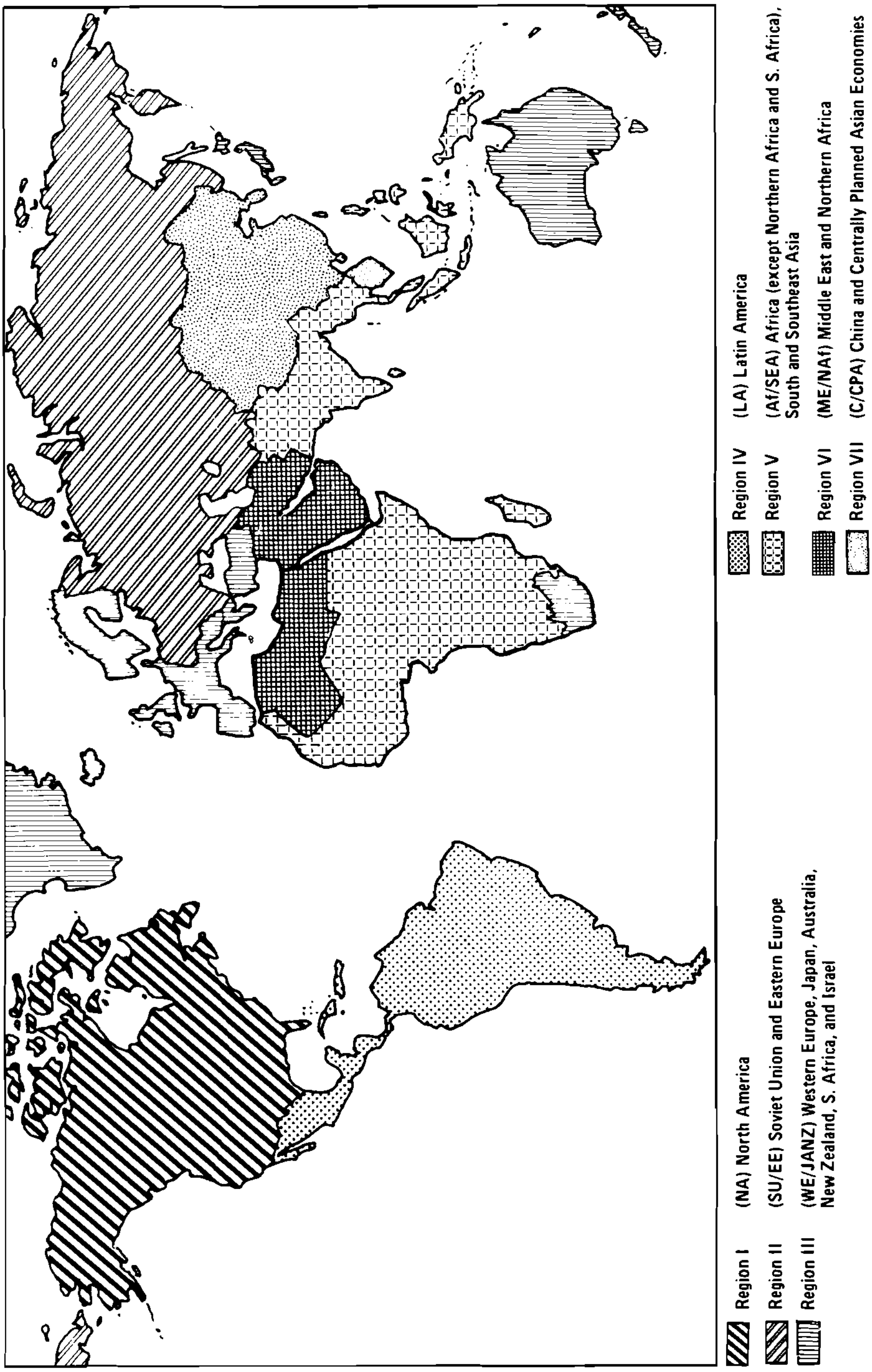

FIGURE 4 The seven IIASA world regions.

options. And here the point was not so much to optimize as it was to discover what is feasible. Feasibility turned out in our studies to be of much more immediate concern than optimality. Put another way, the constraints (mentioned at the left of Figure 5) played a very important role in our considerations. Principal constraints were the environmental and public-health risks associated with different energy supply technologies.

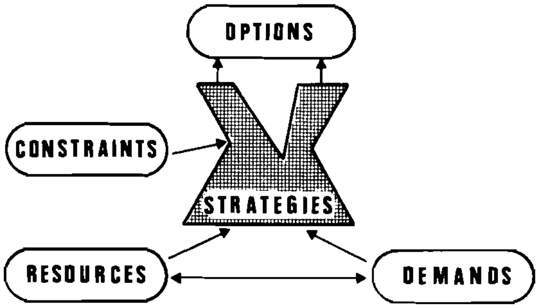

FIGURE 5 The approach to energy systems.

These were studied in cooperation with the International Atomic Energy Agency (IAEA), and, I may say, it was a particularly enjoyable and productive exercise. We looked into the climate problems – the case of waste heat and carbon dioxide – and above all we looked into the problem of time; do we have enough time to make it?

Identifying energy strategies cannot be done qualitatively according to the slogan "try harder and you'll make it." One must identify more clearly what is meant by trying harder. A quantitative analysis is required, and it is important to be precise about what we mean by a quantitative analysis.

Three types of mathematical model are listed in Figure 6. The first model, or the first type of model, is built upon the physical and chemical laws of nature, which precisely describe a very large part of reality. In fact, it is tempting to say that they represent

1. MODELS FORMULATING LAWS OF NATURE
→ VERIFIABLE PHYSICS.
2. MODELS BUILT UPON TIME SERIES
→ SHORT-TERM ECONOMIC ANALYSIS.
3. MODELS FOR A QUANTITATIVE CONCEPTUALIZATION OF COMPLEX SYSTEMS WITH EMPHASIS ON CONSISTENCY → SCENARIOS TO PUT THINGS INTO PERSPECTIVE.

FIGURE 6 Three kinds of mathematical model.

reality entirely, and whether we refer to them as reality or as only a model is merely a philosophical question. However, they make up only one type of mathematical model. The second category includes short-term econometric models that use intelligent processing of time-series data. These models also describe reality, perhaps not with the same precision as those in the first category and with a time horizon of only two to three or four years. The third type of mathematical model is the one identified with writing scenarios, and it is this approach that we adopted.

I stress at this point that, in writing scenarios, we are not trying to make predictions. In fact, by concentrating explicitly on defining a factual basis, our results indicate, in a sense, a potential and upper limit to what can be done without political constraints. But, in general, one should not view scenario writing as an attempt to predict the future. Rather it is a way of organizing one's thoughts and the information available, and its basis is a rigorous insistence on two things: internal consistency and global comprehensiveness. For example, in the past there have been many, many exercises at a national level, each of which has essentially concluded that any excess of energy demand over energy supply would be met by imports. Now, if every nation goes through a similar exercise, and practically every one does, the question arises of whether one given barrel of imported oil has been, at least analytically, appropriated by several different parties. That is, are the world's resources really as sufficient as they appear based on the collection of uncoordinated national studies? It is precisely such weaknesses that can be avoided with the help of carefully constructed scenarios.

TWO SCENARIOS

In constructing our scenarios, the principal tool used to ensure internal consistency on a global scale over 50 years was the set of quantitative computer models listed in Figure 7. At the top of the figure are shown the two key characteristics that essentially define any scenario – economic growth and population growth.

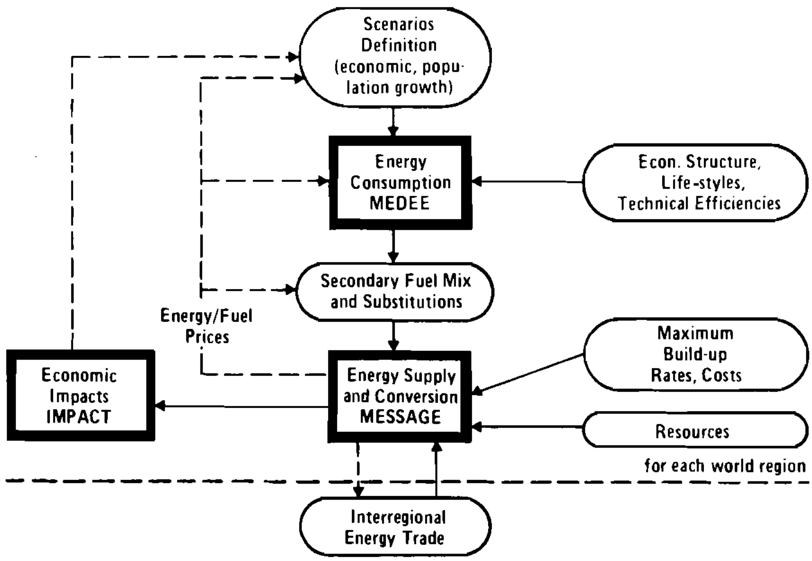

FIGURE 7 A simplified representation of IIASA's set of energy models. (MEDEE stands for Modèle d'Evolution de la Demande d'Energie. MESSAGE stands for Model for Energy Supply Systems Alternatives and their General Environmental Impact. IMPACT is the acronym representing a model that calculates the required direct and indirect (energy-related) costs of new energy facilities and that thus provides the basic information for assessing whether or not an economy can afford a given energy scenario.)

Our assumptions about population growth are shown in aggregated form in Figure 3; in our scenarios we used the population figures forming this aggregate.

However, in the case of economic growth rates, we distinguished two principal sets of assumptions, as shown in Table 1. These two sets of assumed economic growth

TABLE 1 Assumptions about the growth rate of gross domestic produce (GDP) for the High and Low scenarios from 1975 to 2030 (percent per year).

IIASA region	High scenario	Low scenario
I (NA)	2.87	1.68
II (SU/EE)	3.91	2.99
III (WE/JANZ)	2.93	1.88
IV (LA)	4.37	3.48
V (Af/SEA)	4.32	3.27
VI (ME/NAf)	5.09	3.57
VII (C/CPA)	3.77	2.64
World	3.44	2.37

rates in turn define two scenarios, which we labeled the High scenario (corresponding to the set of higher growth rates) and the Low scenario (corresponding to the lower growth rates). In both scenarios, however, the growth rates assumed for the developing countries outpace those assumed for the developed countries. It is important to note that the growth rates assumed for the developing regions do not match the aspirations that these countries express.

RESULTS ON ENERGY DEMAND

Having defined the boundaries of our scenarios – the population assumptions, the economic growth rates, and the seven world regions – we now turn to interior detail, the purpose of the MEDEE model, described briefly in Figure 8 and in more detail in Lapillone (1978). (Figure 7 showed its position in the overall model set.) Basically we had to go through a detailed accounting of energy end uses in the various sectors, such as transportation, industry, or household. For instance, we had to identify what room temperatures will be appropriate in India by the year 2000. Of course, these are assumptions but in any exercise like this one, such assumptions must be made. It is crucial to make them explicit and to document them. We have done this at several levels: in a book for the general reader, in a comprehensive technical report, and, at a more detailed level, in a series of research reports and working papers.*

In developing the demand figures, we assumed substantial energy conservation. Thus a clear, qualitative result of the overall analysis is that, without energy conservation,

*Energy Systems Program Group of the International Institute for Applied Systems Analysis, Wolf Häfele, Program Leader (1981) *Energy in a Finite World:* Volume 1. *Paths to a Sustainable Future;* Volume 2. *A Global Systems Analysis.* Cambridge, Massachusetts: Ballinger. Volume 1 is the book for the general reader, Volume 2 is the comprehensive technical report; the latter provides detailed listings of the supporting literature.

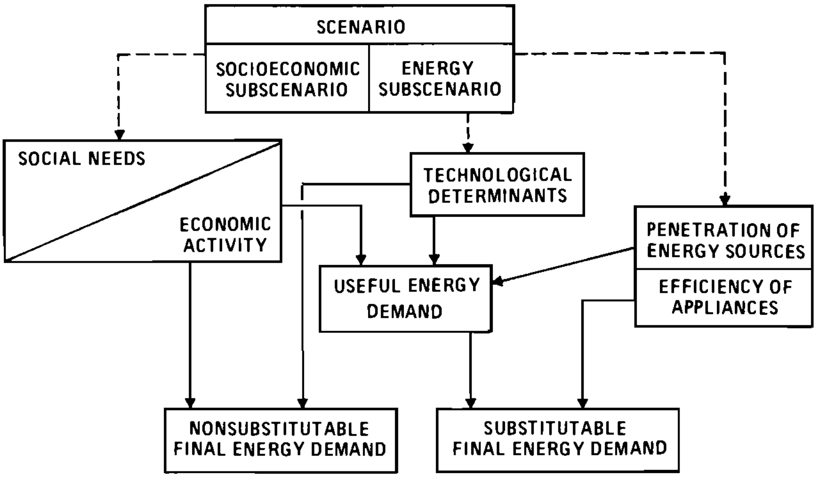

FIGURE 8 The MEDEE approach. (MEDEE stands for Modèle d'Evolution de la Demand d'Energie.)

it just cannot be done. The issue is not whether to pursue energy conservation, but rather how much energy conservation must be realized.

I do not want to go into the details of the analysis here, but I do want to show you some central results.

- Currently, in North America, Region I, the final energy per capita, as shown in Table 2, is on the order of 7.89 kilowatt-years per year (kW-yr/yr) (or, in brief, 7.89 kW/cap). For the Low scenario we arrived at a modest increase by the year 2030 to a figure around 8.37 kW/cap, which is not very high. In fact, it essentially implies zero energy growth over the next 50 years. In the High scenario the increase is a little higher.
- The numbers for Region II (SU/EE) are not arbitrary numbers. They were calculated in close cooperation with the Academy of Sciences of the USSR in Moscow, and we therefore consider them reliable and realistic: 8.57 kW/cap in 2030 in the High scenario and 6.15 kW/cap in the Low scenario.

TABLE 2 Final (commercial) energy consumption per capita for the High and Low scenarios from 1975 to 2030 (kilowatt-years per year per capita, abbreviated in the text as kW/cap).

IIASA region	Base year 1975	High scenario 2000	High scenario 2030	Low scenario 2000	Low scenario 2030
I (NA)	7.89	9.25	11.63	7.95	8.37
II (SU/EE)	3.52	5.47	8.57	4.98	6.15
III (WE/JANZ)	2.84	4.46	5.70	3.52	3.90
IV (LA)	0.80	1.75	3.31	1.28	2.08
V (Af/SEA)	0.18	0.42	0.89	0.32	0.53
VI (ME/NAf)	0.80	2.34	4.64	1.76	2.46
VII (C/CPA)	0.43	0.93	1.87	0.64	0.93
World	1.46	1.96	2.86	1.58	1.83

• Of special note is the situation in Region V (Af/SEA), where the consumption level currently is only 0.18 kW/cap for commercial energy (see Table 2). However, there is necessarily consumption of noncommercial energy on top of this, some 0.3 kW/cap from dung, wood, and other sources. But these noncommercial sources have supply problems of their own and, in the end, one must substitute commercial energy for the noncommercial sources. Therefore, parts of the 2000 and 2030 figures for Region V include something that is already there. In general, the Region V figures seem low; however, we were assisted in this analysis by representatives of the Indian Statistical Office, thus incorporating the wisdom and judgment of people from the region.

• In Region IV (LA), where current consumption is only 0.8 kW/cap, we see in Table 2 that the High-scenario 2030 consumption level is approximately 3.3 kW/cap, exceeding the average consumption in Region III (WE/JANZ) in 1975. This comparison reflects the high expectations and the high expected growth rates for Latin America; it provides a yardstick for considering the distribution of energy consumption over the regions.

• Turning to aggregate primary energy consumption, we find in Table 3 a current rate of 8.2 terawatt-years per year (TW-yr/yr) for the world as a whole. (One TW-yr/yr is a large energy unit; it equals roughly a billion tons of coal per year or 14 million barrels of oil per day, which is greater than Saudi Arabia's current possible production rate.) Most of the 8.2 TW-yr/yr goes to Regions I, II, and III, with only a minor fraction going to the four other regions.

TABLE 3 Primary (commercial) energy consumption by IIASA regions for the High and Low scenarios from 1975 to 2030 (terawatt-years per year).

IIASA region	Base year 1975	High scenario 2000	High scenario 2030	Low scenario 2000	Low scenario 2030
I (NA)	2.65	3.89	6.02	3.31	4.37
II (SU/EE)	1.84	3.69	7.33	3.31	5.00
III (WE/JANZ)	2.26	4.29	7.14	3.39	4.54
IV (LA)	0.34	1.34	3.68	0.97	2.31
V (Af/SEA)	0.33	1.43	4.65	1.07	2.66
VI (ME/NAf)	0.13	0.77	2.38	0.56	1.23
VII (C/CPA)	0.46	1.44	4.45	0.98	2.29
Total[a]	8.21[b]	16.84	35.65	13.59	22.39

[a]Columns may not sum to totals because of rounding.
[b]Includes 0.21 TW-yr/yr of bunkers – fuel used in international shipments of fuel.

• In the High scenario, where primary energy consumption in 2030 reaches 36 TW-yr/yr, the assumed higher growth rates are associated with the additional benefits of innovation and support for equalizing social differences. Thus, by 2030 Regions I (NA), II (SU/EE), and III (WE/JANZ) account for a much smaller share of the global primary energy consumption than they did in 1975. In the Low scenario, where primary energy consumption reaches 22 TW-yr/yr in 2030, the trend toward equalization across regions can also be seen, although it is less pronounced than in the High scenario. The two numbers 36 TW-yr/yr and 22 TW-yr/yr are not meant to represent extremes in either direction, but rather are assumed to cover a middle ground. Still, their magnitudes indicate that an increase in energy supply by a factor of around three or four will be required over the next 50 years.

ENERGY RESOURCES

It is on the basis of energy demand, then, that we have to contemplate the supply problem. Do we have enough energy resources, particularly fossil resources? Typically, the answer is, "yes and no." Originally, when I was more naive, I thought that looking into the resource problem would not be too difficult and that the numbers would be well established. Not so: it proved to be a most complex problem. And our fundamental concern was to look at the problem in terms of the right categories – not the traditional ones, but those of tomorrow. Table 4 illustrates my point. According to traditional

TABLE 4 Global energy resources and their costs (terawatt-years).

Resource	Cost category 1	2	3	Total
Coal	560	1 019	–	1 579
Oil	264	200	373	837
Gas	267	141	130	538
Total	1 091	1 360	503	2 954

NOTES: Cost categories represent estimates of costs either at or below the stated volume of recoverable resources (in constant 1975 US$).
For coal – category 1: 25$, and category 2: 25–50$ per metric ton of coal equivalent.
For oil and natural gas – category 1: 12$, category 2: 12–20$, and category 3: 20–25$ per barrel of oil equivalent.

wisdom, 1000 TW-yr is a very good indication of global fossil resources, and it is consistent with the 1091 TW-yr shown in the table as the global total of what may be referred to as conventional fossil resources. Furthermore, the 560 TW-yr of category 1 coal listed in the table equal some 600 billion tons of coal equivalent (tce), essentially the conventional component of coal resources as, for instance, reported at the Detroit World Energy Conference (WEC 1974). The same can be said for oil, with 264 TW-yr, and gas, with 267 TW-yr. But when one goes to higher-cost categories – and here I mean not only monetary costs, but also environmental-impact and social-difficulty costs – one gains additional resources amounting to a threefold increase: that is, not 1000, but 3000 TW-yr is the more appropriate figure. However, this does not mean that the additional resources have the same nature as the first 1000 TW-yr. The difficulties that accompany category 2 and 3 resources are significant, and I shall return to them later. And, of course, there is the key question: how do we use these 3000 TW-yr most intelligently, if at all?

We looked, not only into fossil resources, but also into alternatives for supplying energy, and Table 5 gives a brief summary of them. In the case of the renewables, it is important to realize that, while wood, for instance, may have an infinite potential, there is a finite limit constraining the possible annual production level: some 2.5 TW-yr/yr is a good figure. When all the renewables are added, within appropriate limits, they total about 6 TW-yr/yr, and certainly do not exceed 14 TW-yr/yr, a large – but not very large – number. Oil and gas production is limited to 8 to 12 TW-yr/yr with a question mark, and, to recognize even greater uncertainty, the production potential for coal is listed as 10 to 14 TW-yr/yr with two question marks.

The case of nuclear energy requires a more detailed discussion. If we continue to use only burners, the total resource that we can exploit is only 300 TW-yr – much smaller

TABLE 5 Alternatives to fossil resources for supplying energy: resources and production potentials.

Source	Production (TW-yr/yr)	Resource (TW-yr)
Renewables		
wood	2.5	∞
hydro	1–1.5	∞
total	6–14	∞
Oil and gas	8–12(?)	1 000
Coal	10–14(??)	2 000(?)
Nuclear		
burner	12 for 2020	300
breeders	≤ 17 by 2030	300 000
fusion	2–3 by 2030	300 000
Solar		
soft	1–2	∞
hard	2–3 by 2030	∞

∞ indicates infinite supply.

than the 3000 TW-yr I associated with fossil resources. This means that, by the year 2030, we could produce only 12 TW-yr/yr, and this for only a few years, after which there would be a rapid decline and the uranium resource would be exhausted. This description is, of course, a simplification, but it captures the essential points of a nuclear future based solely on burners.

However, if breeders are introduced, the most efficient possible energy strategy would lead to a nuclear-energy production level by 2030 of 17 TW-yr/yr, which could continue well beyond 2030 in view of the associated resource potential of 300 000 TW-yr. The potential for fusion is also 300 000 TW-yr, but here the build-up must be more limited and very slow. If fusion finally does come into use, its major contribution must come after the year 2030. It is difficult to conceive that by 2030 fusion could offer more than 2 to 3 TW-yr/yr of caloric power.

The situation for solar energy is also noteworthy. For the localized, decentralized use of solar power, which Table 5 labels "soft," it is difficult to conceive of more than 1 or 2 TW-yr/yr, although the resource is indeed essentially infinite. The other category of solar power that Table 5 shows is "hard" solar, a classification perhaps best typified by a large centralized facility located in the Sahara Desert. In the final analysis, production in this category could be very large. Still, the hard-solar option takes time, and it will be difficult to bring to reality. To expect more than 2 to 3 TW-yr/yr by the year 2030 would be unrealistic. Again it is time, and not resources, that is the principal constraint during at least the next 50 years.

COMBINING THE ENERGY RESOURCES

The next question, then, is: how do we combine all these various resource potentials? Table 6 shows the primary energy supply mixes associated with each of the two scenarios. Because there is so much discussion of optimality – of optimal supply mixes and optimal strategies – I want to stress again that we do not offer either of the scenarios as an optimal future; rather, both represent plausible and feasible futures. It is feasibility, not optimality, that is the immediately pressing constraint.

TABLE 6 The primary (commercial) energy sources used in the High and Low scenarios from 1975 to 2030 (terawatt-years per year).

Primary source	Base year 1975	High scenario 2000	High scenario 2030	Low scenario 2000	Low scenario 2030
Oil	3.62	5.89	6.83	4.75	5.02
Gas	1.51	3.11	5.97	2.53	3.47
Coal	2.26	4.95	11.98	3.93	6.45
LWR	0.12	1.70	3.21	1.27	1.89
FBR	0.00	0.04	4.88	0.02	3.28
Hydro	0.50	0.83	1.46	0.83	1.46
Solar	0.00	0.10	0.49	0.09	0.30
Other	0.21	0.22	0.81	0.17	0.52
Total[a]	8.21	16.84	35.65	13.59	22.39

[a]Columns may not sum to totals because of rounding.

Significantly, as can be seen from Table 6, the production and consumption of oil in both scenarios go up, not down, compared to 1975. The relative share of oil declines, but the absolute numbers go up.

The trend is even more pronounced in the case of coal: from 2 TW-yr/yr in 1975 to 12 TW-yr/yr in 2030 in the High scenario and to 6.5 TW-yr/yr in 2030 in the Low scenario. So Carroll Wilson is absolutely right in concentrating on studying coal use over the next 50 years (Wilson 1980). Many of you might tell me that it will be impossible to produce 12 billion tons of coal per year. My first answer is, yes, it will be impossible. But, because we are globally comprehensive and consistent, we must then necessarily ask what primary energy source will assume the burden. Relieving the pressure on one resource can only increase the pressure on another. One may therefore argue that the High scenario is impossible, and that the Low scenario should be considered. But, in this case, it is important to understand the implications of lower energy-use levels in the developing parts of the world. If we insist on being globally comprehensive, there is no escape.

Let us look at the oil situation; after all, it is our most pressing problem. In the High scenario, as shown in Figure 9 for the world's market economies, known reserves of conventional oil will be exhausted by the year 2010. This is essentially the man in the street's perception of the energy situation, and he is absolutely correct. This means, first, that we must seek new reserves of conventional oil; Mexico, for instance, is a case in point. However, our High scenario already takes into account all the Mexicos still to come, and yet production never gets above 25 million barrels per day. Therefore, we must turn to the unconventional oil sources, such as the Athabasca tar sands in Canada or the Orinoco heavy crudes in Latin America. At the same time, we should recognize the completely new geopolitical patterns that will develop when the unconventionals begin to play such a major role. However, just changing to unconventional oil sources is not enough. Even after all this, it will still be necessary to import oil from Region VI – the member countries of the Organization of the Petroleum Exporting Countries (OPEC) and particularly the member countries of the Organization of Arab Petroleum Exporting Countries (OAPEC) – in order to meet the demand for liquids.

It is a tough picture that we draw, but one that we cannot ignore. It means, among other things, that oil trading will play a key role in the world energy situation. Today,

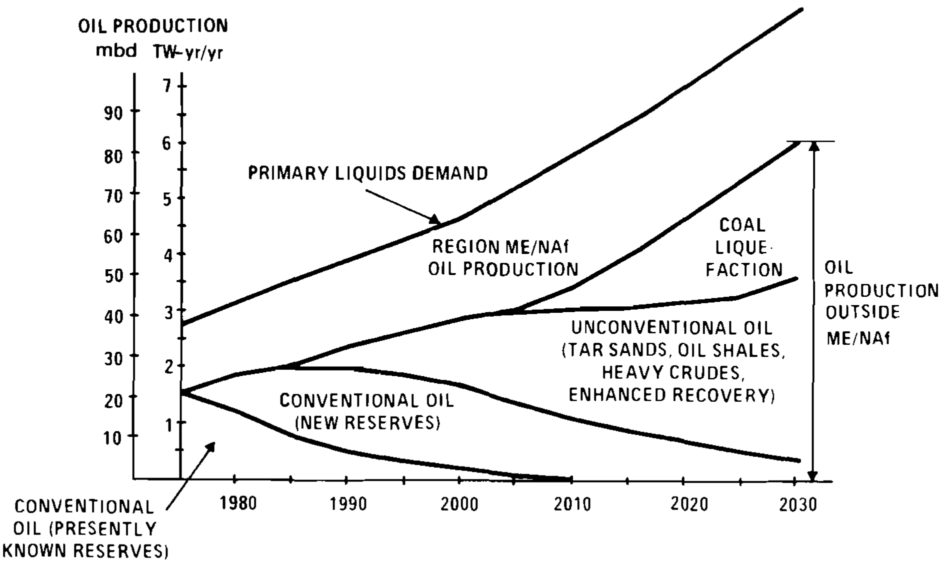

FIGURE 9 Oil production for the world's market economies in the High scenario from 1975 to 2030. (mbd is million barrels per day. TW-yr/yr is terawatt-years per year.)

as shown in Figure 10, we have two net oil-consuming regions, three supplier regions, and two regions that are exactly self sufficient. In order to have a feasible match between demand and supply in 2030 in our High scenario, we have assumed that Region I (NA), Region IV (LA), Region II (SU/EE), as well as Region VII (C/CPA), will be self sufficient. Only Region VI (ME/NAf) will be an exporter, and these exports will go to the imports of Region III (WE/JANZ), a developed region, and Region V (Af/SEA), a developing

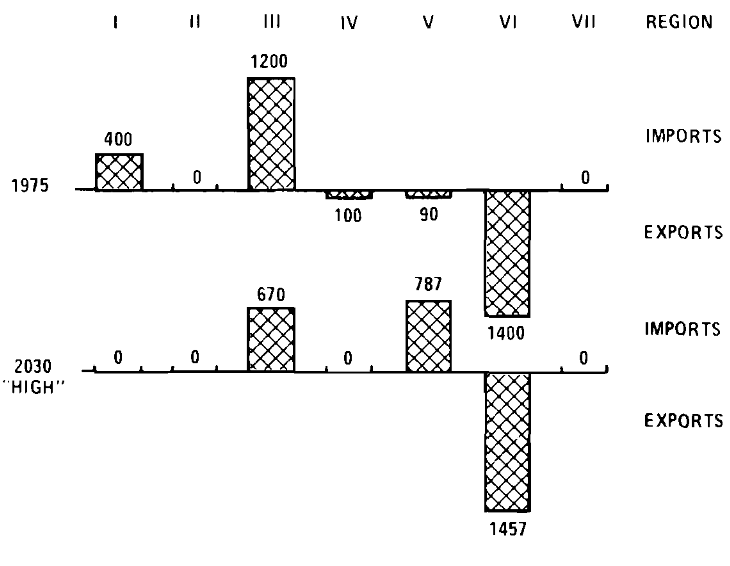

FIGURE 10 Imports and exports of oil for the IIASA regions for the High scenario in base year 1975 and in 2030.

region, with an associated set of political implications somewhat different from those of today. While it is not our duty here to perform the political analysis, this example illustrates how we serve by identifying the factual basis necessarily underlying global politics in the decades to come.

Now the question is, "where are we by the year 2030?" Table 7 shows that "in between" is the most appropriate answer. In the High scenario 68 percent of categories 1 and 2 oil is consumed by 2030, although only 1 percent of category 3 oil is consumed.

TABLE 7 The cumulative uses by 2030 of fossil fuels in the High and Low scenarios.

Fossil fuel	Total resource available (TW-yr)	Total consumed as percentage of total available	
		High scenario	Low scenario
Oil			
categories 1 & 2	464	68	57
category 3	373	1	0
Natural gas			
categories 1 & 2	408	49	36
category 3	130	0	0
Coal			
category 1	560	61	40
category 2	1 019	0	0

NOTES: For definition of cost categories see Table 4 in this paper.

Some 370 TW-yr of category 3 oil would be left, but, at a consumption rate of 30 to 50 TW-yr/yr, it will not last forever. The same is essentially true for natural gas, although the situation is slightly more favorable. Moreover, for the near future our more detailed analyses indicate that the potential for natural gas is remarkable. Other analytical results point to the same conclusion. In the case of coal, only 61 percent of category 1 resources will have been consumed, leaving more than 1000 TW-yr of coal still in the ground.

Translating the quantitative findings into a qualitative conclusion, we say that in the next 50 years it will not be the resources that limit us. Instead, it will be the build-up rates associated with doing something new: time will be the constraint. In the second half of the next century the fossil resources will indeed come to an end, and we will have to take this into account when developing strategies for the next 50 years, because time will always be the limiting factor.

CONCLUSIONS

Before summarizing the principal insights that emerge from the analysis, I should note that the two scenarios I have just discussed were not the only ones we investigated; for example, we examined one assuming very low energy demand and a nuclear moratorium and one based on an all-out nuclear effort until the year 2030.

The question that arises after all this analysis is, how do we translate it? What does it boil down to? What do we have to say to someone who wants to understand the essential meaning of all this? We have identified qualitatively a number of important conclusions, the most important being that *it can be done* – the world's energy needs can be met. There are difficulties and expenses involved, but we cannot subscribe to the idea that the world is doomed to failure because nature has not given us the necessary endowments for 8 billion people, or even a larger number, such as 10 or 12 billion. It will be difficult to do it, and it will be at an expense, but it can be done.

With respect to demand, the important conclusions can be summarized as follows:

- Only radical changes in life-style and the structure of the economy can lead to a very low energy demand.
- The demand for liquid fuels is a principal driving force in the energy problem. We have an energy problem within the energy problem.
- The conservation measures implied by our Low scenario are strict, but probably more realistic than those of the very low-demand scenario.
- Our High scenario projects growth rates that may be considered moderately satisfactory but that will transfer the hardship to the supply side.
- Over the next 50 years, under any set of circumstances, economic growth rates will be limited.

The institutional implications deserving particular emphasis are the following:

- The hard/soft controversy is essentially a political issue and not a factual one.
- The realities of political, social, and institutional problems will make the situation grimmer than has been described in our two scenarios.
- Society has not yet developed adequate mechanisms for dealing with the risks associated with energy-supply techniques.

With respect to supply, there are these conclusions:

- Fossil fuels will continue to be available but will become increasingly unconventional and expensive.
- Renewable energy sources can contribute in an important, albeit limited, way to meeting demand.
- The oil-exporting countries will continue to dominate the oil market.
- Accordingly, an international coal market must be developed.
- Coal liquefaction must be installed with a strategic outlook. It must serve as a bridge to the future.
- Energy investments will grow significantly but will not be a large portion of the gross domestic product (GDP) in the developed countries.

Beyond the 50 years of the detailed analysis, the message can be summarized in two conclusions:

- It is indeed possible to have a sustainable global energy system. It will take time, but nature has provided us with the possibility.
- In order to arrive at this future, the build-up and operation of a sustainable energy system must make prudent use of the carbon atom.

APPLICATIONS

In view of these conclusions, what should individual nations do? After all, IIASA has National Member Organizations (NMOs), not Regional Member Organizations. What can the NMOs do with these results? From an early stage of its work, the Energy Systems

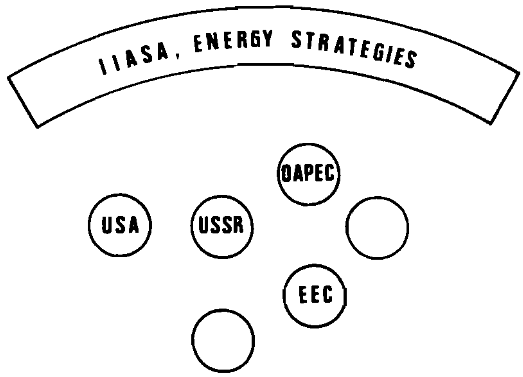

FIGURE 11 Evaluating national and regional energy policies against the global background of IIASA's energy studies. (OAPEC stands for the Organization of Arab Petroleum Exporting Countries. EEC stands for the European Economic Community.)

Program's purpose has been to provide a background of information against which local and national policies can be assessed, as suggested by Figure 11. Indeed, we have made – and are continuing to make – such assessments.

• In the case of Austria (see Figure 12), we reviewed the official estimates made by the Austrian Institute for Economic Research in 1978 (Musil 1978) and discovered them to be more energy intensive than our Region III (WE/JANZ) High and Low results. It was straightforward to translate our regional results into national results, with Austrian High and Low cases, as shown in the figure. A report on this work is in preparation.

• We have also worked with the Commission of the European Communities (CEC), as described in a remarkable report, *Crucial Choices for the Energy Transition* (CEC 1980), recently published by the Commission. As Figure 13 shows, the role played by IIASA was exactly the role described above: we provided the global background for the

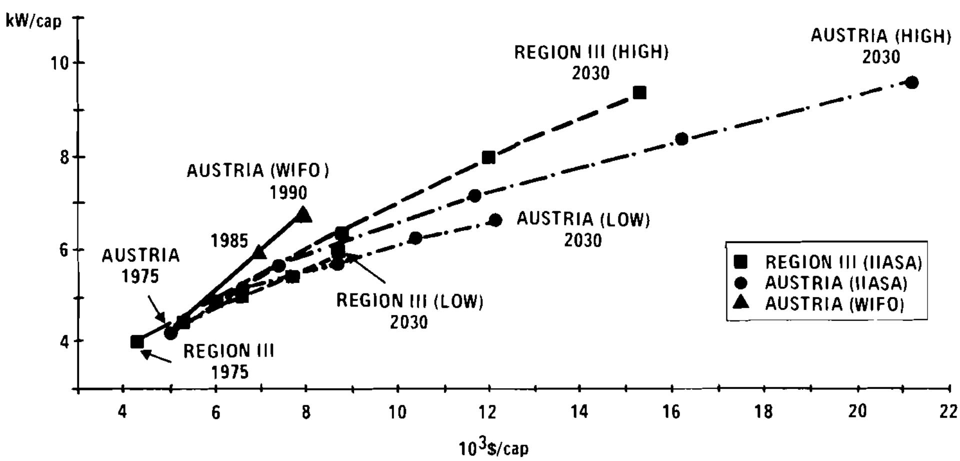

FIGURE 12 Projections of primary energy as a function of gross domestic product per capita for IIASA's Region III (WE/JANZ) and for Austria. The Austrian estimates shown by triangles were made by K. Musil (1978) for the Austrian Institute for Economic Research (WIFO).

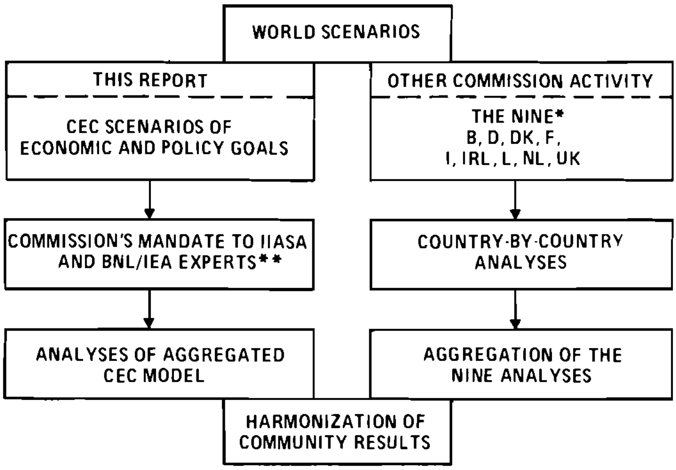

FIGURE 13 The design of an energy study by the Commission of European Communities and IIASA. IIASA's role is shown on the left; that of the CEC is shown on the right. *Belgium, the Federal Republic of Germany, Denmark, France, Italy, Ireland, Luxemburg, the Netherlands, and the United Kingdom. **Experts from Brookhaven National Laboratory in Upton, New York, and from the International Energy Agency in Paris. Source: CEC 1980.

Commission's assessments of energy strategies. Where the Commission used the bottom-up approach for all the nine member countries, the top-down approach came from IIASA, the point being to harmonize these results in the end.

• Our efforts in cooperation with Bulgaria are represented in Figure 14. There, through the NMO, we have interacted with the Systems Analysis Group that has been

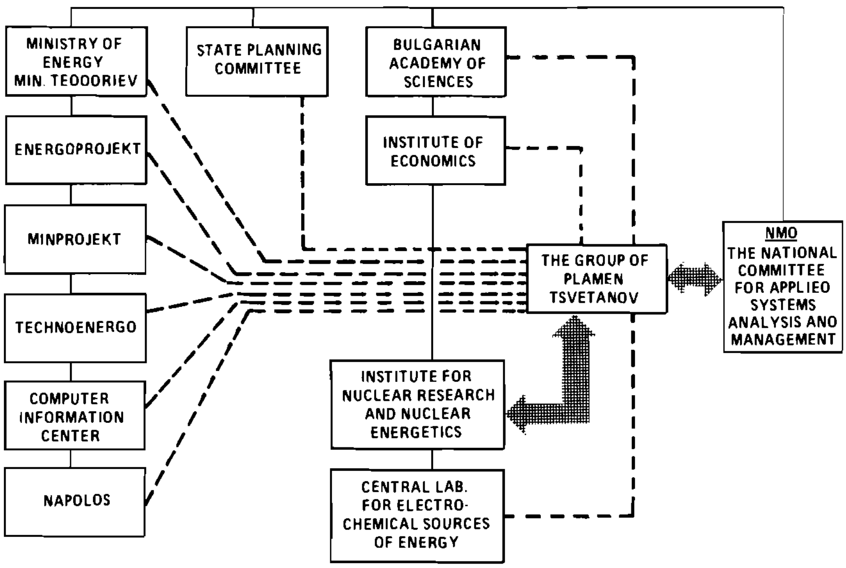

FIGURE 14 Conceiving energy strategies for Bulgaria.

established in Sofia under the leadership of Dr. Plamen Tsvetanov, a former participant in our Energy Systems Program.

• In the Federal Republic of Germany the Federal Parliament (Bundestag) instituted a commission on future nuclear energy policy with this charge:

> It is the task of the commission to define future policy options and future policy requirements, taking into account ecological, economic, social, and safety concerns, both national and international, and to prepare related policy recommendations.

Throughout its deliberations, the Commission has interacted with the IIASA Energy Systems Program. Specifically, the IIASA High and Low scenarios have served as reference cases for the Commission's scenario development; the more specific assessments of the Commission have been based on MEDEE-type demand projections; the IIASA analyses have provided a background beyond the year 2000 for assessing imports of oil, gas, and coal, as well as uranium; and these analyses have also provided the basic inputs for estimating the upper limit of the potential for renewable energy sources in the Federal Republic of Germany. The Commission itself visited IIASA in January 1980.

These cases by no means exhaust the list of cooperative efforts. We have interacted with other NMOs, especially those of the USA and the USSR. In addition to the NMOs, Pakistan and Brazil must be mentioned. Throughout these efforts, the idea, as illustrated in Figure 15, has been to establish a dialogue. Can we handle the energy problem – can it be solved? Yes, I think it can be. But in order to understand the associated implications and conditions, it is necessary for a dialogue to exist, a dialogue including the USSR, the European Community, and all the others, a dialogue through Laxenburg, and perhaps eventually without Laxenburg, but with a language that may have been created here.

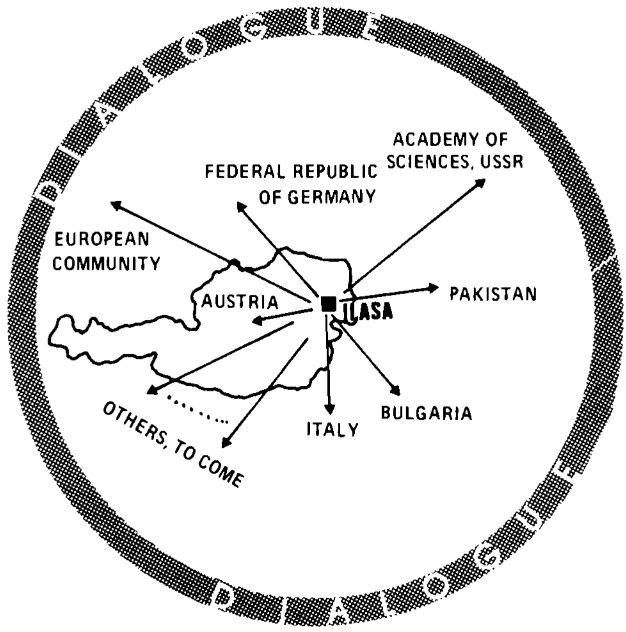

FIGURE 15 The possibility of using IIASA results as a language for a dialogue.

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FOOD AND AGRICULTURE SYSTEMS: GLOBAL AND NATIONAL ISSUES

Ferenc Rabar
Leader of the Food and Agriculture Program

INTRODUCTION

When we began our research in the field of food and agriculture in 1976, we started with these objectives: to evaluate the nature and dimensions of the food problem, to look into its causes, and to investigate possible courses of action to ease the situation. There is an important feature of this definition: it is vague and general. However, this choice was deliberate because we wanted to have enough freedom to find our place later on and to define our research accordingly.

The starting point for our work was the 1974 Conference of the Food and Agriculture Organization of the United Nations (FAO), at which it was stated that there are about 462 million hungry people, partly in developing countries and partly in developed countries. This was a shocking – and at the same time controversial – number. However, if we look at the recent estimates shown in Table 1, especially those made by the FAO in its study of agriculture toward the year 2000 and the ones set forth by the Organization for Economic Co-operation and Development (OECD 1979), we see that the estimated number of hungry people, even in the year 2000, could be, according to the scenario one accepts, 242 million or 350 million.

TABLE 1 Recent estimates of the numbers of undernourished people in the world.

Year: Source	No. of undernourished people, in millions (% of population)	The grain equivalent needed to eradicate hunger, in millions of tons
1974: FAO 1974.	462 (25)	*a*
1979: World Bank's US Presidential Commission on World Hunger 1979	1 000	*a*
2000 (1979 trend): FAO 1979	387 (11)	32
2000 (normal trend): FAO 1979	242 (7)	20
2000: OECD 1979	350	*a*
2000: US Presidential Commission on World Hunger 1979	*a*	32

[a]No statistics given.

Thus, hunger appears to be a stubborn problem. An optimist approaches the problem from a favorable point of view: the estimates seem to say that the proportion of the undernourished population will decline from 25 percent possibly to 7 percent by the end of the century. However, this positive view is hard to sustain in the face of the figures showing the amount of grain needed annually to ease the problem of hunger: 32 million tons in one estimate, 20 million tons in another. From the technical side the problem is marginal. But it is hardly marginal to those who are hungry: for them it is a question of life and death.

Against this background, in our early work we wanted to achieve a problem definition as a framework for our research that would be as close to the realities as possible. This problem-definition work consisted of three studies:

(1) We began with a series of problem assessments made on a nation-by-nation basis, with centrally-planned and market economies treated differently.
(2) The second study was a state-of-the-art survey of modeling experience to discover differences and commonalities in what others had done.
(3) Finally, we examined the policies that could be adopted to ease the situation and classified them in an appropriate way.

In brief, the outcomes of this research were that food problems are local problems, that they appear in different parts of the world, and that they generally have different causes, often country-specific. In some countries hunger is the result of lack of resources; in others it has a historical connection with the country's stage of development; in still others it is a demographic or income-distribution problem. However, in each case, the problems are embedded in the national economies of the countries. Thus, agricultural policies cannot be understood without looking at the overall economic policies country by country. It follows that the goals of agricultural policies have to be derived from the overall economic goals on a country-by-country basis.

On the other hand, no matter how local and country-specific these problems are, they are not independent of one another; rather, they interact, and therefore depend on international interactions and development. Nevertheless, the countries play key roles in this system.

In a given country we can identify the resources, the technologies (which depend on the country's stage of development), the sectoral relations (different from country to country), the decision makers (those who initiate and carry through policies), and the economic settings (within which policies can be set). However, our detailed knowledge of what goes on inside the country is in stark contrast to our lack of knowledge of what goes on outside its borders. The agricultural policy of a country has side effects, and these side effects have uncalculated influences on other countries. Other countries react to these influences in uncalculated ways. These reactions in turn produce unexpected influences on the originating country, as well as others. In sum, these intercountry interactions produce myriad effects.

Thus, our understanding of the system is fuzzy, and it is made more so by the shifts that it exhibits.

- *Sectoral shifts.* As an example, we know that the energy price changes in 1973 caused price rises in fertilizer and in fuel for well pumps that resulted, according to some experts, in a shortage of as much as 15 million tons of grain.

Changes in infrastructure have an important impact on food distribution. On the other hand, agricultural production is the basis for developing rural industries. Thus, changes in other sectors greatly affect agricultural production, which in turn induces changes in other sectors.

- *Spatial shifts.* We know that droughts have effects, not only where they occur, but also elsewhere. We know that agricultural policies made in one country often have important effects in others.
- *Temporal shifts.* An energy price change may have an effect only on the harvest of the next year, but this will affect feed prices, raising the prices of meat in the following years, and so on.

If we take into consideration that all of these shifts combine in the actual international food system, we can agree that the local and global effects are difficult to separate.

In sum, we have found the characteristics of the international food and agriculture system to be these: it is hierarchical; the global system consists of a set of national food and agriculture systems embedded in their national economies, which in turn interact with each other internationally. In each country its economy dominates, with food and agriculture being one of the economic sectors. Since the nations play a key role that extends into the international system, the local and global changes interact inseparably.

OUR APPROACH

Since the food problem is a highly complex one, IIASA uses a systems approach to it. We describe the national systems and represent their connections with a system of linkages.

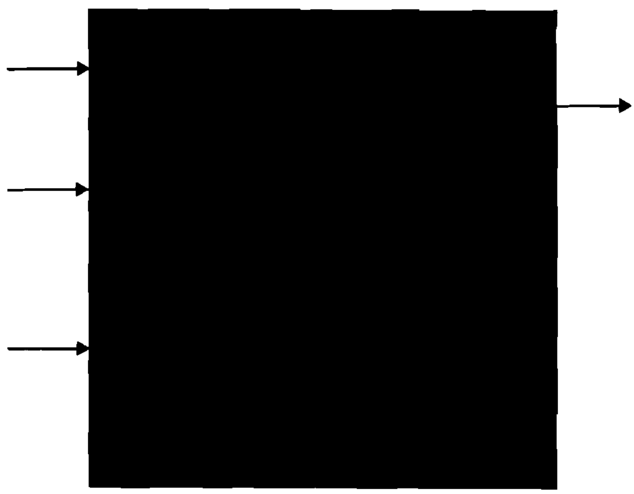


FIGURE 1 The global food and agriculture system as a black box.

To see how we built up our approach, let us look first at how others have viewed the field. Figure 1 shows the food and agriculture system as a black box. Although this approach is oversimplified – and even simplistic – it has been used by many people who have added up the world's resources as an input and then used a simple formula to

TABLE 2 The world's food resources converted to estimates of the numbers of people who can be fed by them.

Study made by	Billions of people
University of California	8
R. Revelle	38–48
J. Klatzman	10–12
C. Clark	45–150
H. Linnemann *et al.*	90

SOURCES: University of California (1974), Revelle (1974), Klatzman (1975), Clark (1967), Linnemann *et al.* (1979).

derive the number of people that the globe can support. Table 2 shows some estimates produced this way – and it can be seen how widely different they are, ranging from the University of California's 8 billion people to Clark's 150 billion. This one-black-box approach neglects everything inside it, the national institutions and social elements, as well as the economic connections among the countries.

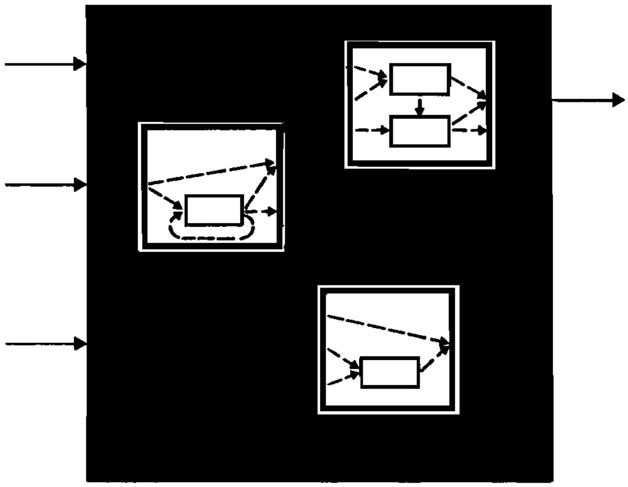


FIGURE 2 The global food and agriculture system as a set of unlinked national models.

Figure 2 shows another approach, in which the nations are the focus of attention. In this figure, the large black box is the environment of the nations within it. Here the nations are described in a very accurate and detailed way, but everything that comes from the environment is assumed to be given exogenously, and everything that steps outside the countries' borders is neglected.

Many researchers feel that this approach is not adequate and thus have tried to connect the national models by various linkages based on a variety of assumptions, as suggested by Figure 3. There are two well-known experiments that take this approach.

- The LINK Project links existing national models while replacing and overruling their export functions with a heuristic algorithm.
- The United Nations approach assumes that the countries import everything

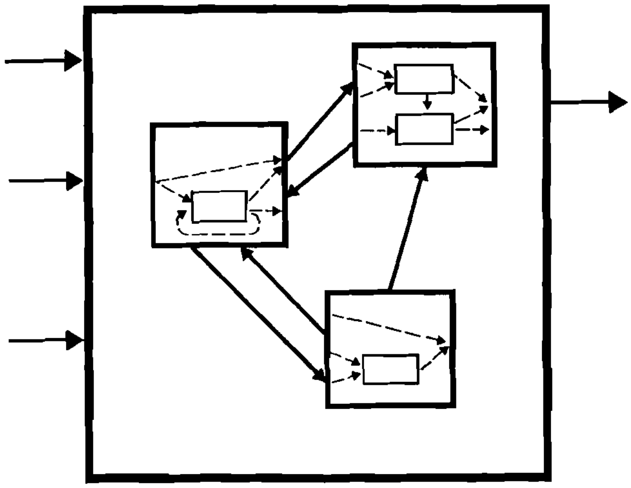


FIGURE 3 The global food and agriculture system as a set of national models with assumed international links.

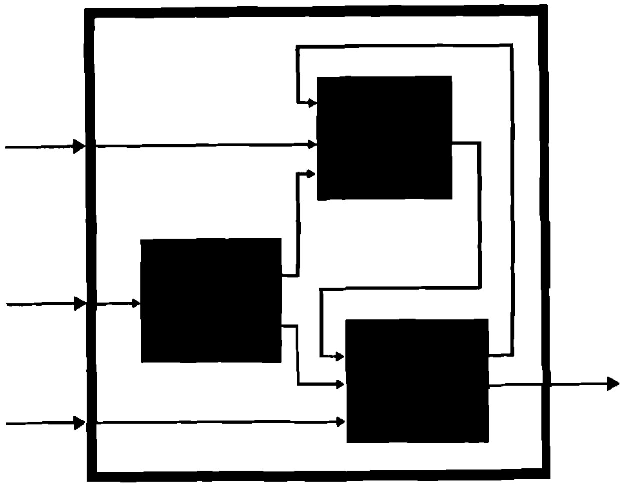


FIGURE 4 The global food and agriculture system as a set of flows among nations considered to be black boxes (trade models).

they need for a given rate of growth and that these imports are covered by exports, the export shares being constant for the entire projected period.

Figure 4 shows still another approach, the so-called trade models, in which the nations are regarded as black boxes. Here the modelers concentrate on the flows among the countries, without taking into consideration what is happening inside the countries. Their predictions use various techniques of extrapolating from past flows.

In Figure 5 the real internal (interregional) and external (international) relationships in food and agriculture are shown. IIASA's approach tries to reflect both of these relationships. This is illustrated in Figure 6. Here there are four countries. Each country has the same structure: a production, an exchange, and a government module. It is important for the government to be represented, because government policies influence both the production and exchange functions. Another important feature is that the food and agriculture sector is not separated from the rest of the economy. Since the rest of the

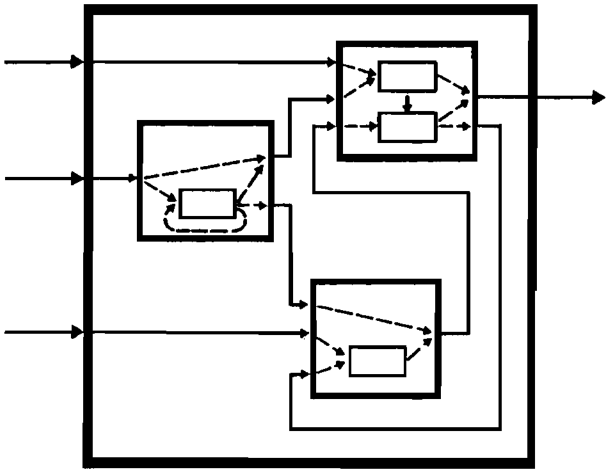
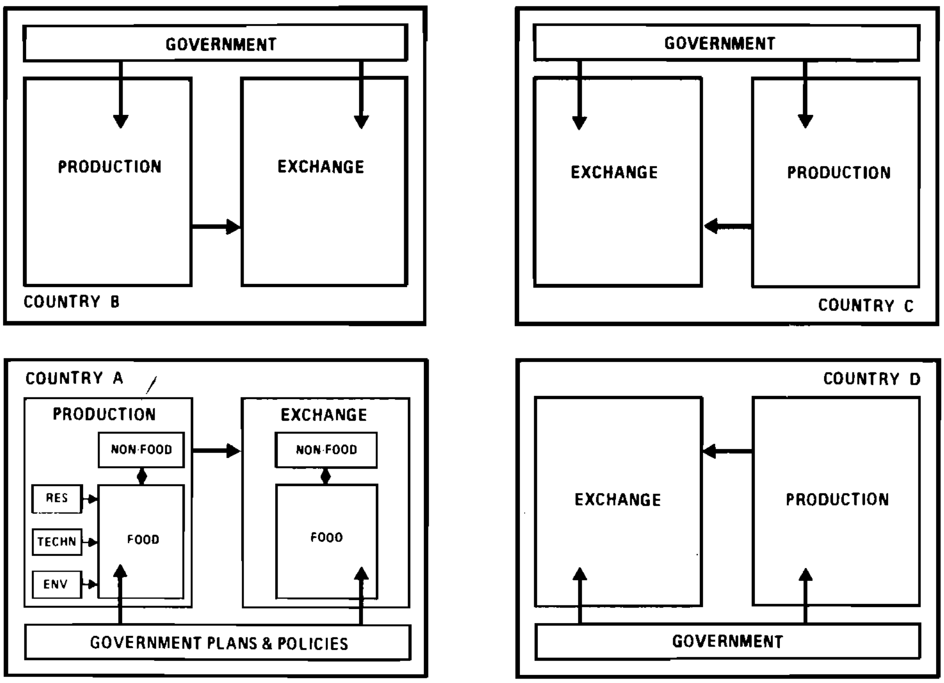


FIGURE 5 The global food and agriculture system.

economy plays an important interactive role, the national models are closed, with the government budgets and balances of trade fully represented.

The first step in our system is to calculate the supply at the market. Supply has a 1-year lag after production decisions are made. This feature yields a simplification: the



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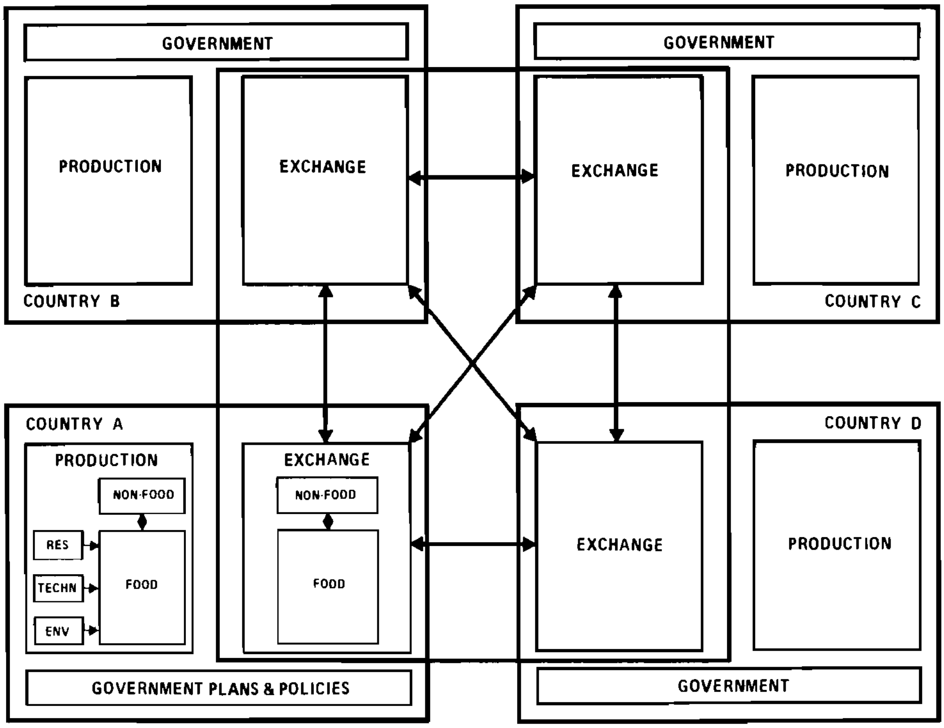
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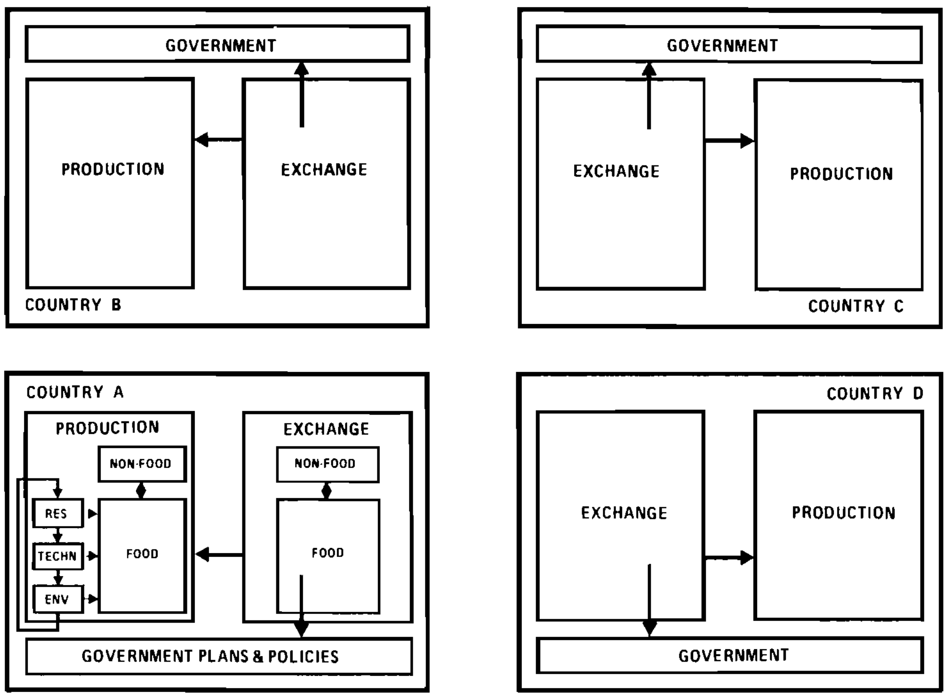
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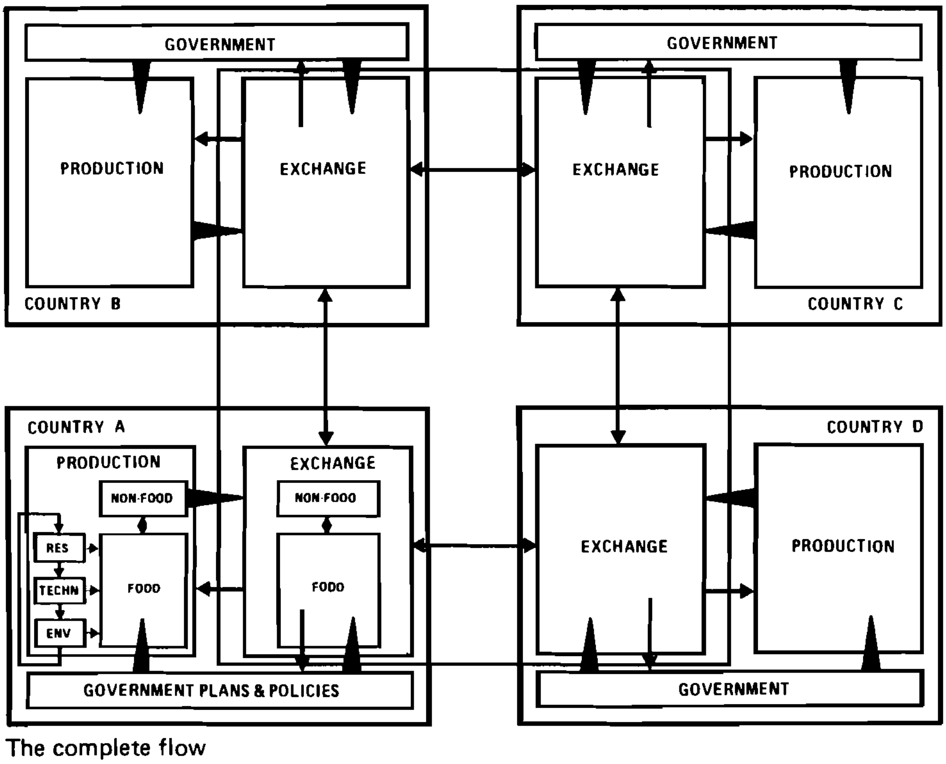

FIGURE 6 The IIASA approach to modeling the global food and agriculture system.

supply modules can be independent of one another. Indeed, there is no reason to have a common supply structure in the countries; each country's supply module can be developed to best suit the country involved. Thus, our supply modules are all country-specific. The supply decisions are made on the basis of past domestic and international prices – a property that makes the model recursive.

Once the supply is on the market, solving a set of simultaneous equations yields the domestic and world prices and demands. This process is based on general equilibrium theory, and uses nondifferential optimization procedures worked out with the help of the System and Decision Sciences Area. Here the system is dealt with simultaneously, all of the country exchange modules being solved together.

This process yields both the domestic prices influenced by government policies and the international prices that are inputs to the next period, during which the governments and producers learn, not only from the price changes, but also from the changed supply-and-demand conditions. This learning process yields changed policies and product mixes for the next period.

Since we go through these steps period by period, we have a dynamic simulation that we use in the short run (that is, for a 5–15-year period) to predict the consequences of various policies, not only for individual countries, but also for the entire system.

We began this work with a simplified system. We knew that it would be difficult to introduce detailed models for all of the countries. On the other hand, we had to test our method and demonstrate that it would work – and we also wanted to show that even a simplified system would be able to answer some important questions.

However, even to develop the simplified system required a major effort.

- We built up a data bank. It is based mainly on data provided through the courtesy of the FAO, and they are complemented by data from the World Bank, the OECD, the US Department of Agriculture, and other sources.
- Anyone who has dealt with a data bank knows that it is useless unless there are data-handling routines to facilitate the work – so we developed them.
- On the basis of our available data, we worked out 21 simplified models based on a common model structure.
- We worked out a linkage system (which will carry over into our final model system) to connect the simplified national models.

In choosing the countries to be represented in the simplified system, we wanted different economic systems, different continents, and different problems represented. Our final choices include developed exporters, developed importers, centrally-planned economies, and developing countries. The developing countries category is broken down as follows:

(1) A group of countries whose balance-of-trade problems are not serious
(2) A group of exporters with balance-of-trade problems
(3) A group of importers with serious balance-of-trade problems

TABLE 3 The 20 countries and 2 groups of countries included in the simplified global food and agriculture system.

Argentina	Indonesia
Australia	Japan
Austria	Kenya
Bangladesh	Mexico
Brazil	New Zealand
Canada	Nigeria
China	Pakistan
CMEA countries[a]	Sweden
EC countries[b]	Thailand
Egypt	USA
Finland	
India	

[a]Council for Mutual Economic Assistance: includes Poland, USSR, the German Democratic Republic, Czechoslovakia, Romania, Bulgaria, and Hungary.
[b]European Community: includes Belgium, Denmark, the Federal Republic of Germany, France, Ireland, Italy, Luxemburg, the Netherlands, and the United Kingdom.

In Nigeria and Indonesia, for example, there is extensive hunger, although they are oil exporting countries. The countries are listed in Table 3 and their geographical locations are shown in Figure 7.

In selecting these countries for the simplified system, we wanted to cover about 80 percent of the world population. We achieved a 76.9 percent coverage. In addition, we covered 80.5 percent of the world's agricultural production, 80.8 percent of the world's

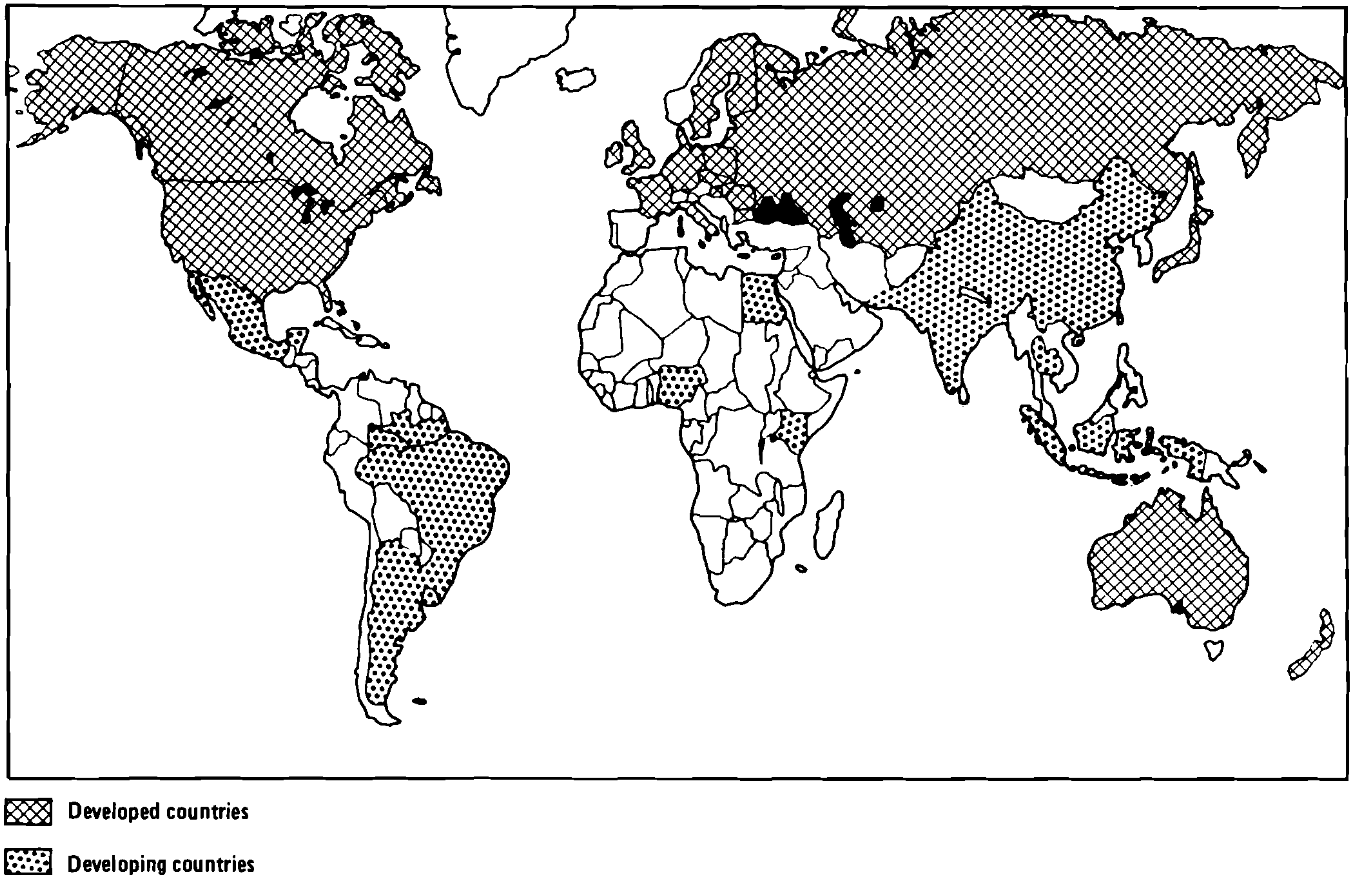

FIGURE 7 The geographical location of the countries included in the simplified system.

arable land, 78.5 percent of the world's agricultural imports, and 77.9 percent of the world's agricultural exports.

The simplified system was our starting point. However, we wanted to extend it in two ways: by including more countries and by replacing the simple national models with detailed ones. In the detailed country models, we wanted to have better representations of the production and demand systems, as well as detailed analytic descriptions of the governmental policies.

GOALS

The goals of our complete global food and agriculture model system are

(1) To provide a nation-specific decision-making tool for each country that builds a detailed country model.
(2) To investigate the consistency of the policy field in each case because agricultural policies have many objectives, and policy instruments, if combined, can lead to unexpected results.
(3) To study the national policies of the countries in an international framework.

To achieve these goals we did not turn to our international data base; rather, we turned to groups in the countries to build models, since they can use internal data and can maintain close connections with their country's decision makers. However, the linkage system remains the one used in the simplified system.

TABLE 4 Countries participating and expected to be represented in the IIASA global food and agriculture model system by a detailed national model.

Countries with national models partially complete	Countries expected to participate soon	Countries we would like to have participate
Austria	Australia	Argentina
Brazil	Bangladesh	Pakistan
Canada	Indonesia	
China	Mexico	
Egypt	New Zealand	
Finland	Nigeria	
Hungary		
India		
Japan		
Kenya		
Poland		
Sweden		
Thailand		
United States of America		

Table 4 shows the state of development of the detailed country models. The left-hand column lists the countries whose national models are partially ready (they are being worked on cooperatively by IIASA and groups in the countries). The second column lists the countries that we expect to begin building models soon. The third column lists the countries that we would like to include in the system.

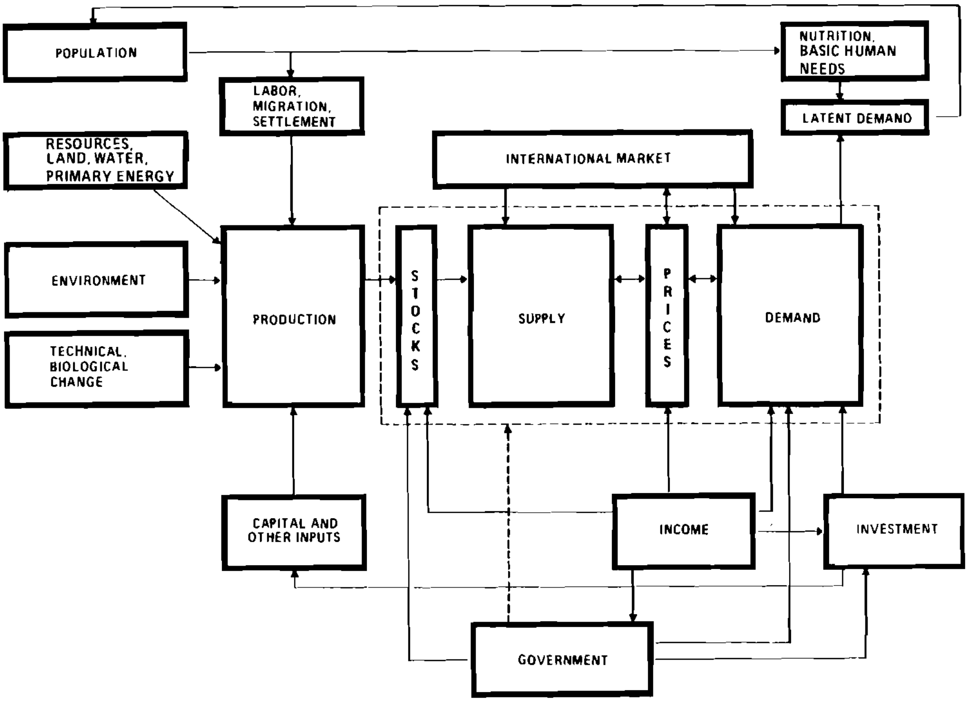

FIGURE 8 The reference model for the country food and agriculture models.

Figure 8 shows the reference system for the country models; it is the skeleton on which these national models are built. It contains various blocks: a production block, an exchange block (the activities within the broken-line rectangle), and government and income-redistribution blocks. In the upper right corner of the figure is a block representing calculation of biological need (which is especially important for the developing countries). There is also an international market block (to show that all of the countries are connected through their exchange blocks).

I would like to call attention to the three boxes that seem to be exogenous to the system: resources, environment, and technical and biological change. So far we have been speaking of short-term problems, and we have regarded resources, the environment, and technical state as given. However, as soon as one turns to a long-term investigation, one must be aware of the consequences of short-term activities for these elements and their interconnections.

We became conscious of these longer-term problems very early in our work, and now we have reached a stage at which we can introduce research on the related issues of resources, technology, and environment. For example, under the short-term pressures of food shortage, a country will try to produce as much food as possible, which may induce a long-term process with environmental consequences that must be understood. A cogwheel–flywheel system offers a useful analogy: the cogwheel is the short-term, high-energy pressure induced by fast economic changes; it brings into motion the flywheel of slow changes in the environment – and this flywheel may well turn out to be the future force. To look at such effects will be important in our future. As an example, we would like to investigate the long-term consequences of short-term energy price changes because these changes alter resource availability, which in turn may induce technical changes that may affect the environment, perhaps in different ways than in the past. After such work, it would be important to reconcile short- and long-term policies.

In the short term, we will investigate the system to see where we can expect tensions, pressures, and problems in the future. Which countries cannot grow as they should owing to food and agriculture problems? What causes produce this effect? Can international policies help?

Four possible environments – market types – in which international policies could be conceived are given below.

(1) The present market remains unchanged. In such a case, what are the chances of specific developing countries to enter the market?
(2) An assumed liberal market. The consequences of such a market present questions that are far from trivial. Some studies say that, if we liberalize the market, it can, for instance, help farmers in the USA and consumers in Europe, but it will not change the situation for the developing countries. Such statements can be checked only by means of a consistent set of models capable of following these assumed policies to their consequences.
(3) A regulated market. This market is regulated in the sense that it is influenced deliberately in the interests of the developing countries. The concept of such a new economic order underlies many of the proposals of the United Nations Conference on Trade and Development; international agreements, like the Lomé Convention; and various commodity agreements. We would like to see who is gaining and who is losing, and how the burden is being distributed among the participants.
(4) A self-sufficiency market. Which developing countries can be self-sufficient? How far can the others proceed toward self-sufficiency? If some individual countries cannot be self-sufficient, are there groups of countries that can be?

We look forward to using our global system of models as a basis for looking into such matters.

However, in addition to international policy matters, there are national policy problems. Indeed, all nations face varying food and agriculture problems. They have to reconcile conflicting policy goals – an especially important undertaking for countries that would like to provide incentives for production and low prices for consumers. There are countries that must choose between an export-oriented and a nutrition-oriented structure. We would like to address such problems through our national models.

SUMMARY

We see that there are short-term problems, long-term problems, country problems, and international problems in food and agriculture – all demanding complex analyses if they are to be addressed properly. Our ambition is to carry out some of this work and to obtain results and recommendations for countries, groups of countries, and international policymakers.

As an interesting by-product of our modeling activity, we have created an international network of modelers with a common language – perhaps one of the main achievements of our work. The common language has been created, not only because we have certain common requirements from the point of view of the linkage system in the exchange module, but also because we meet often and share concerns over common problems. These exchanges promote consistency and a unified approach. A newsletter supports these exchanges further. While the groups meet among themselves (e.g., Sweden and Finland, Canada and the USA) in a variety of places, IIASA is the central meeting place and leads the group in reaching a common understanding.

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National and regional issues

MIGRATION, URBANIZATION, AND DEVELOPMENT

Andrei Rogers
Chairman of the Human Settlements and Services Area

INTRODUCTION: PROBLEM PERSPECTIVES

Growing global economic interdependence, increasing competition for diminishing stocks of resources, and widening disparities in material welfare have made future population growth an unavoidable issue in international affairs. Rapid population growth has important social, economic, and political consequences. It affects levels of public health and welfare and the quality of the environment in which people live. Many of the consequences are poorly understood, yet it is clear that reducing such growth can alone only ease, but not resolve, the diverse problems associated with demoeconomic growth and development.

Developing improved methods for *analyzing* the determinants and consequences of demoeconomic growth and for *understanding* the fundamental issues and options that are associated with it is the principal goal of IIASA's Human Settlements and Services Area. The Area's recent efforts to contribute to an *interdisciplinary* analysis of the problems and a *multidimensional* (systems) understanding of the strategic options available for coping with them are reviewed and summarized here.

Urban Development

World population in 1980 stands at about 4.3 billion and is exhibiting a growth rate of approximately 1.8 percent per year. At this rate of growth the world's population will be 6.3 billion by the end of this century. However, recent declines in fertility rates in many less-developed countries have led demographers to project the lower figure of just over 6 billion for the year 2000 and a widening "fan" ranging from 8 billion to 10.5 billion for the year 2050.

Urban population growth has been even more explosive (Figure 1). Roughly 1.8 billion people, 42 percent of the world's population, live in urban areas today, and this total is growing by almost 3 percent per year. At the beginning of the last century, the urban population of the world totaled only 25 million. The United Nations estimates that about 3.1 billion people, nearly twice the size of today's urban population, will be living in urban areas by the year 2000 (United Nations 1976), a multiple of 124 in just two centuries.

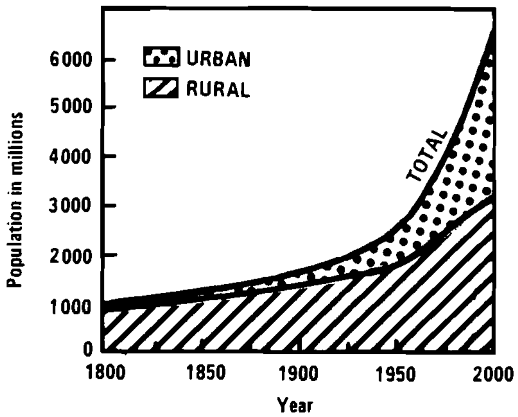


FIGURE 1 The growth of the world's urban and rural population, 1800–2000 (in millions).

TABLE 1 Population estimates and projections for fifteen large cities.

City	Population (millions)			Multiple increase over base year	
	1950	1975	2000	1950–1975	1975–2000
Cairo, Egypt	2.4	6.9	16.4	2.9	2.4
Addis Ababa, Ethiopia	0.2	1.1	4.2	4.8	3.9
Nairobi, Kenya	0.1	0.7	3.4	5.5	4.5
Lagos, Nigeria	2.9	2.1	9.4	7.2	4.6
Kinshasa, Zaire	0.2	2.0	9.1	12.5	4.4
Mexico City, Mexico	2.9	10.9	31.6	3.8	2.9
São Paulo, Brazil	2.4	10.0	26.0	4.1	2.6
Bogota, Colombia	0.7	3.4	9.5	5.2	2.8
Guayaquil, Ecuador	0.3	1.0	3.1	4.0	3.1
Lima, Peru	0.6	3.9	12.1	6.4	3.1
Jakarta, Indonesia	1.6	5.6	16.9	3.6	3.0
Teheran, Iran	1.0	4.4	13.8	4.3	3.1
Seoul, Korea	1.0	7.3	18.7	7.1	2.6
Karachi, Pakistan	1.0	4.5	15.9	4.3	3.6
Bangkok, Thailand	1.0	3.3	11.0	3.4	3.4

SOURCE: United Nations (1976, pages 77–83).

Rates of urban growth are even more dramatic at the level of the individual urban settlement. Table 1 sets out recent United Nations projections of the growth of some of the less-developed world's largest urban centers, indicating that the size of the population-growth multiplier – the urban momentum – for some cities is truly awesome. For example, during the 25 years between 1975 and 2000, Lima, Mexico City, Jakarta, and Teheran are expected to triple their populations; São Paulo and Seoul are projected to grow by a factor of 2; and Addis Ababa, Nairobi, Lagos, and Kinshasa are to increase fourfold. The largest city is expected to be Mexico City, with over 31 million inhabitants. Not far behind will be São Paulo, with about 26 million (United Nations 1976).

Urban Problems

As with rapid population growth in general, rapid urban growth increases the difficulties of providing a population with the necessary sustenance, employment, services, and infrastructure. A rapidly burgeoning urban population strains health and educational budgets, complicates reducing unemployment levels, and exacerbates problems connected with providing adequate housing, food, energy supplies, transport, water, and sanitary facilities. The "demographic investment" needed just to maintain present standards in many rapidly urbanizing areas means a doubling or tripling of the institutional plant within the next 25 years. That these areas are to be found mostly in countries least able to afford such an investment only multiplies the difficulties associated with expanding the insufficient absorptive capacities of cities in the less-developed world.

About one-third of the urban population in most of the less-developed world lives in settlements that have inadequate access to water, sewerage, transport, health, education, and housing and as many as 60 percent in some countries live in squatter settlements (Table 2).

TABLE 2 Slums and uncontrolled settlements as a percentage of total city population (circa 1960–1970).

City, country	%	1970 GNP/cap (US$)
Caracas, Venezuela	40	980
Mexico City, Mexico	46	670
Lusaka, Zambia	58	400
Bogota, Colombia	60	340
Nairobi, Kenya	33	150
Kinshasa, Zaire	60	90
Manila, Philippines	35	210

SOURCE: Sinclair (1978).

Conclusion

Rapid rates of urban population growth and increased consumption arising from a growing per capita income continuing at an annual rate of 4 to 5 percent mean an annual growth rate of total urban income and demand for goods and services of about 9 percent, a doubling every seven to eight years.

An examination of future prospects for world population growth and urbanization reveals very forcefully that the twin historical developments that have combined to create the problems of human settlements today will continue for the rest of this century and beyond in most parts of the world. Therefore, the number of people in the world will continue to increase in the near future, as will the proportion of people living in urban settlements. Populations in urban centers are likely to continue to grow at an alarming rate, particularly in the larger urban agglomerations of the less-developed world. The problems created by this transformation are manifold and involve large private and social costs. But there are obvious benefits too, and it is important to keep these in mind when considering policies for intervening in the urbanization process. A better understanding of the dynamics and consequences of urban–rural population growth and economic development appears to be an essential ingredient of such considerations, and this requires a focus on the processes of change, together with their manifestations. The improvement of this understanding is the principal goal of the Human Settlements and Services Area research on migration, urbanization, and development.

RESEARCH PERSPECTIVES: ANALYZING THE DETERMINANTS AND CONSEQUENCES

A noted Harvard University professor used to tell his students that the difference between economics and sociology is simple.

> Economics is all about how people make choices. Sociology is all about why they don't have any choices to make. (Duesenberry 1960, p. 233)

With roots in sociology and the actuarial sciences, it is not surprising that the research perspective of the demographer relies principally on the method of *decomposition*. The contribution of various causes and the behavior of various groups are accounted for, first, by disaggregation to a subgroup in which all individuals may be assumed to exhibit uniform behavior, and, second, by a consolidation in which each subgroup is appropriately weighted to reflect its changing share of the aggregate total. Thus mortality patterns are explained by different decompositions of age-, sex-, and cause-specific death rates; fertility behavior is accounted for by different patterns in age at marriage, desired family size, and timing of births.

The economist's research perspective, on the other hand, is usually directed at explaining the choice behavior of individuals and establishments. Decisions regarding what is produced, how, for whom, and with what consequences lie at the heart of the economist's perspective. In some market settings, for example, satisfaction-maximizing consumers are assumed to interact with profit-maximizing producers to determine an equilibrium set of prices and quantities. In this way the economic decisions of seemingly independent agents are tied together.

Finally, there is the research perspective of the geographer. The first law of geography asserts that "everything is related to everything else, but near things are more related than distant things" (Tobler 1970). Thus the principal perspective of this discipline is: what happens at one location is tied to what happens at all other locations. It is this view of the spatial interdependence of all phenomena that is reflected in geographical explanations of spatial regularities in patterns of urbanization and development.

Demographers, economists, and geographers have all contributed to the study of urbanization and development processes and problems at IIASA. Each group of scholars, however, has sought to identify the principal determinants and consequences as revealed by the perspectives of their particular discipline. All have been brought together at IIASA in the belief that the combination of these different views of the same societal process can contribute significant insights into understanding urbanization and managing its effects.

Urbanization: The Demographer's Story

Demographers have interpreted today's accelerated rates of population growth and urbanization in the less-developed countries to be direct consequences of increases in rates of natural increase (births minus deaths) and rates of urban net migration (urban in-migration minus urban out-migration). Their explanations of temporal and spatial variations in the patterns exhibited by these two sets of rates have followed conventional descriptive generalizations that appeal to historical regularities described as "transitions" or "revolutions." Specifically, population growth is attributed to the *vital revolution*, the process whereby societies with high birth and death rates move to a situation of low birth and death rates in the course of development. Urbanization is explained to be the result of the *mobility revolution*, the transformation experienced by societies with low migration rates as they advance to a condition of high migration rates. These two revolutions occur simultaneously and jointly they constitute the *demographic transition*: the demographer's classical story of population and development (Figure 2).

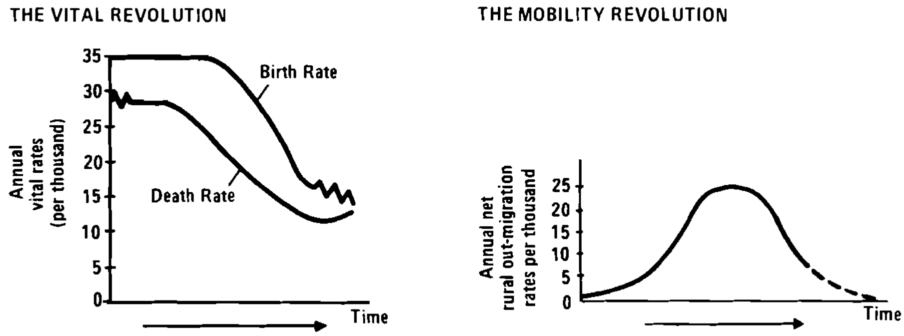


FIGURE 2 The demographic transition. Sources: Berelson (1974) and Zelinsky (1971).

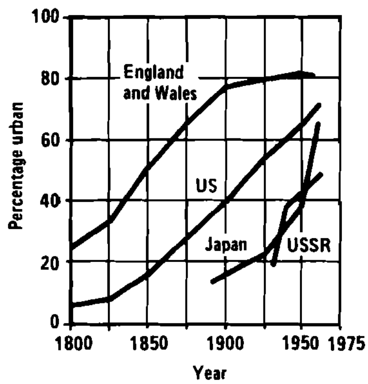
Urbanization results from a particular spatial interaction of the vital and mobility revolutions. It is characterized by distinct urban–rural differentials in fertility–mortality levels and patterns of decline and by a massive net transfer of population from rural to urban areas through internal migration, generating an urbanization process all nations go through in the course of their transition from an agrarian to an industrial society. These urbanization patterns can be depicted by elongated S-shaped curves (Figure 3). They typically show a swift rise to around 20 percent, a flattening out at a point somewhere between 40 and 60 percent, and a halt or even a *decline* in the urban proportion at levels of about 75 percent.

Development: The Economist's Story

The principal features that characterize the economist's story of urbanization and development are:

- High rates of per capita income or product growth (15–20 percent per decade)
- Relatively high rates of population growth
- A sharp decline in the relative importance of the agricultural sector (about 10 percent per decade)

The decline in the relative fraction of the labor force engaged in agriculture that accompanied economic growth in the West is generally explained by the twin forces of the lower demand for food and agricultural products compared to other products and the



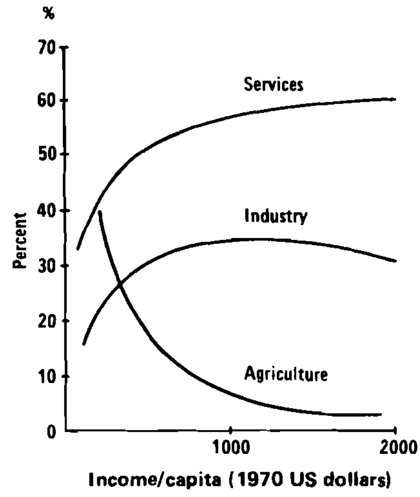


FIGURE 3 Historical evolution of the proportion of a population classed as urban. Source: Davis (1965).

FIGURE 4 The structural transformation: changes in the percentages of the population in agriculture, industry, and services as a function of rising income per capita. Source: Chen (1979).

effects of labor-displacing technology in agriculture. The structural shifts toward the non-agricultural sectors are evident in the changing sectoral shares of national product and the associated industrial composition of labor. The share of the agricultural labor force declines from as much as 80 percent in the preindustrial economy to as little as 10 percent or less at advanced stages of development. Corresponding to this decrease, there are increases in the shares of the secondary and tertiary sectors: industry and services (Figure 4).

A major correlate of the structural transformation of a national economy is the concomitant spatial redistribution of its labor force and population away from rural and toward urban settlements (Figure 5). Urbanization in the developed countries was associated with industrialization; in today's less-developed countries urbanization is occurring

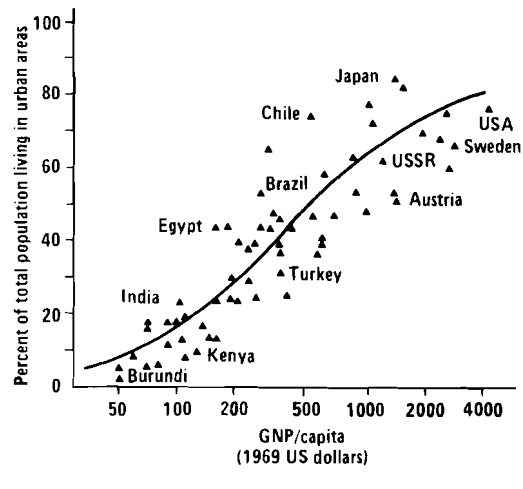


FIGURE 5 Degree of urbanization compared with GNP/capita. Source: Graph redrawn from Berry (1973, p. 75).

in advance of industrialization, leading some scholars to label such countries as "over-urbanized."

Settlement: The Geographer's Story

Geographers have examined patterns of urbanization and development somewhat differently. Taking an overall view of national settlement patterns, they argue that regularities in city-size distributions reflect the system-like character of the growth and decline of a nation's cities and the process of urbanization. They believe that, in every country, urban centers are organized functionally into a hierarchy that reflects the spatial integration of the national economy. Population size is the simplest index of a city's position in such a hierarchy, and differences in the numbers of cities in various size classes reveal differences of hierarchical organization. This organization, in turn, is related to differences in patterns of urbanization and development (Hansen 1978; Sheppard 1980).

Geographers have shown that a particular size distribution arises from a growth process in which the growth of cities is proportional to their size. Moreover, some have

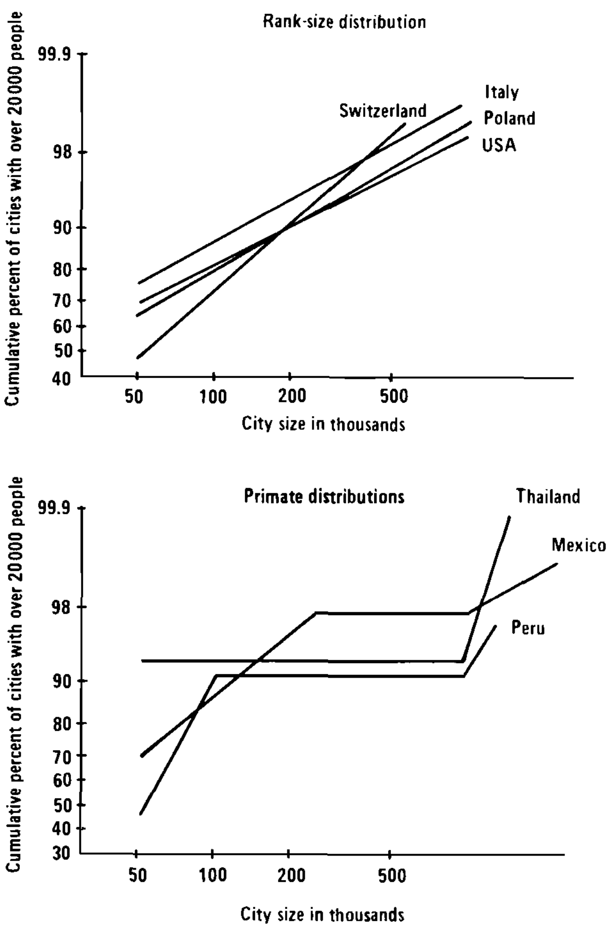


FIGURE 6 City-size distributions. Source: Berry (1961).

asserted that, when such a growth pattern prevails, the frequency distribution that evolves is the well-known rank size or *lognormal* distribution (Berry 1961 and 1973). If this latter distribution holds true, then a graph of the cumulative percentages of cities over some minimum threshold size, located along a normal probability scale against the logarithm of city size, gives rise to a straight line.

Systematic deviations of the largest city or cities from the expected populations given by the rank-size law give rise to a diagnosis of "primacy." A striking example is provided by Thailand, whose largest city, Bangkok, is about 40 times larger than the second largest city (Figure 6).

Regularities in the form of lognormal distributions have become associated with city systems in the economically more-developed countries. Primate distributions, on the other hand, have been associated with the less-developed countries. Examinations of historical city-size distributions have led some geographers to posit an evolutionary process in which primate distributions gradually become transformed into lognormal distributions in the course of national development (Figure 7).

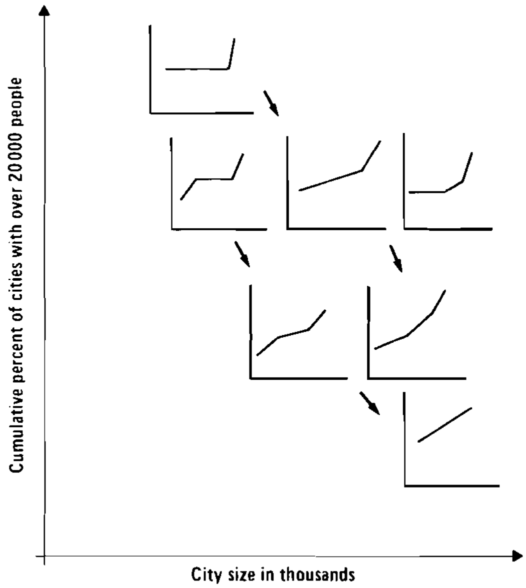


FIGURE 7 A developmental model of city-size distributions. Source: Berry (1961).

Population Growth, Structural Change, and Spatial Interaction: IIASA's Interdisciplinary Story

During the past few years, demographers, economists, and geographers have all contributed to IIASA's story-telling efforts on the subject of urbanization, development, and settlement dynamics. Although a truly interdisciplinary perspective is still only in its formative stages, significant progress has already been made in linking multiregional demographic cohort-survival models with multisectoral economic general-equilibrium models, and with multilocational geographic spatial interaction models.

The principal function of demoeconomic simulation models of urbanization and development is to ascertain the quantitative importance of *indirect* effects of changes in the demographic or economic environment. The fundamental importance of this interdependence in demoeconomic modeling leads naturally to the use of *general equilibrium* approaches in both theoretical and empirical analysis. While partial equilibrium models have usefully focused on the operation of various components of the economic growth process, by their very nature they cannot deal with the interdependences and feedbacks that are characteristic of processes of structural change.

The general-equilibrium modeling of demoeconomic development has been further advanced at IIASA during the past two years. The purpose of such modeling has been to provide analytical structures and empirical frameworks for analyzing the determinants and consequences of urbanization and structural change. These models highlight population–service demand connections, and they highlight substitution in both consumption and production. They aim to contribute to the debate on long-term strategies for urbanization and development. And they are designed to be empirically implementable.

The ideas that the IIASA models strive to convey are ideas about:

- urbanization
- income distribution
- growth and structural change
- demography of development

In addition to these primary themes, these models also have been designed to integrate several of the research themes at IIASA, such as the provision of basic human needs (food, health, education, and housing) and resources (energy, land), and they include a government policy-making sector with its powerful instruments of tax, spending, pricing, and regulatory policies. Although the models are general-equilibrium in character, they can incorporate disequilibrating features and lags.

Finally, the IIASA models are scenario-building models that are designed to be used in the development of so-called counterfactual simulations, i.e., "what if" simulations. To find out how two different policies of economic growth would have influenced the economy and demographic factors the models can be run with different sets of assumptions regarding national economic growth policies and impacts of exogenous factors not included in the models.

POLICY (USE) PERSPECTIVES: UNDERSTANDING THE ISSUES AND OPTIONS

Scholars and policy makers often disagree when it comes to evaluating the desirability of current rates of *rapid urbanization* and *massive rural–urban migration* in the less-developed world. Some, the "optimists," see these trends as effectively speeding up national processes of socioeconomic development; whereas others, the "pessimists," believe their consequences to be largely undesirable and argue that both trends should be slowed down.

Those taking the negative view argue that most developing countries are "overurbanized" in the sense that urban growth rates have greatly outdistanced rates of industrial development and economic growth. This has created an imbalance that finds cities in the less-developed world perpetually struggling with crisis.

Supporters of current urbanization and migration patterns in LDCs point to the modernizing benefits of urbanization and to the improved well-being of most rural–urban migrants. They contend that urbanization transforms people's outlook and behavioral patterns, while broadening their skills. They also argue that concern on welfare grounds is probably misplaced, because, despite job insecurity and squalid living conditions, most rural–urban migrants are better off than they were before their move. Their transfer from the farm to the city enables them to raise their personal income and to obtain social services of a much wider variety and superior quality than were available to them before.

The three urbanization-related long-term strategies most frequently suggested for dealing with the urban problems of less-developed nations are fertility and migration reduction, economic development, and a redistribution of the urban population away from the largest cities. In an effort to gain an improved understanding of how effective such strategies might be, IIASA's research on migration, urbanization, and development began by focusing on the demographics of the following three important questions:

- Is it high fertility or high rural–urban migration that is the principal cause of current rapid rates of urbanization and urban growth in LDCs, and which of these two components of population change should receive the major attention of national population policy?
- Is a strategy of rapid industrialization, with its predominantly urban bias, the appropriate model for most developing countries, or should agricultural and rural development programs play a much larger role than they do today?
- Are the major cities in the less-developed world too big, and do they consume a disproportionately large share of national resources and services, or is the problem not one of urban size but one of urban growth management?

We have studied these questions and have reached tentative conclusions, but as our interdisciplinary research on urbanization and development processes has evolved, we have become increasingly conscious of the narrow and disciplinarily-bound character of such questions. Each academic discipline addressing the problems of urban development all too often sees only a partial view and focuses on policy interventions specifically connected with that view. Thus, demographers seek to relieve the problems of urban growth by policies directed at fertility and migration reductions. Economists, on the other hand, addressing the same phenomenon, consider appropriate investment, fiscal, and monetary policies. And geographers advocate rearranging the human settlement pattern.

But these partial views are inadequate perspectives for designing a national urban development policy. For example, several scholars have repeatedly pointed to the unintended territorial impacts of nonterritorial governmental programs, such as highway construction and laws regulating the treatment of depreciation and capital gains (Alonso 1972). Others have emphasized the necessity of pursuing a coordinated multiregional development of both the rural and the urban sectors when adopting development strategies to redress rural–urban imbalances (Edwards 1974). Still others have directed attention to the important interrelationships that connect traditional and modern sectors in the urban labor markets of today's LDCs (Rempel 1979).

Different governmental programs, different geographic regions, and different economic sectors are all interlinked pieces in the evolving urban development puzzle, and they therefore should not be considered in isolation. The recognition that "everything is connected to everything else" leaves the analyst no alternative but to deal with the full complexity of the *multidimensional* systems problem when generating policy recommendations for national strategies for urban development. Moreover, the goals of such strategies must mirror those of other national policies: they must include safety, stability, environmental quality, and economic growth, efficiency, and equity. Thus, in urban development policy, as in foreign policy for example, no simple unified set of operational guidelines can be identified and adopted; the central considerations must be set in the general context of broad national objectives before effective strategies can be formulated (Alonso 1972).

As our understanding of the complex multidimensionality of problems associated with urbanization and development has increased, our policy perspectives have become more modest in scope. At the present stage in the evolution of our work we are asking two fundamental questions: will future urban growth rates in LDCs slow down (will Mexico City, for example, have 31 million residents by the year 2000?), and what can systems analysis contribute to the resolution of some of the more pressing management problems associated with such growth rates? The IIASA demoeconomic models are being used to help address both questions.

Reduced Urban Growth in LDCs?

Research carried out at IIASA indicates that the explosive urban growth rates in today's developing countries are unlikely to continue for long and that reduced urban growth is in prospect after the urban transition phase of development has passed in each developing country.

IIASA's multiregional demographic models suggest that urban growth is partly self-limiting, since urban growth rates have tended to decline as urban proportions have increased and as rural populations have slowed their growth. The demographic models appeal to the forces of the demographic transition to reduce urban growth rates in the future. The "braking" forces in these models, for example the lower fertility rates of urban populations, require a relatively long time horizon to show a significant impact (Rogers 1978). Economic forces, such as rising urban costs of living, on the other hand, are likely to act earlier to slow urban in-migration and to retard urban growth. The prototype demoeconomic model adopted by IIASA (Kelley and Williamson 1980) introduces potential feedbacks of various rising city costs on the rural-to-urban migration decision. It internalizes some of the important costs that may slow down current rates of urban growth. Some of the principal forces that are set in motion to curb the rate of urbanization are

- changing cost of living differentials between urban and rural areas
- changing access to urban housing
- changing qualities of urban public goods and services
- changing input requirements of the modern production sector and resource "bottlenecks"
- changing demands for "unproductive" urban capital accumulation

These endogenous forces generate "limits to urban growth" in the IIASA model of urbanization and development. However, their impact has as yet not been measured quantitatively, inasmuch as the case-study applications of such models have been started only recently.

Managing Urban Absorption

If the current rapid pace of urban growth in the less-developed world is a transitory phase in urban development, the systems analyst's contribution to urban policy making can come in the form of an improved understanding of the likely levels of the forthcoming demands for resources, jobs, housing, and services during this transition period and beyond. The overwhelming challenge to urban planners and managers in cities in LDCs is to absorb large numbers of newcomers in an effective and equitable manner in the course of developing an enlarged urban absorptive capacity. Demoeconomic simulation models have an important role to play in these planning efforts, since they can be used to trace out the likely consequences of alternative policies on patterns of demand and supply.

Resources and services are demanded by people; hence, if all else is fixed (including tastes and prices), the level of demand should be approximately proportional to population size. Demand above this level may be attributed to affluence.

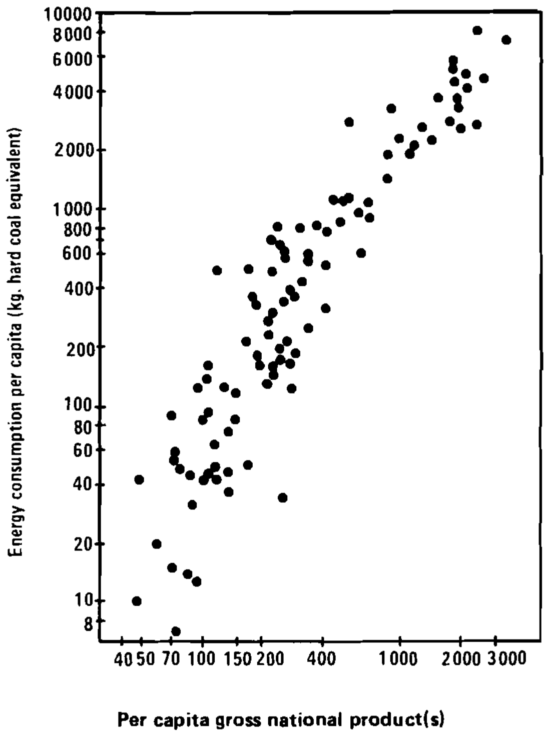


FIGURE 8 The relation between per capita energy use and per capita gross national product for 96 nations (1965 data). Source: Fisher and Potter (1971).

The association between energy consumption and affluence is shown more explicitly in Figure 8, which plots per capita energy consumption against per capita income for 96 nations of the world. The correlation is striking: as a poor country develops, it requires a larger throughput of energy resources to run its economy and supply the needs of its population.

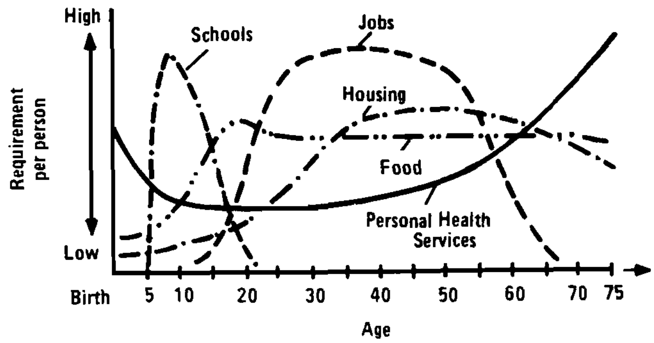


FIGURE 9 Relations between age and demands for goods and services. Source: Corsa Jr. and Oakley (1971).

A satisfactory first approximation of the demographic and economic determinants of the level and composition of demand may be obtained by considering only changes in population size and in its income. However, to obtain a more complete assessment of the impacts of different population trends on resource and service demands, it is necessary to go further and to examine the effects of changing population age compositions on such demands. Figure 9 illustrates the relations between age compositions and demands for a number of services. These data show, for example, that demands for educational services occur largely between the ages of 5 and 20, with a peak at age 10. Jobs are in demand during the labor force participation ages of 15 to 65. And health-service demands are relatively high for infants and older adults.

To the variables of population size, per capita income, and age composition, we must add geographic location, particularly the distinction between urban and rural places of residence. The data for Japan set out in Figure 10 clearly indicate the changing patterns of food consumption that occur in the course of a nation's urbanization and development. For each of the three years shown the fraction of total household expenditures

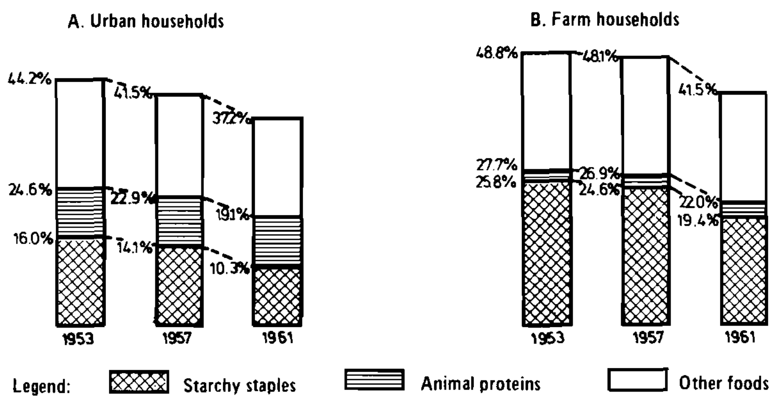


FIGURE 10 Percentages of total household expenditures devoted to specific food groups by urban and farm households in Japan. Source: Kaneda (1970).

devoted to food declines over time and is lower for urban households than for rural (farm) households. Moreover, the fraction of total expenditures that is devoted to starchy staples (cereals, potatoes, etc.) is also lower for the urban population, which tends to consume instead larger quantities of animal protein foods, such as meat, dairy products, eggs, and fish.

Finally, the demand for urban infrastructure and services is not solely a function of urban residents; it is also a function of the number of industrial and commercial users. This is especially true of public utilities, such as water supply, electricity, and sewerage facilities. Thus, industrialization generates its own increased demands for urban infrastructure.

In summary, the usefulness of IIASA's demoeconomic models of urbanization and development lies in their contribution to a better understanding of the underlying processes of growth and change and in their ability to assess the probable levels of future demands for various goods, services, and infrastructure. Their most important feature is their ability to provide a systems-wide multidimensional policy perspective that takes into account the likely indirect effects of alternative policy decisions.

CONCLUSIONS: LESSONS LEARNED ABOUT PERSPECTIVES

The founders of IIASA, the Charter informs us, put forward three goals for the Institute:

- to strengthen international cooperation and collaboration
- to advance the science and art of interdisciplinary systems analysis
- to apply systems analysis to help resolve important problems of mankind

The organizers of this Conference reflected such goals in the theme "from *problem* through *research* to *use*."

Our research on the processes and problems of urbanization and development has been designed with these goals in mind. International collaboration, interdisciplinary science, and applied systems analysis have been key ingredients.

Good applied analysis is a difficult enough task to set for any discipline in any country. To add the interdisciplinary and international dimensions to this activity is to complicate the situation enormously. Yet IIASA has tried to do this, and, in several instances, the results have been very good. What lessons have we learned in our work on urbanization and development about processes of scientific interaction that may shed light on some of the reasons for the difficulties and successes?

A principal lesson is the recognition that, for successful applied systems analysis, it is essential to develop an appreciation of different views about problem assessment, research design, and use by decision makers.

Different Problem Assessments: Optimists and Pessimists

International policy debates on global and universal problems generally pit the arguments of the optimists against those of the pessimists. The former counsel caution and believe that "time will take care of the situation;" the latter urge dramatic interventions in societal processes of development.

In the population policy arena, for example, the optimists argue that high fertility and rural out-migration rates are a transitory stage in the demographic evolution of pre-modern into modern societies; the pessimists point to the persistence of traditional beliefs and to the momenta of population growth that are embedded in current high-fertility populations.

In the economic policy debate the optimists argue that income inequalities will diminish over time as a natural consequence of the development process; the pessimists point to the widening gap between the rich and the poor and argue that only major redistribution programs will narrow this gap.

In the geographical policy debate, the optimists argue that the urban city-size distribution will ultimately reach a harmonious equilibrium state that reflects a spatial integration of the national territory; the pessimists remain unconvinced by the "filtering-down" diffusion process put forward by the optimists and counsel that a deliberate investment policy to redirect migrant flows is called for.

Different Research Perspectives: Interdisciplinary Analysis

Earlier we described the different research perspectives held by demographers, economists, and geographers. That discussion can be broadened considerably if the interdisciplinary group of social scientists is expanded to include natural scientists, engineers, and mathematicians. Consider, for example, the different ways in which such a broader group of interdisciplinary scientists might view an IIASA global or universal problem. In some fields, such as engineering, the research style is problem-oriented and looks to the generation of recommendations about how a problem might be resolved or eased based on today's knowledge, not tomorrow's. In other fields, such as economics, the research style is more discipline-oriented and seeks to advance understanding as the necessary prerequisite first step before offering policy recommendations. Followers of the former research style are likely to be impatient with advocates of the latter, and misunderstanding can result.

Related to these two different perspectives are different styles of modeling: large versus small, and disequilibrium versus equilibrium. Those striving to offer prescriptions regarding complex systems often adopt a relatively large and complex model. Others, on the other hand, frequently use a model only to illustrate a parable (an interesting story with a moral to it) and, therefore, often are content with a small transparent model if it makes their point. Followers of the latter perspective are likely to criticize the designer of complex models as wanting to build skyscrapers with only wood for building material. Again, misunderstanding can result.

Finally, some systems analysts tend to focus on quantities and see their limited availability as setting ceilings to society's growth. In this view, the system often seems to be in disequilibrium and headed for disaster if left uncontrolled. Others, on the other hand, tend to focus more on relative values, rather than quantities, and believe that substitution will push the system back toward an equilibrium. They believe that, when something becomes scarce, it also becomes more expensive and that therefore people will use it less, thereby easing the shortage.

Different Uses by Decision Makers: Plans and Policies

Systems analysis has been widely identified with comprehensiveness and consistency.

This identification has fostered the design and development of large and complex system-wide models. For a number of reasons this sort of comprehensiveness has been sharply criticized and what has been suggested in its place is a form of policy analysis that links scientific–technical intelligence with organized societal action on a wide range of issues. A central question in this debate has been the appropriate form of the scientific–technical intelligence offered by the systems analyst.

Some systems analysts believe that the decision maker, be he a mayor of a city, a head of a corporation, a minister of health, or a governor of state, needs a comprehensive plan, a set of blueprints designed on the basis of agreed-upon standards and implemented by means of a set of consistent regulations. Other systems analysts believe that no plan can possibly be comprehensive, that different people prefer different standards, and that policies implemented through programs and incentives are much more effective instruments of societal action. The first perspective can be characterized as being more concerned with projecting *outcomes* and how to influence them, the latter perspective can be characterized as being concerned more with examining the *rules* of behavior that produce the outcomes, and how they should be changed.

The principal contribution that systems analysis can make to policy making is a broad multidimensional understanding of the relevant issues and strategies, based on an adequate interdisciplinary analysis of the behavior of the relevant systems.

Rates of population and economic growth and the geographical distribution of such growth across a national territory are interlinked facets of a single intricately interconnected whole: nothing less than the evolution of a society during its structural transformation from an agrarian to an industrial–service economy. In order to be effective, projects and programs designed to modify any single aspect of this evolution must take into account the broad system-wide interdependences that characterize such processes.

We at IIASA are increasingly learning that "everything is connected to everything else" in the systems with which we are dealing, and this learning experience is teaching us to be more cautious and realistic in the issues that we examine and in the strategies that we propose to policy makers.

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REGIONAL DEVELOPMENT: FROM CASES TO GENERALIZATION

Murat Albegov
Leader of the Regional Development Task

INTRODUCTION

The Regional Development Task at IIASA was created in 1977 to study socioeconomic development problems in a regional context. The initial year of the Task's existence was one of exploration, in which the main research directions were defined and the analytical tools were chosen. During this period, it emerged that both the scope of the Task's activities and the methods to be employed were different from those of previous undertakings at the Institute, although in some respects the activities can be compared to those of the Large Organizations Project (LOP), which ran from 1974 to 1977. The LOP dealt with important regional economic issues but gave priority to managerial problems. The processes of planning and completing already existing large-scale programs – for the Tennessee Valley Authority (USA), the Bratsk–Ilimsk Industrial Production Complex (USSR), North Sea Oil (Europe), and the Shinkansen Railway (Japan) – were examined in order to determine the features and problems common to large-scale activities.

The work of the Regional Development Task, on the other hand, is oriented toward integrated regional analysis, using mathematical modeling for future development planning, and toward in-house investigations that are carried out in collaboration with members of other institutions. The current activities, which can be defined as elaborating, collecting, generalizing, and disseminating improved methods for regional development planning, form the main part of the Task's work on policy formulation. The models are intended to aid decision makers and planners in choosing the most appropriate strategic policies under given conditions.

Regional case studies were chosen as the most suitable vehicles for testing the practical use of the proposed methods and models and for reaching an understanding of the requirements of local decision makers.

THE DEVELOPMENT PROBLEMS OF THE REGIONS UNDER ANALYSIS

At present, there are four ongoing case studies within the Task. After completion of some preliminary investigations, the practical work on the Silistra region (Bulgaria) and the Notec region (Poland) case studies began in 1978. In 1979, the Skåne (Sweden) case study was established, and at the beginning of 1980 we began a study of the Tuscany region in Italy.

The Silistra and Notec regions are faced with similar development problems. In both of these regions the dominant economic sector is agriculture, the development of which is dependent upon the extension of irrigation. Industry currently plays a relatively minor role. In both Silistra and Notec, rural–urban and interregional migration occur; these migration flows should be regulated or stopped and the system of local settlements and services improved.

For regional development modeling purposes, the major differences between these two regions can be attributed to the structure of local agriculture, the degree of dependence on irrigation, and requirements for regulating migration. In the Silistra region, all farms are state-owned agroindustrial complexes. Here the development of an irrigation network is considered to be only one of many ways of attaining an increase in agricultural productivity. With regard to migration, the aims are, first, to minimize rural–urban migration and, second, to curb regional out-migration. In the Notec region, farming is organized on a different basis. Approximately two-thirds of all farms in this area are privately owned, with relatively small acreages, and much emphasis is placed on developing the irrigation system as a means of increasing agricultural output. Migration in the Notec region is treated as part of the general labor-force allocation problem.

The Skåne region constitutes an important part of the Swedish economy. It has many natural advantages: fertile soil and a coastal area that is ideal for developing recreation facilities. In addition, it is relatively densely populated and has a productive industrial (transportation, communication, commerce, and manufacturing) as well as agricultural sector. As a consequence, serious conflicts have arisen over the use of land and water; the main problems of the region are centered around the use of these natural resources. The choice of further regional specialization is therefore being thoroughly examined, owing to its influence on solutions to, for example, water-supply and environmental-protection problems.

The problems related to the development of the Tuscany region are wide-ranging, but perhaps the most important is the direction and rate of future economic growth, primarily for the industrial and service sectors. In this region, there is considerable localized unemployment, resulting in a steady outflow of migrants. Employment opportunities must be created to solve this problem. The development of tourism has also created some difficulties for the region. In recent years Tuscany has attracted an increasing number of visitors; this is especially evident in the city of Florence and its surrounding area, which has become an international center of tourism. It is now necessary, not only to improve the existing infrastructure to cope with the increased demand for services, but also to protect the natural and architectural beauty of the area from the environmental damage caused by the upsurge in the tourist population.

METHODS FOR REGIONAL DEVELOPMENT ANALYSIS

Regional development planning analysis must take into account several requirements:

- Development of the region must be compatible with national development plans.
- The most important sectors of the regional economy and their interdependence should be modeled.
- Economic, social, environmental, and institutional problems should be examined.
- Decision-making processes in conditions of uncertainty should be modeled.
- Effective instruments for influencing regional development should be evolved.

A Three-Dimensional View of Regional Problems

The set of regional problems can be considered as three-dimensional (Figure 1). The first dimension includes the main economic activities, such as industry, agriculture, and services, as well as employment and living conditions (settlements, environment) in the region.

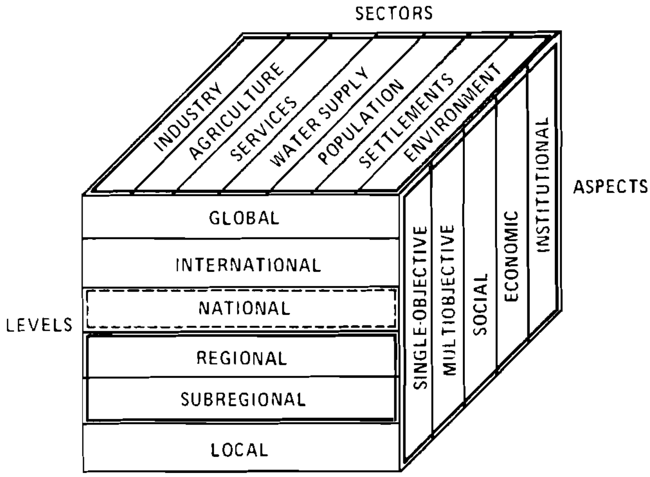


FIGURE 1 A three-dimensional view of regional problems.

The second dimension relates to the features of each problem. In addition to solving single-objective or multiobjective problems, one should be prepared to solve a set of multiobjective problems that is not necessarily purely economic, but that may also be social or institutional in character.

The third dimension refers to space and its representation in the regional system. Regional analysis is concerned mainly with the development of the subregional levels of the national economy. However, it is possible to consider national development at the regional level if the problems of all regions are of a similar nature. Although the international, national, and local levels are generally not explicitly considered within the regional framework, coordination between the regional/subregional and these other levels is very important. This is especially true for the international and national levels, which can influence the behavior of the region significantly.

Two Approaches to Regional Analysis

There are at least two possible approaches to the analysis of regional problems: the "top-down" and the "bottom-up" approaches. These two methods correspond to two different sequences of economic analysis. The first procedure is based on consecutive analysis of economic problems from the international through the national down to the regional framework, coordination between the regional/subregional and these other levels plans up to the national level, then confronting the regional and national aggregates with the world markets. Both approaches require a two-way information flow between the regional and national levels.

The Top-Down Approach

A system of regional models that corresponds to the top-down approach has been proposed by Åke E. Andersson; it is shown in Figure 2. The system operates on four levels: international, national, interregional, and intraregional; it deals first with international problems, among which technological development and trade are considered to be of prime importance. A technological-development model and a world-trade model (INFORUM) provide the main inputs (i.e., information on economically justified technological innovation and commodity trade flows and prices) to the national-level models.

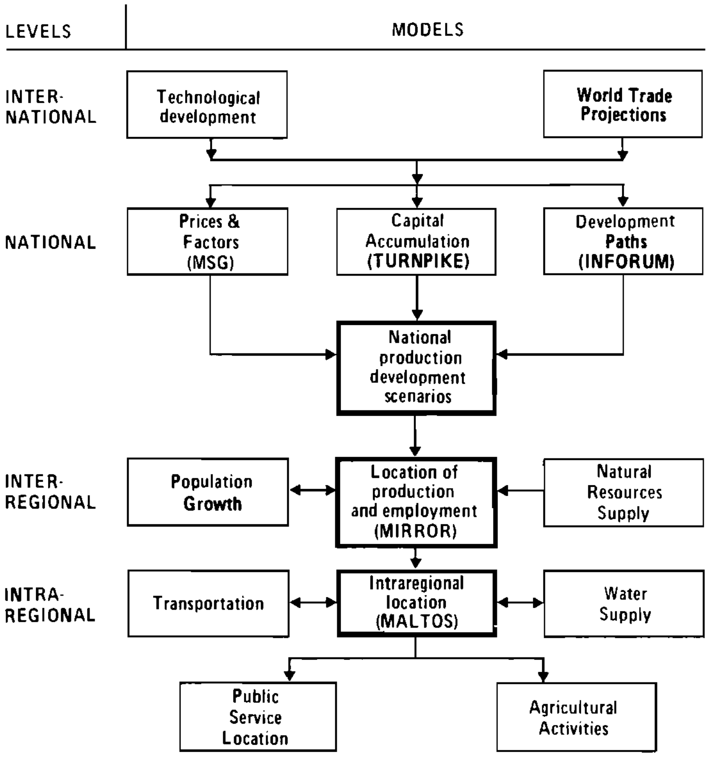


FIGURE 2 The top-down approach to regional development.

Three national-level models are used to generate sectoral growth scenarios: a multisectoral growth (MSG) model, a growth-maximizing investment model (TURNPIKE), and a dynamic input–output model (INFORUM).

These three models have complementary features. The TURNPIKE model searches for the growth-maximizing investment policy for an economy that is assumed to grow with an equilibrium between supply and demand during the whole growth process.

The model requires that input–output and investment coefficients be determined exogenously. This is achieved by estimating capital output ratios and by using the energy and labor input coefficients obtained from the MSG model. This procedure can provide investment and consumption patterns for the dynamic input–output model in order to generate a yearly trajectory for each sector. This package of models provides a set of price, production, investment, and employment scenarios for each sector of the national economy. The main work on the input–output and TURNPIKE models is being carried out by the System and Decision Sciences Area.

The next stage of the analysis uses an interregional location model for employment, investment, and production (MIRROR). This model is designed to search for a location of production that can fulfill national sectoral-production and regional-employment goals, given the sectoral and regional resource constraints, while at the same time minimizing regional restructuring of the national economy. It takes as initial information the national sectoral growth scenarios, as well as local information on regional population growth and regional employment. The principle of minimum information gain is employed and a minimum of regional reorganization is therefore required.

The growth scenarios for national sectoral production and investment can be used as constraints on aggregated regional development. The population-growth model provides labor-supply scenarios for each region. Thus, national sectoral-production and regional-employment scenarios are used as constraints in the interregional location model and natural inertia to relocate production is then built into its goal function.

Allocating activities using the MIRROR model creates the basis for the next step: analyzing intraregional problems. For the analysis we have developed an intraregional dynamic location-of-production model (MALTOS). This model allocates indivisible areas of land to the different production sectors over a discrete set of time periods and generates patterns of land use. The results can be used in more detailed analyses of service location, agricultural location, industrial location, transportation behavior, etc.

The Bottom-Up Approach

Figure 3 shows the bottom-up approach. This procedure is based on a detailed description of the sectors in the regional economy, where intraregional problems are carefully examined and the sectors are coordinated with respect to major resources such as capital and labor. It is assumed that plans for regional economic growth can be related (with minimal use of external information) primarily to regional features (i.e., available resources, regional demand, etc.), classified as follows:

- Prices of raw materials and intermediate and final goods (which can be imported or exported)
- External capital investment in the regional economy
- Living conditions in the given region compared with those in the country as a whole (wage levels, number of dwellings per capita, quality of services, etc.)

The model system fitted to this approach operates on four levels: the first level deals with specialization problems, the second level with intraregional location problems, the third level with labor and financial allocation problems, and the fourth level with problems related to human settlements, services, and pollution.

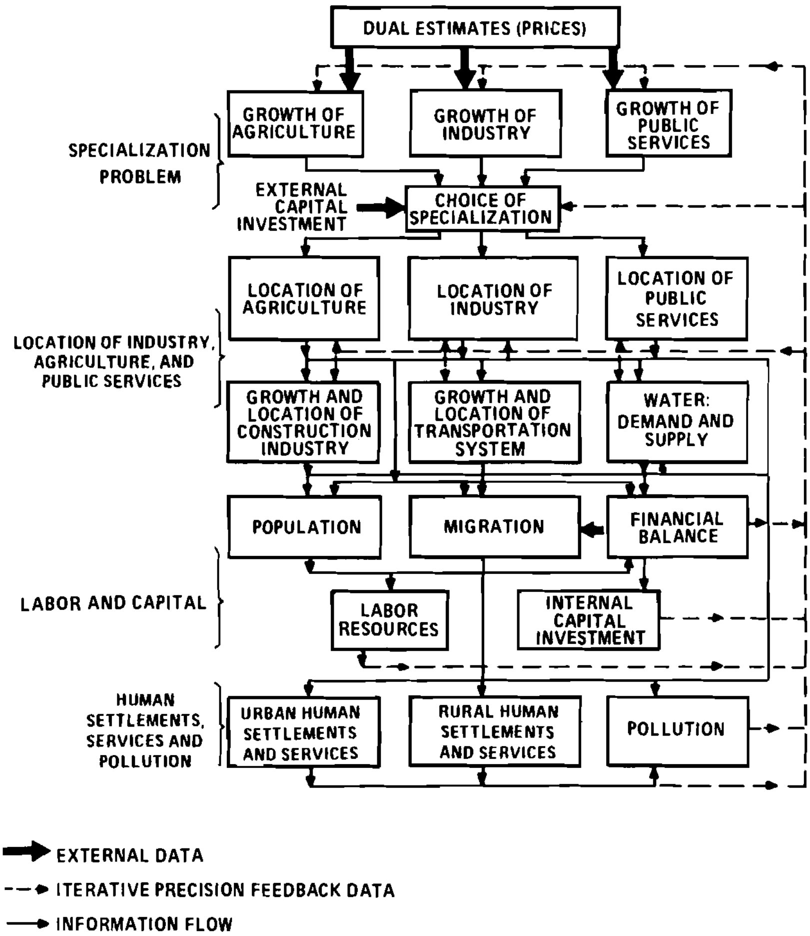


FIGURE 3 The bottom-up approach to regional development.

At the first level, the region is considered to be an aggregate in which an initial choice of specialization under average conditions can be made without accounting for the different subregional characteristics. At the second level the region is divided into subregions (no more than 30–40), with specific and disaggregated data on water and energy supply, quality and price of land, etc. By aggregating this information, better data can be obtained for the region as a whole. If these improved data are used in the second iteration of calculations at the first level, coordination of the first and second levels becomes easier.

The main task at the third and fourth levels is to estimate the future size of the labor force. This calculation reflects the scale of sectoral activities (according to information obtained at the first and second levels) and takes into account

- The local salary and wage levels compared with the national average
- The local situation concerning size of dwellings and provision of services per capita compared with the national average

- The extent of environmental pollution in the region under analysis relative to that of other regions

The regional labor force can often be calculated relatively easily, once the regional population size is known.

Coordination between the first two levels and the second two levels is essentially linking the estimated level of future regional economic growth with the size of the labor force. If one of the regional development objectives is to maintain a given level of employment, the models of the first and second levels will, of course, include this constraint. If there are no constraints on the labor force in the given region, the rates and causes of in- and out-migration should be calculated and influenced. Sectoral efficiency is considered to be the principal factor governing the number of employees required.

The model system used for the bottom-up approach displays two important features:

- A detailed general description of each sector is given.
- A special method is employed to coordinate the sectoral models.

Coordination of the sectoral models involves: defining the main resources (irrespective of the model formulation – linear or nonlinear); calculating the optimal solution, not for one combination of constraints (resources), but for all possible combinations; and comparing the values of objective functions and expressing their differences as a function of the main resources. Usually labor (L) and capital (C) are the principal resources; therefore, the efficiency function $E = f(C,L)$ must be calculated. However, in certain cases it may also be necessary to take into account water, land, and energy resources.

The size of the sectoral problem can be reduced by using the efficiency function, since a particular sector is represented by this function only during the coordination procedure. Figure 4 shows the efficiency function used for the agricultural sector in the Notec case study; it was calculated by means of linear programming. The problem involved approximately 1000 constraints and more than 500 variables.

If the effect of resource use on sectoral growth is known, then

$$\Sigma_i E_i(C_i, L_i) \to \max$$

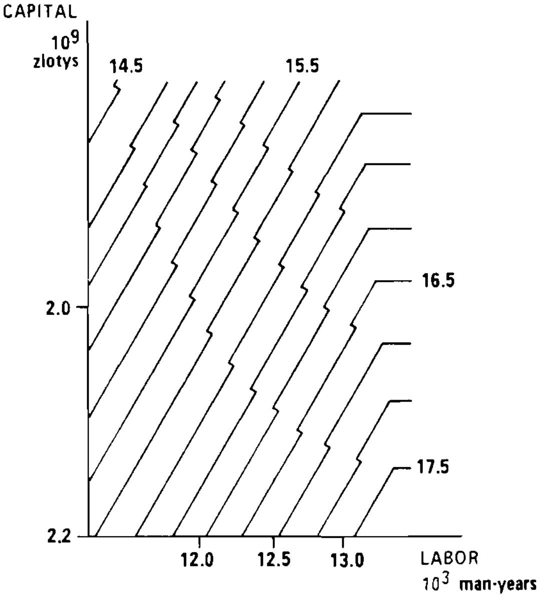
subject to

$$\Sigma_i L_i \leqslant L_E \ , \ \Sigma_i C_i \leqslant C_E$$

$$0 \leqslant L_i^{\min} \leqslant L_i \leqslant L_i^{\max} \ , \ 0 \leqslant C_i^{\min} \leqslant C_i \leqslant C_i^{\max}$$

where index i denotes a sector or group of sectors, E_i is the efficiency function for sector i, C_i is the capital investment in sector i, and L_i is the number of employees in sector i. This formulation is used to determine the optimal sectors for future regional specialization.

Developing the system of models shown in Figures 2 and 3 requires significant effort. Therefore, since the Regional Development Task is relatively small in terms of personnel, other Areas within the Institute have collaborated in the methodological activities. Members of the System and Decision Sciences Area (see, for example, Bergman and Pór 1980; Andersson and Kallio 1979) and of the Human Settlements and Services



$$E = \begin{cases} -2.519 + 4550 \cdot C + 0.771 \cdot L, & L \leqslant 13.39 \\ 7.970 + 4550 \cdot C, & L > 13.39 \end{cases}$$

FIGURE 4 The efficiency function for agriculture in the Notec region.

Area (see, for example, Willekens and Rogers 1978; Andersson and Holmberg 1980; Leonardi 1980) have cooperated in work on the top-down approach, and members of the System and Decision Sciences Area, the Human Settlements and Services Area, the Resources and Environment Area, and the Energy Systems Program are participating in work on the bottom-up approach.

GENERALIZING SECTORAL MODELS

The work of the Regional Development Task is directed toward developing a system of models that not only is designed to fit a specific case, but that can also be adapted easily to the conditions of other regions. In addition, considerable effort has been devoted to developing computer programs for the model system.

The Generalized Regional Agriculture Model (GRAM) is an example of this type of model (Albegov 1979). It is a large-scale linear programming model that includes a detailed description of the agricultural sector of a given region. Because of the model's generality, it has proved useful in regions with differing natural and institutional conditions, for example, in the Notec and Silistra regions. GRAM accounts for

- Soil quality and its potential for improvement
- Water-supply conditions
- Size of farm and type of farm ownership
- Different farming activities (crop growing, livestock raising, etc.)
- Number of harvests
- Technological choices
- Different markets

GRAM is intended to be used in formulating regional agricultural specialization policy, and, although it is restricted to solving agricultural problems, it is capable of including significant feedbacks and results from the other models of the system, such as those dealing with water, industry, and labor.

The main features of regional agricultural development described in the model are

- Specialization of regional agriculture
- Crop and livestock production in disaggregated form
- Land-use conditions (irrigation, drainage, use of pastures, etc.)
- Alternative animal-feed compositions (protein, rough and green forage, etc.)
- Crop-rotation conditions and the possibilities for second-crop cultivation
- Regional resource availability (labor, capital investment, fertilizers, water, etc.)

Applying the model to the Notec region was facilitated by the special matrix generator developed at IIASA by William Orchard-Hays (GRAM Generator Reference Manual, IIASA internal paper, October 1979). The results have indicated the problem areas for Notec regional agriculture. A significant imbalance in resource allocation exists; it appears that the constraints on production are caused in part by an inadequate allocation of resources. The improvement of infrastructural facilities should therefore be more carefully considered.

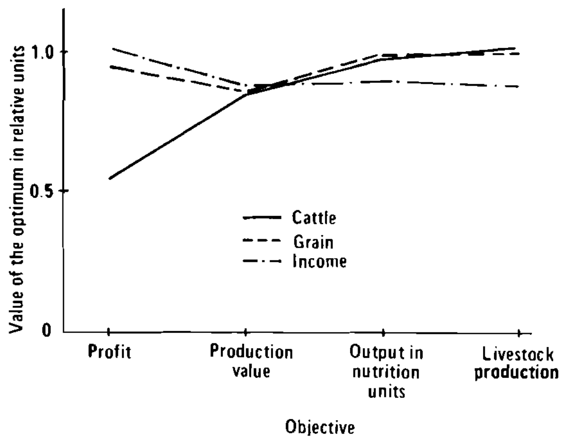


FIGURE 5 The results of applying the Generalized Regional Agriculture Model (GRAM) in the Notec region.

Figure 5 shows the results of optimizing Notec agricultural development using different criteria. The solution to the main problem, i.e., the extent to which local agricultural land should be irrigated, depends on the objective function used. If the objective is maximization of profit, the production volume and the irrigation area will be relatively small. However, if the goal is to maximize agricultural production in monetary terms, nutrition units, or units of livestock product, the irrigation area will form 50 percent of the total agricultural area, and livestock production will increase accordingly.

GRAM has also been applied to the Silistra region and some important qualitative results have been obtained. They indicate that the existing pricing system stimulates crop-growing activities rather than livestock production. They also show that poultry raising is the most effective form of livestock production in the region and that subregional irrigation is not always economically justified. In two cases, the irrigation area should be smaller than the value proposed originally.

Implementing the solutions obtained from GRAM should increase profits by up to 15–20 percent. This increase is higher than could be expected from models in which the region is considered to be spatially differentiated.

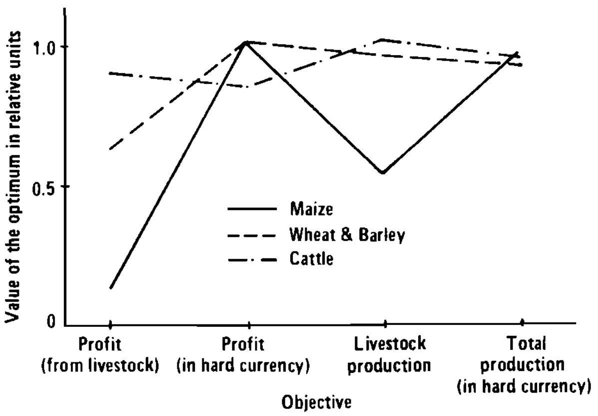


FIGURE 6 The results of applying the Generalized Regional Agriculture Model (GRAM) in the Silistra region.

As Figure 6 shows, the significance of quantitative results depends on the type of objective function used. The objective of profit maximization from livestock production leads to relatively low production of maize, wheat, barley, soybeans, and sunflowers. However, if the objective function is based on the international market price system, an intensification of crop growing can be expected. We are now applying different techniques for multiobjective analysis in both the Notec and Silistra case studies.

The same approach was used in modeling another sector of the regional economy – the water-supply system. In this case a model has been designed, not only to include a general description of the water-supply system, but also to be operated by engineers or decision makers who have no training in using computers. The high level of automation in the modeling process and the possibility for interactive computing make the Regional Water-Supply Model very simple to use.

Being constrained by lack of funds and personnel, IIASA cannot do by itself all of the extensive work required by integrated regional development analysis. Therefore, in addition to the in-house modeling activity, we are using models developed elsewhere that meet our needs.

One example of such a model is the Regional Industrial Location Model developed at the Central Institute of Economics and Mathematics, Moscow. This model is general enough for our purposes and includes a description of

- Several products
- Industrial production capacity and technological choices

- Transportable and nontransportable products
- Different types of demand (local, external, fixed, etc.)
- Substitutable elements (in production and consumption)
- Several types of transportation network (rail, road, etc.)

Another important feature of this model is its detailed system of service programs, which greatly increases its accessibility to planners and decision makers. (The development of these programs required 40–50 man-years, a manpower input that could not be matched by an institute of IIASA's size.)

In the future, we plan to experiment with the Laxenburg–Moscow computer line in order to gain access to CEMI's model and the programs of the State Planning Committee Computer Center.

POLICY-ORIENTED RESEARCH

A system of regional models has no practical value unless it can solve the decision maker's problems and evaluate the consequences of different policy options. Therefore, a variety of institutional and decision-making features must be considered at the model-development stage.

Decision makers generally pursue policies of integrated development. For example, in the Notec region the development objectives are

- To maximize the growth of regional agricultural production
- To eliminate the inequity between the northwestern and southeastern parts of the region
- To accelerate the growth in living standards in rural areas, making them comparable to those in urban areas
- To modernize the urban and predominantly rural infrastructure to facilitate economic growth

Usually, if capital investments are limited, it is impossible to fulfill all such requirements and some compromise must be found. A policy-evaluation model is therefore needed to aid the decision maker in choosing the optimal allocation of investments. Roman Kulikowski has developed a set of models for solving such a problem in a planned economy (Kulikowski 1978). Shown in Figure 7, the set includes an interactive regional development model, a model of water-system development and water allocation, an agricultural model, and a policy-evaluation model.

This interactive system should enable the decision maker to evaluate the alternative policies and strategies for

- Population growth and migration (e.g., production age limits)
- Agriculture (e.g., size of private farms, rents paid by old farmers)
- Living standards (e.g., employment, wages)
- Urbanization (e.g., housing, infrastructural facilities)
- Industrial and technological change (e.g., size and location of new plants)
- Pricing (e.g., domestic and foreign market prices)
- Environmental issues (e.g., pollution standards, taxes on polluters)

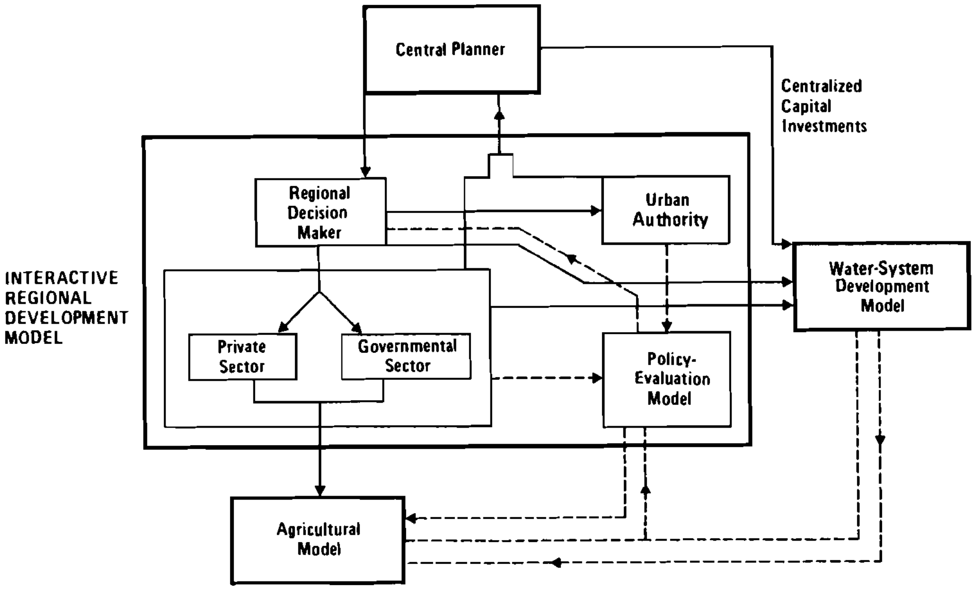


FIGURE 7 A system of models for the Notec region.

In the first, and simplest, version of the model system, the regional economy was aggregated into two sectors – rural and urban – with three levels of management. At the highest level is the "central planner," who is responsible for allocating subsidies (investments) to regional decision makers and for special projects of national importance, such as water-system development. The regional decision makers are responsible for allocating subsidies between local economic sectors and for dividing the regional budget. The sectoral decision makers are responsible for allocating subsidies within rural and urban sectors.

The policy-evaluation model plays the central role in the scheme. It consists of the regional development (core) model and several detailed submodels describing structural changes in agriculture, population growth and migration, the environment, and the urban economy. The core model includes the production and consumption subsystems of rural and urban subregions.

A production function (depending on capital, labor, land, and water) and a utility function (depending on access to employment, services, and environmental goods) were used to describe production and consumption in the region under analysis. The method was successfully implemented using the PDP 11/70 computer at IIASA (Kulikowski and Krus 1980).

In developing this approach in an actual case, two points must be considered: first, it may be important to have a disaggregated solution; and second, the structure of the regional model system should not be considered as fixed, since different components of the system will be used according to the problem to be solved.

To deal with the more urgent problems of the Silistra and Notec regions and to create a detailed system of models with a flexible structure, we derived a simplified scheme based on the bottom-up approach (Figure 8).

In this scheme, the central level is represented by capital investment, which can be allocated by the central decision maker to the productive and nonproductive sectors of the regional economy. The behavior of the regional decision maker is represented by the "coordination model," in which available investments and labor are allocated among different sectors. With respect to sectoral coordination, only the most important links

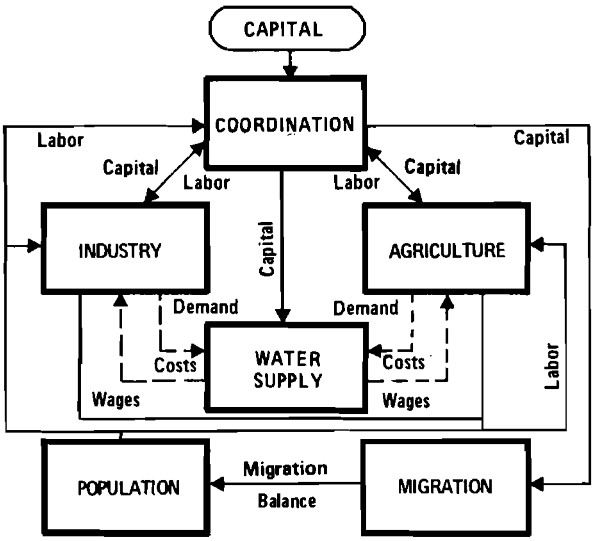


FIGURE 8 A simplified system of models for regional development. Full arrows: information flow; broken arrows: iterative precision feedback data.

among sectors are described in the model system. For example, if agricultural water demand does not influence the development of the water-supply system, these links would be omitted (see Figure 8).

In finding the optimal solution for developing productive sectors, account must be taken of the possible variations in the allocation of external capital investment and the constraints on raising living standards. It may also be necessary to include additional constraints, such as a reduction in migration.

By balancing production activities with the regional labor force, the coordination model plays a central role in the system of regional models. The approach given by the equations in the section on the bottom-up approach is used here to transfer from detailed to aggregated analysis. All the submodels shown in Figure 8 are operational, and they are being coordinated to form a unified system.

FUTURE ACTIVITIES

The Regional Development Task plans to pursue three major activities in the future:

- Work on the models still under development will be completed.
- All models will be tested for their practical feasibility.
- A flexible structure will be created for the system of models, so that the system can be adapted to the conditions of many regions.

The general description of some sectors of the regional economy is still incomplete. In the future some of the models already in operation may be adapted for sectors – such as the urban and rural system of settlements, water and air pollution, and regional income and expenditure balances – or new models will be created.

The ongoing case studies will serve as a means of testing the models. General models must be proved to be reliable and any new models to be included in the system will have to be tested for their suitability in practice.

Finally, for operational purposes, the model system is relatively simple and compact. Thus, during regional analysis only the more important problems are defined. Since each region has a different set of problems, the system of models has a flexible structure, in which the number of subsystems and their links can be altered according to the characteristics of the region under analysis.

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TOWARD INTEGRATED POLICIES FOR WATER-RESOURCES MANAGEMENT

Janusz Kindler
Chairman of the Resources and Environment Area

The research activities of the Resources and Environment Area, which was led by Professor Oleg Vasiliev from 1977 to early 1980, include a variety of topics relating to environmental media and mineral resources, as Figure 1 suggests. It is not possible to report on all our work in the time allocated. Therefore, I shall deal with only one aspect of our studies – water resources – that has been a subject of inquiry here since the Institute was established.

Many of you no doubt remember the IIASA Water Project, led first by Professor Alexander Letov from the USSR, then by Professor Yuri Rozanov from the USSR, and finally by Professor Zdzislaw Kaczmarek from Poland. Its activities were reported four years ago at the first IIASA Conference. In 1976 water-related research found its place in the Resources and Environment Area.

I shall focus here on one type of water resource: lakes. Thus I shall report on some problems related to lakes, on research we have done in relation to lakes, and on the use of our lake-related research. At IIASA we do not view lakes as the limnologist does. Rather, our interest in lakes is of a broader nature: lakes as a source of drinking water,

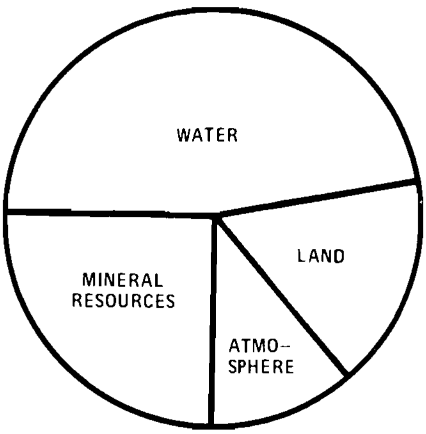


FIGURE 1 The field of interest of the Resources and Environment Area.

lakes as bodies of water providing recreational opportunities for the population, lakes as environments for breeding fish, man-made lakes as basic tools in water management providing storage potential, and finally, lakes as components of complex regional systems where different natural, social, and economic processes interact – systems that should be managed to achieve various objectives, which often conflict with one another.

The scope of our lake-related investigations is of a regional nature. But why regional, when we so often hear about "the global water problem?" Although several studies, made in both the East and West, have come to the conclusion that, on a global scale, mankind does not face any danger of water shortage in the future, this optimistic conclusion is valid only if one assumes that regional water problems are taken care of. The prospect of disabling regional water shortages in the face of abundant global supplies underlines the intensely regional nature of water-resource management. There is no world water economy in existence, and it is rarely even meaningful to speak of a national water economy. The creation of a balance between water demand and water supply occurs within smaller economic or hydrologic provinces – we call them regions – that may, of course, vary tremendously in size, depending on the problem at hand.

But there is no such thing as a hypothetical region. I suspect that integrated policies for water-resource management in a hypothetical region would not be of much interest to real-world regional water-resource decision makers. There must be real regions and real issues, which, in accordance with IIASA terminology, have a universal character: problems that occur in many regions of the world and that have universal aspects in spite of their local peculiarities.

The list of regions taken under study in the past few years by Resources and Environment Area scholars, is quite long (see Table 1). This list, of course, is not confined to water studies; it refers to various kinds of resource and environmental studies – some large in scope and some small in scope. As you can see, all of our study regions are located in IIASA's National Member Organization countries. Indeed, these studies could not be carried out without the support and close collaboration of the National

TABLE 1 The study areas used in the work of the Resources and Environment Area in recent years.

Country	Region
Austria	*Salzkammergut, Neusiedlersee*
Bulgaria	Silistra
Canada	Lake Ontario
Czechoslovakia	Ohre, Kromeriz
Finland	Under discussion
France	Languedoc
Federal Republic of Germany	Rhine
German Democratic Republic	Under discussion
Hungary	*Balaton*
Italy	Venice
Japan	Tokyo Metropolitan District
The Netherlands	Rhine, Berkel
Poland	Vistula
Sweden	*Skåne*
United Kingdom	Cam, Bedford–Ouse
USA	California
USSR	Lithuanian Republic

Member Organizations and various national institutions concerned with both research and management issues. Our sincere gratitude to all of them cannot be overemphasized.

I shall focus here on four of the regions: the Neusiedlersee and the Salzkammergut lake district (Figure 2) in Austria; the Lake Balaton region in Hungary (Figure 3), where water quality is deteriorating; and the Southwestern Skåne region in Sweden (Figure 4), where water-quantity problems are of primary importance. In all of these regions, using water – regardless of the purposes of use – means primarily using lake-water resources. I shall refer now to these regions and their lakes to illustrate how the Resources and Environment Area proceeds from *problem* through *research* to *use*.

THE PROBLEMS

In our lake-related studies we have dealt with the problems of lake-water quality and quantity. A brief summary of these problems follows.

Over the past decade, the quality of the water in the lakes of the Salzkammergut system has deteriorated continuously. Discharge of domestic sewage, which is heaviest in summer due to the number of tourists, and the greater development of lake shores and watersheds increasingly affect lake-water quality. Thus, the lakes are becoming less attractive for recreational purposes. Moreover, the possibilities of using the lakes as a source of drinking water are becoming limited. The principal cause of deteriorating water quality is eutrophication, a process of modifying the physicochemical and biological properties of water in lakes and slow-moving waterways. It is caused by nutrients from sewage effluents, fertilizer-laden runoff, and other sources. These nutrients, when they accumulate, increase the productivity and subsequent decay of aquatic organisms, especially of phytoplankton, reduce the dissolved oxygen content of the water, and consequently reduce the possibilities of water use.

Taking the shallow Neusiedlersee, which is located in Austria and Hungary, as another example, we note the problem of structural changes in the reed belt, located around the open surface of the water. The reed belt is very important for the life of the Neusiedlersee. It acts as a filter and recipient for nutrients entering the lake. However, the number of weekend houses is increasing rapidly, and channels are being cut through the reeds in many directions. Thus, this natural barrier protecting the lake is increasingly affected.

Lake Balaton experiences a similar problem. During the past 30 years an enormous change has been taking place in the development of the Lake Balaton watershed (see Figure 5). The structure of industry and agriculture, and accordingly the ratio of population working in different sectors, has changed. The use of fertilizers has increased tenfold between 1960 and 1975. Large farms have been set up in the watershed. The number of tourists has grown (30 percent of the total income from tourism in Hungary comes from Lake Balaton), and the length of motoring roads has increased considerably. The level of eutrophication has increased with the intensification of human activities in the lake watershed, which ultimately have led to a deterioration of the lake-water quality. I must stress that Figure 5 concerning Lake Balaton illustrates a situation that, to a lesser or greater extent, is encountered in all lake watersheds.

I turn now to the problem related primarily to scarce water supplies, using the Southwestern Skåne region in Sweden as an illustration. The regional water-supply system is based here on two lakes: the Vomb Lake in the south and the Ring Lake

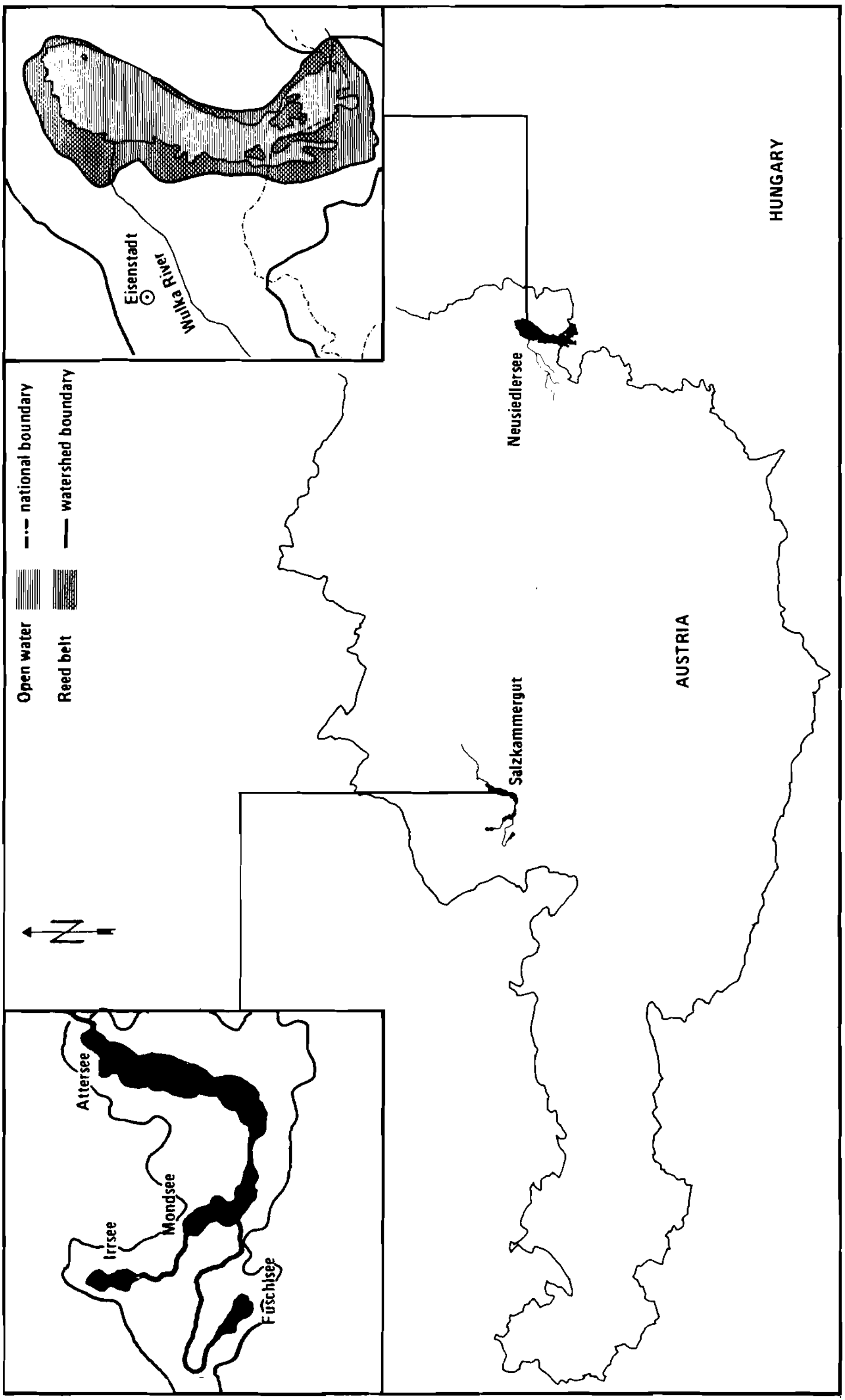


FIGURE 2 The Salzkammergut lake district (Austria) and the Neusiedlersee and its watershed (Austria and Hungary).

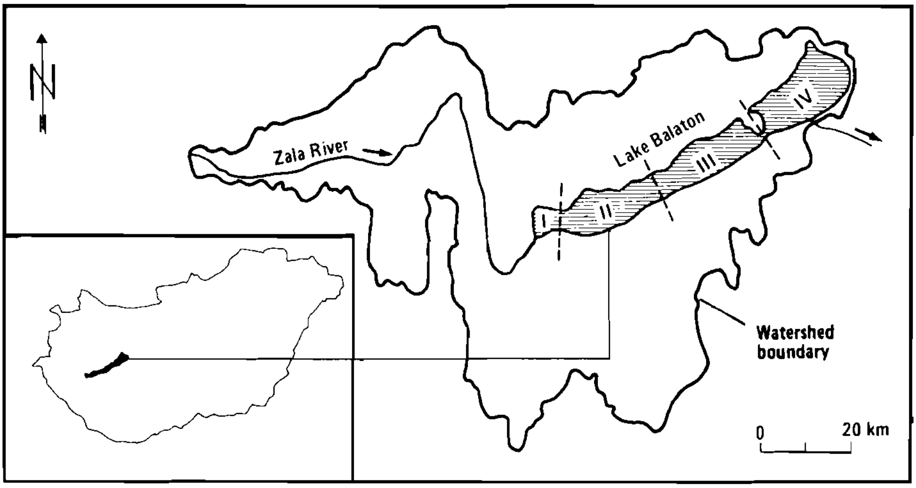


FIGURE 3 Lake Balaton (showing basins I to IV) and its watershed in Hungary.

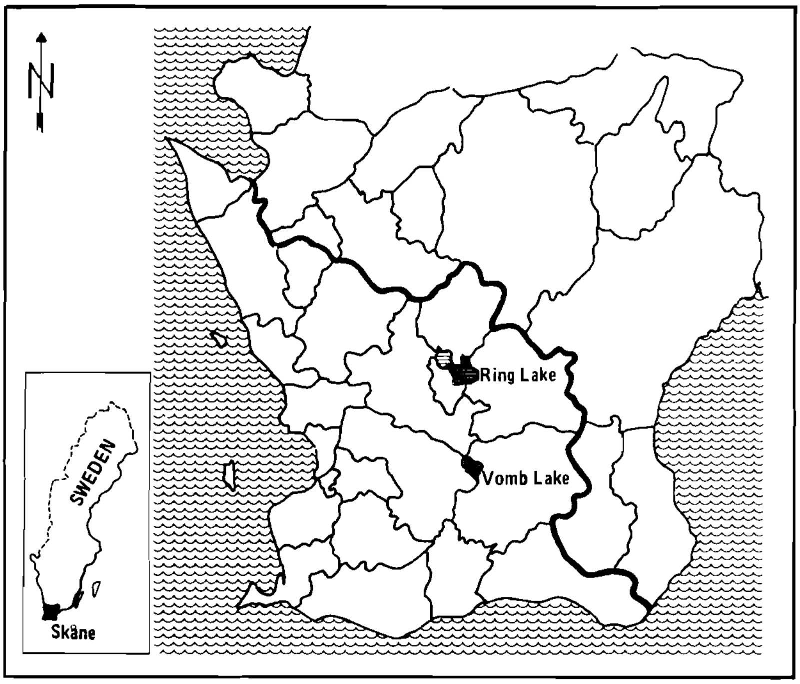


FIGURE 4 The Southwestern Skåne region in Sweden.

in the north, which, together with groundwater resources, are used as sources of drinking water and industrial water for a population of about 750,000. Unlike the Hungarian and Austrian lakes, the water in these lakes is still of acceptable quality. However, occasionally there just is not enough water. This region is one of the few in Sweden where water resources are scarce.

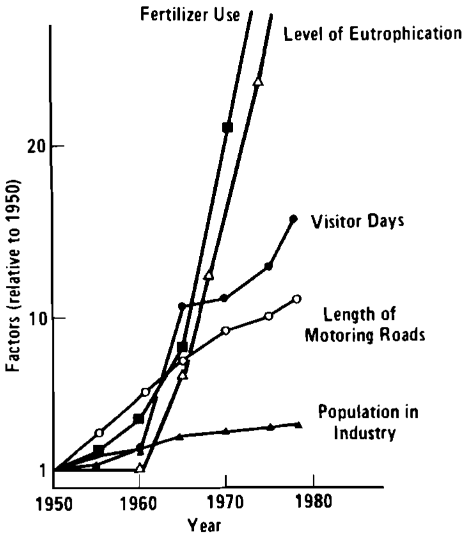


FIGURE 5 Changes since 1950 of the anthropogenic factors affecting the eutrophication of Lake Balaton in Hungary.

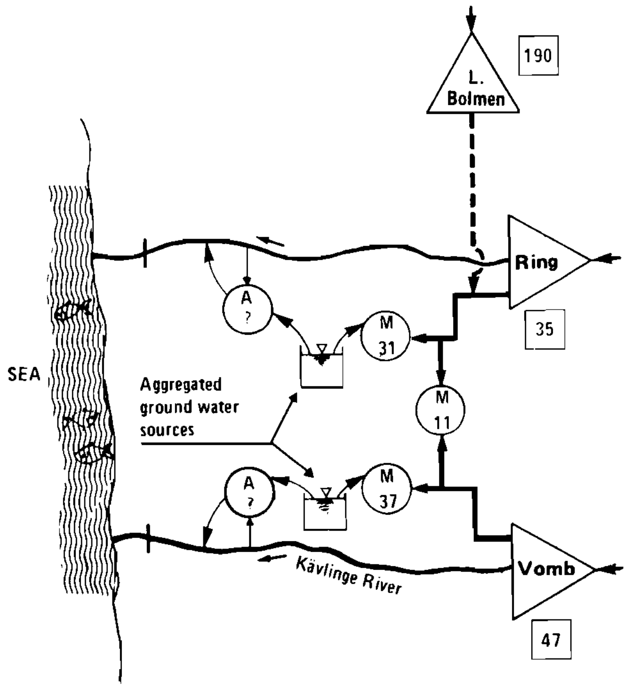
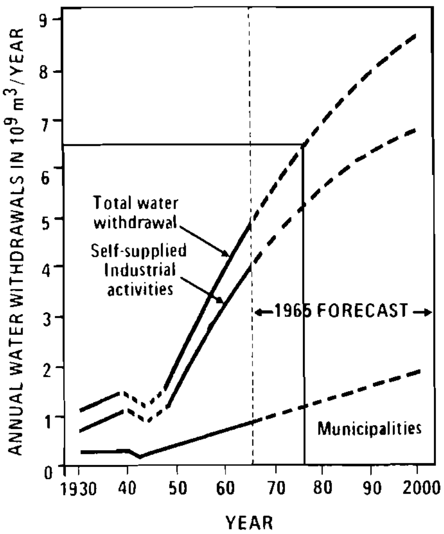


FIGURE 6 A schematic representation of the municipal and industrial water-supply system based on the Vomb and Ring Lakes and on the groundwater sources in the Southwestern Skåne region of Sweden. The broken line shows the proposed link with Lake Bolmen. The two main categories of water use are denoted M, municipal; A, agricultural. Numbers in circles show the volumes of water (in million m^3) used in 1976; numbers in squares show the usable capacities (in million m^3/year) of each lake.



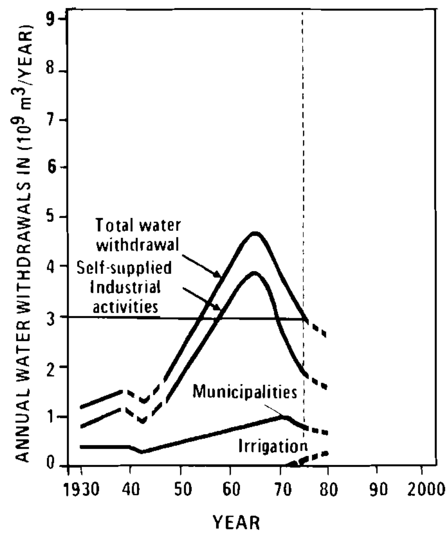


FIGURE 7 The 1965 forecast of water use in the Skåne region of Sweden. Source: Falkenmark (1977).

FIGURE 8 The water-use situation in the Skåne region as seen in the mid-1970s.

The Southwestern Skåne region (Malmö County) consists of 20 municipalities,* each of which enjoys considerable autonomy. However, all the municipalities come together, negotiate, and agree on any decision regarding the whole region. Figure 6 is a schematic representation of the municipal and industrial water-supply system based on Vomb and Ring Lakes, as well as on the local groundwater resources. Since there is no regional water authority in the Skåne region, management of the scarce supply of water is difficult.

In 1965, a forecast of water use was prepared by extrapolating past trends (see Figure 7). A comparison of the forecasted water-use levels with the locally available resources indicated that in the future there would be a serious water shortage. Therefore, a decision was made to develop a new source of water, Lake Bolmen, located about 150 kilometers north of the Skåne region. In the late 1960s, 12 municipalities formed the Sydvatten AB company that, in the early 1970s, began building the Bolmen–Skåne water-transfer facilities. However, by the mid-1970s, the earlier forecasts had proven to be incorrect (see Figure 8). The effects of legislation made during the late 1960s that dealt with the environment had not been anticipated. These laws led Swedish industrial-water users to install new water-recycling equipment with the aim of cutting the costs of complying with water-quality requirements; the incidental effect was to reduce water withdrawals substantially. It should be noted that this reduction in water withdrawals took place in spite of a substantial increase in industrial production over the same period.

This experience underlines the importance of understanding the various factors that determine the use of water in different activities. In this case, particularly the introduction of new government policies relating to water-quality management and the impact of changes in technology were the deciding factors.

Water quantity is also affected by the introduction of new water uses. As a result of some consecutive dry summers in the early 1970s, a new water use emerged in the

*We define municipality here as a subregion.

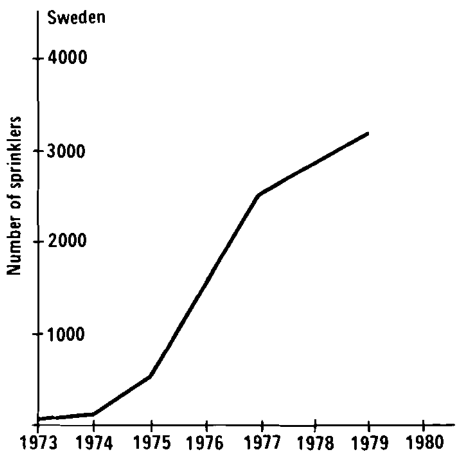


FIGURE 9 The number of agricultural sprinkling machines in Sweden for the years 1973–1979.

Skåne region. Although still on a limited scale, local farmers withdrew considerable amounts of water for irrigation. Figure 9 shows the growth of the number of sprinkling machines in Sweden. This led to occasional conflicts over water-resource use. These conflicts were especially difficult to solve because there is no regional water authority but rather 20 independently functioning municipalities.

I have used the Skåne region as an illustration of problems related to scarce water supplies but other regions provide us with equally good examples of problems calling for analyses of water management and policy issues.

THE RESEARCH

Figure 10 illustrates in some detail the general structure of our lake-related research when we deal predominantly with the quality issues.

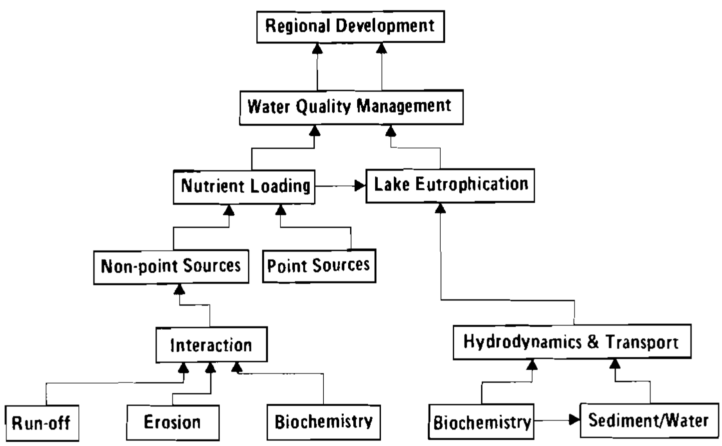
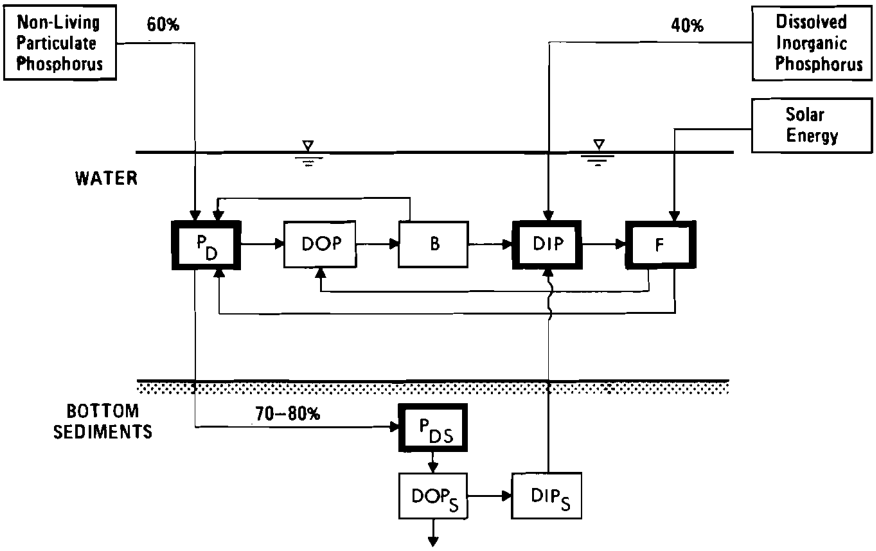


FIGURE 10 The general structure of the lake-related research on water quality.



PHOSPHORUS TRANSFORMATION

FIGURE 11 A simplified scheme of a phosphorus-transformation submodel that forms part of one of the lake-eutrophication models developed at IIASA. F stands for phytoplankton (or algae), DOP for dissolved organic phosphorus, B for bacteria, DIP for dissolved inorganic phosphorus, P_D for nonliving particulate phosphorus, and subscript S for sediments.

Figure 11 presents a simplified phosphorus-transformation submodel ("Biochemistry" block in Figure 10) that forms part of one of the lake-eutrophication models developed at IIASA. For Lake Balaton, the Neusiedlersee, and the Salzkammergut lakes, phosphorus is the main eutrophication-control factor. The nonliving particulate phosphorus and the dissolved inorganic mineral phosphorus enter the lake. Phytoplankton and algae, depicted by F, transform, with the help of solar energy, inorganic phosphorus into dissolved organic phosphorus (DOP) and (P_D). The middle box B represents the bacteria that make an important link in the phosphorus-transformation process. There are several feedback loops to be noticed.

Of particular interest is the fact that about 70–80 percent of all phosphorus entering the lake settles into the bottom sediments. Thus, there is a continuous accumulation of phosphorus in the lake bottom sediments. This environmental problem is not confined to lakes – it is typical: the pollutants are already there! Thus, its solution calls for more than just control of the current pollution-emission sources.

As Figure 5 indicated, the use of fertilizers (phosphorus is one of their major components) in the Lake Balaton watershed has increased tenfold between 1960 and 1975. Certainly, intensification of fertilizer use is one of the major causes of lake eutrophication. Presently, we do not know what policies will be followed in the future concerning fertilizer use; they remain to be studied and decided. But what we can do, and, as a matter of fact, what we have done, is to generate some hypothetical scenarios of future fertilizer use and to analyze the lake responses to them with the aid of the lake eutrophication model. Figure 12 shows six "loading" scenarios. The most dangerous one follows the assumption that the total amount of fertilizers (expressed in equivalent P_2O_5) will grow by 100 percent per year. This assumption roughly follows the trend observed in the past 10–15 years. The other loading scenarios shown in Figure 12 are self-explanatory.

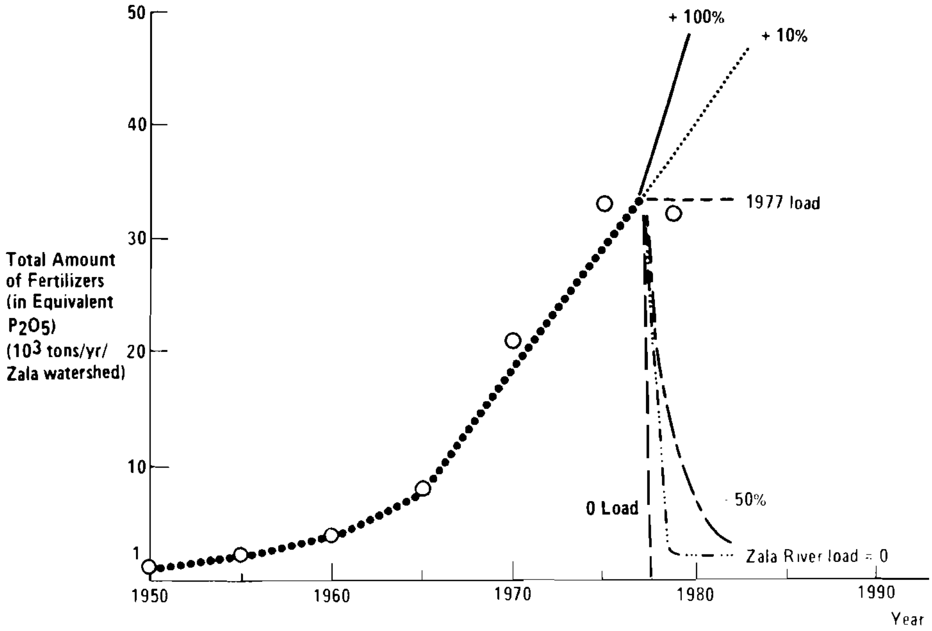


FIGURE 12 Scenarios for future fertilizer use in equivalent P_2O_5, based on the Lake Balaton history.

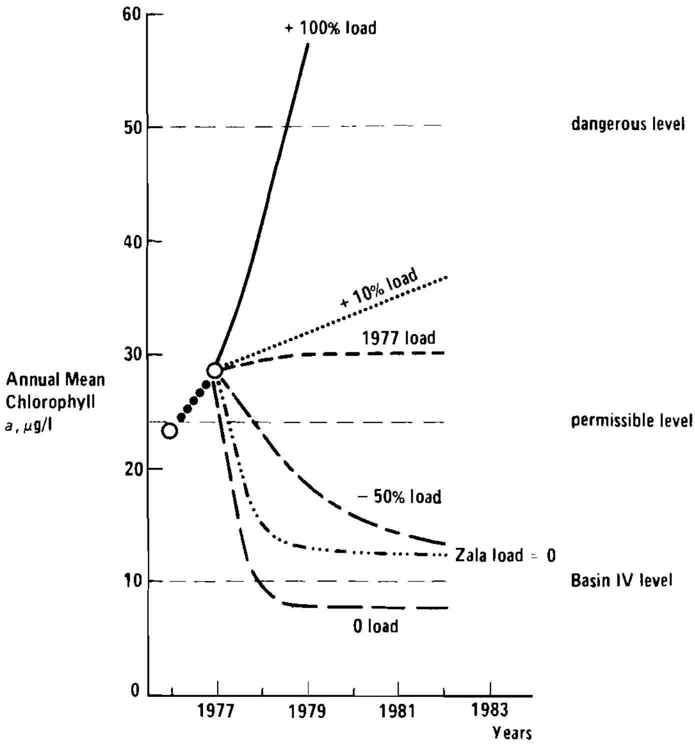


FIGURE 13 The lake responses to the future fertilizer-use scenarios.

Figure 13 shows the lake responses to these six loading scenarios, expressed in terms of the mean annual content of chlorophyll *a*, which is one of the indicators used for characterizing the level of lake eutrophication. The lake response was simulated with the aid of the lake eutrophication model, part of which is shown in Figure 11. The results of this preliminary analysis indicate that, if the fertilizer use in the watershed is allowed to grow in accordance with the past trend, the mean annual content of chlorophyll *a* in the lake water will exceed the dangerous level in the relatively short period of three to five years. Even maintaining the 1977 load stabilizes but does not improve the situation. The results indicate that thorough investigation of the future policies concerning fertilizer use in the watershed (along with policy analysis concerning other causes of eutrophication) is required.

However, to assess every possible policy alternative (and there may be a large number of them) by using a complex lake-eutrophication model would be computationally difficult and time-consuming. This is why, based on several simulation runs of the lake-eutrophication model with different loading scenarios, we have developed relatively simple relations between different eutrophication-generating factors and the lake responses. To illustrate, Figure 14 shows such a relation between the annual dissolved inorganic phosphorus load (cause) and the mean annual chlorophyll *a* content in Lake Balaton (effect). Figure 15 presents the same type of relation for the Attersee (located in the Salzkammergut). This one, however, takes explicitly into account the uncertainty embedded in the observational data, in the model structure, and in the forecast of the future external conditions. The figure shows the response of the Attersee water quality to different levels of phosphorus loading. Lake response is shown as probability distri-

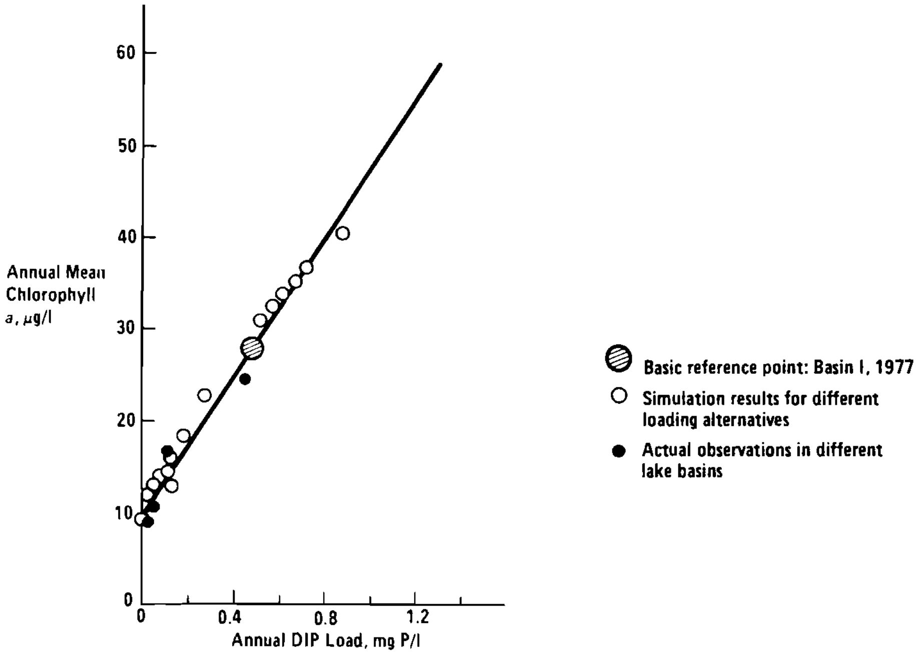


FIGURE 14 The relationship between the dissolved inorganic phosphorus (DIP) load and the mean annual chlorophyll *a* content for Lake Balaton.

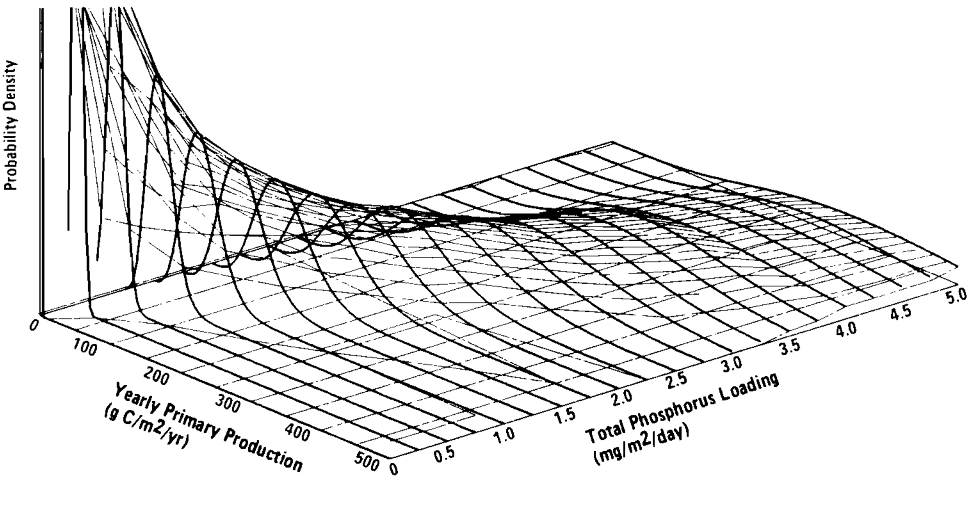


FIGURE 15 The response of the Attersee's water quality to different levels of phosphorus loading.

butions of the water-quality variable "yearly primary production" (i.e., production of algae) along an axis of phosphorus loading. Such relations are used next for the management and policy analysis. The models employed for the latter are often fairly complex and there is a clear advantage of feeding them (in the sense of model input) with the simple relations wherever possible.

Work of the type I have described has brought us to research concerned with resource management and control policies. In this respect, our work on the Hungarian and Austrian lakes is still in its early stages; therefore, for the purpose of illustration, I shall discuss the Southwestern Skåne region, where our research focuses on institutional problems, uncertainty, and conflicts in water-resource management. On the one hand, these topics are of great practical importance for the Skåne region (and for other regions as well) and, on the other hand, they present several methodological challenges.

A typical form of conflict derived from implementing a water-resource project is the problem of allocating costs among participants, as in the Southwestern Skåne region, where a group of municipalities is developing a joint water-supply system. Figure 16 shows how the total cost of the regional water-supply system in the Southwestern Skåne region could be allocated to six groups of municipalities (indicated by letters A, H, K, L, M and T) that will benefit from this project. The total cost is allocated using three alternative methods: (1) allocation proportional to population (the method used in Sweden); (2) allocation by the separable cost/remaining benefits method (SCRB); and (3) allocation by the weak-least-core method (WLC), developed at the System and Decision Sciences Area and based on game-theoretic concepts. The allocation proportional to population method yields results quite different from those of the other two methods; this method, in fact, penalizes some municipalities (the share of costs allocated to the municipality is higher than the cost incurred by the municipality going alone), and in effect, some municipalities subsidize the others. On the other hand, there appear to be only minor differences in the results obtained by the SCRB and WLC methods. Are these relatively small differences important in practice? The answer is undoubtedly

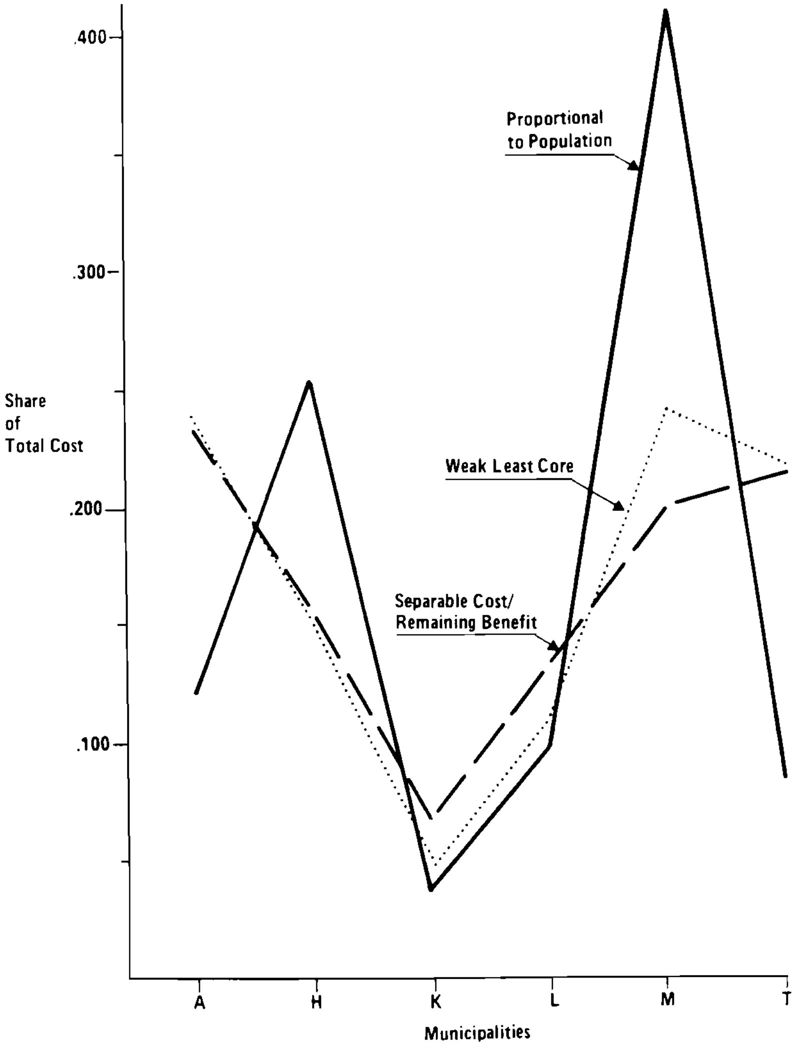


FIGURE 16 The allocations of cost for a water-supply system to six groups of municipalities in the Southwestern Skåne region of Sweden developed by three methods.

"yes"! Actually, the WLC method is the only method investigated in our comparative study on cost-allocation methods that satisfies all the criteria we chose. In choosing our criteria, we considered the economics, equity, common sense, and incentives for individual municipalities to participate in the joint regional effort.

It is worth mentioning that the cost-allocation study also served as the basis for a gaming experiment involving the decision makers in Sweden, who showed considerable interest in the principles and procedures we have advocated.

However, allocation problems arise, not only with respect to the cost of a joint project, but also with respect to periodically scarce water resource.

The past decade has witnessed the development of a large number of computer-aided procedures designed to assist water-resource planners and managers in analyzing and evaluating multiobjective resource-allocation problems. What is common to almost all multiobjective analysis procedures is that they provide a mechanism for estimating the trade-offs among conflicting objectives. However, it must be emphasized that estimating these trade-offs is not synonymous with making the choices among these conflicting objectives, especially when they are noncommensurable. Thus, it is necessary that those responsible for pursuing each objective be involved in the process of selecting the satisfactory nondominated solution. This process is usually complex, involving negotiations and bargaining among all parties concerned. The interactive procedure we developed in 1979 in collaboration with the System and Decision Sciences Area provides an example of how systems analysts may contribute to this process ultimately leading to a compromise solution acceptable to all concerned. Our procedure was applied to five conflicting factors (irrigation, municipal supply, recreation, maintenance of in-stream quality standards, and minimum acceptable flow) in the Kävlinge River system in the Southwestern Skåne region (see Figure 17). We demonstrated our procedure to Swedish regional planners

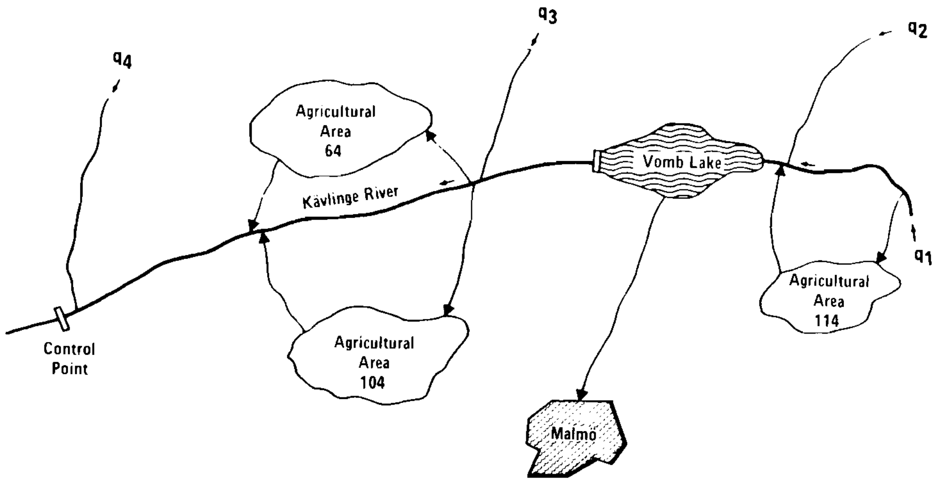


FIGURE 17 The context for applying the IIASA approach to multiobjective allocation of water resources in the face of conflicting objectives. q_i represent flow rates.

at a workshop held in Lund, Sweden, in November 1979. Work to improve the procedure further is under way.

Water-resource development is characterized by uncertainties, on both the demand and supply sides and by long lead times for project development. As Figures 7 and 8 showed, demand uncertainty can involve, not only random variations about some estimated future mean demand, but also abrupt structural shifts in future demand. These shifts, which are typically not considered in forecasts, are often called "surprises." When project lead times are long, the possibility of being surprised between beginning and completing the project can be great. Our study on the effects of surprises on water-resource planning has been motivated particularly by the Southwestern Skåne region case, where water usage suddenly ceased to increase according to the original forecast after work had been initiated on a large project to increase supply. The mathematical model, which has been developed to analyze the effects of a surprise, initially assumes that future water demand will continue to grow as originally projected. The model randomly generates the occurrence of a surprise within the projection period. When a surprise occurs, demand growth effectively ceases, as in the Southwestern Skåne region. If a large water supply project is to be undertaken and if the project is started too soon, the probability is substantial that some or all of the supply available from the project may not be needed. However, delaying the commitment to start the project increases the probability of a water shortage if a "surprise" does not occur. A tentative conclusion drawn from applying the model is that even a small probability of a surprise occurring each year would make a significant delay in the project commitment time desirable. We are expanding our model to make it more flexible. By flexibility we mean that the project lead time can be reduced for some additional cost and that the project can be abandoned if a surprise occurs.

To complete my discussion of our research on water-resource management, I shall speak briefly of another study inspired by the situation in the Southwestern Skåne region: An Analysis of Multipurpose Demand/Supply Integration: From Subregional Solutions toward Regional Water-Resource Systems. The southern part of the system is based mostly on water supplies from the Vomb Lake and Alnarp aquifer. The northern part of the system is based on water supplies from the Ring Lake and several local groundwater sources. In the future, when the Lake Bolmen scheme is operational, it will be able to supply practically unlimited amounts of water to the western part of the Southwestern Skåne region. The major question now is: What are the advantages and disadvantages of integrating all subregional solutions into a regional water-resource system (in terms of economic efficiency, increased reliability, etc.)? Although Figure 6 emphasizes municipal water use, the study will also be concerned with water use for supplementary irrigation. Most of the work is still to be done; however, in 1979 special investigations were initiated whose results (jointly with the results of several studies mentioned previously) will be used for analyzing the above question.

THE USE OF RESEARCH RESULTS

The users of our research results include scientific institutions concerned with analyzing policy alternatives in the field of resource and environmental management as well as institutions concerned with overall regional economic and social development policies. Table 2 gives a list of such institutions in Austria, Hungary, and Sweden – the

TABLE 2 Institutions in Hungary, Austria, and Sweden that are users of IIASA's lake-related studies.

Country	Institute
Hungary	The Academy of Sciences The National Water Authority The Ministry of Construction and Urban Planning
Austria	University Institutes Federal Institutes The Ministry of Agriculture and Forestry Provincial Administrations Local Administrations
Sweden	University Institutes Municipalities Municipality Federations The National Environment Protection Board

countries in which most of our lake-related studies are conducted. They are our collaborators and the immediate users of our research results.

However, let me now comment on the more general usefulness of the results derived from our case studies, which illuminate the complexities of the real problems as they may be encountered in practically all IIASA National Member Organization countries.

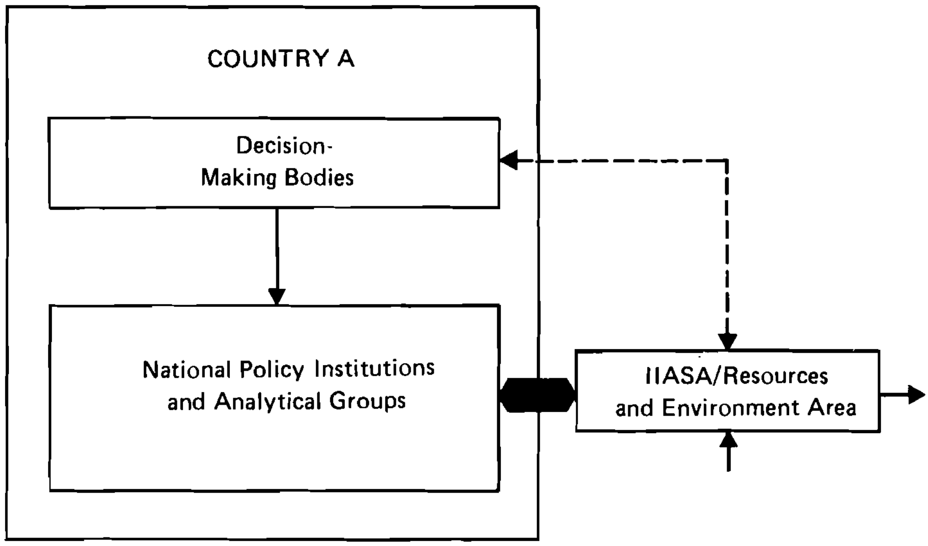


FIGURE 18 A schema related to the use of IIASA research.

As in Figure 18, we may have a "concrete" case study in country A. In this country, there are several decision-making bodies involved in solving a given problem. My almost four-year-long experience at IIASA tells me that it is rare for direct working relationships to be established between these decision-making bodies and our research teams at IIASA. Our contacts with the national analytical groups that prepare material for these difficult-to-reach decision-making bodies are much more effective. There are many such contacts established in the three countries in which the regions we have studied are located. As Dr. Levien often states, our most effective role is that of "second-order consultants." If we take as an example the Lake Balaton case study, there is no doubt that the results of our work will make a substantial contribution to solving Lake Balaton's eutrophication problem. But how is our research related to our National Member Organization countries for which we have no case study area and to the world in general?

Figure 18 shows this by two arrows, one entering and the other leaving the IIASA/Resources and Environment Area box. It is a simple schema, but it illustrates precisely the realities in which our case studies are carried out. First, each case study involves, not only the Resources and Environment Area team and some collaborating institutions from country A, but also, as a rule, many institutions and individuals from other IIASA National Member Organization countries. For example, the Massachusetts Institute of Technology has participated in the Lake Balaton case study, and Resources for the Future has assisted us in our work on the Southwestern Skåne region. The arrow entering the IIASA/Resources and Environment Area box stands for such involvement. Secondly, there is an outflow of information on our approaches and our methods; this is effected through the collaborators who join our research efforts, through participation in various international meetings, symposia, etc., organized both at IIASA and elsewhere, and through our many publications.

CONCLUSION

I have argued that integrated policies for water-resource management call for joint analyses of water quality and quantity; that structural, as well as nonstructural, policy alternatives must be taken into consideration; and that water-resource management issues should be looked on in the context of the overall economic and social policies of a region. The discussion of our lake-related research has exhibited our general approach to resource and environmental problems, from problem identification through efforts to understand the problem to formulating and assessing alternative policies leading to solving the problem.

If such terms as management and policy are to be taken seriously, we have to work as closely as possible with those who are directly involved in generation of management and policy decision alternatives. Usually it is difficult to reach them. Sometimes we do not know exactly who and where they are. Although we have had some successes in reaching and working with them, there is much to be achieved. Much more has to be done; we shall continue our efforts.

REFERENCE

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SYSTEMS APPROACHES TO INDUSTRIAL PROBLEMS

Rolfe Tomlinson
Chairman of the Management and Technology Area

This paper is concerned with the relation between IIASA and industry, and illustrates this theme with examples of the work we are currently undertaking in the Management and Technology Area. This discussion will provide some understanding of the work and approach of the Area, as well as show both the potential advantages and difficulties in developing closer coordination between IIASA and industry.

Before saying anything further I would, however, like to introduce a quotation from part of the discussion at a recent workshop held at IIASA on the problems of scale. This workshop attracted a number of industry representatives, one of whom was Mr. J.D.van Dalen from the Basic Chemicals Manufacturing Division of Shell International. In the course of the discussion Mr. van Dalen said:

> . . . for whom is IIASA's research intended – is it intended for industry or is it intended for other bodies who have some control or some bearing on the way our society develops, for example, trade unions or governmental institutions, who have to deal with economic parameters and who want to have at their disposal some general ideas and formulate how to respond to economic changes within private industry? I get the feeling that IIASA is mostly directing its efforts to these institutions rather than to industrial companies themselves.

One purpose of this quotation is to show that industry representatives do visit IIASA, that they do contribute to the discussion, and that they are listened to. More importantly, however, Mr. van Dalen has raised a question that is central to our present discussion. Indeed, I think it is necessary to start this discussion with *two* critical questions. They are:

1. Is IIASA genuinely interested in industry *qua* industry, or is it only interested in industry in so far as it is a factor affecting government policies?
2. Why should industry be interested in IIASA?

The best answer to such questions lies in practice, and much of what follows will point to the answer. But let me start by giving some personal answers. I believe that industry is worth studying in its own right. This is hardly surprising, since I came to IIASA from industry and I would not have come if I thought otherwise. But, even if it were agreed that IIASA was primarily concerned with common issues of national policy, it would still be essential for IIASA to pay particular attention to industry. If you are considering economic policy, it is absurd to do this without considering the source of wealth that makes it possible to plan economic development. It is clearly absurd to consider technological policy without considering the part of national life where technological change primarily takes place. And it is equally absurd to consider social policy without paying some attention to what happens in the place where half the population spends half of its waking life. Moreover it must be emphasized that, when I say "IIASA must take industry into account," I do not believe that this can be done by inserting another statistical equation into some overall model. An activity as complex as industry, so sensitive to economic, social, and technological change, cannot be reduced to a single index or equation. Yes, IIASA must be interested in industry, and in depth.

My answer to the second question, relating to industry's interest in IIASA, is based on the fact that in our modern society industry faces entirely new problems arising from the increased complexity and the increased rate of change in our modern world. The complexity is largely induced by developments in communications, the world-wide connectedness of trade, and the supply of resources and energy. The current rate of change of technology and international negotiation is such that most of the traditional managerial learning devices are no longer appropriate. By the time one has acquired enough experience to improve one's practice in a given situation, the external situation has changed. These are fields where systems analysis is particularly applicable, but is still in the infancy of its usefulness. IIASA has a major role to play in providing a focus where ideas can be exchanged and developed on an international basis. Such a focus is seriously needed – indeed one of the noticeable features of our workshops has been the way that they have helped to produce new communities of people concerned with similar problems.

In the following sections, I shall discuss some research projects being undertaken in the Management and Technology Area that are specifically directed toward industry:

1. Problems of scale
2. Innovation
3. The management/computer interface
4. Decision making under high risk
5. Gaming
6. Industry studies: issues for the eighties

Before doing this, however, it is worth making three points with regard to the work of the Area as a whole:

- Only one of the projects described has been in progress for more than 15 months; most of the work started more recently than that. Many working papers are now available and two conference proceedings are in the press. Other formal publications will, however, not appear until 1981, and full interaction with interested parties will then start to appear. The cycle "conception-to-use" is at least five years long! Nevertheless, it must be emphasized that "use" dominates both problem and research – even though use lies in the future.
- Every one of the projects is related to a real problem that I needed to tackle in my research team in the National Coal Board in the United Kingdom, but in some cases was unable to. The need to develop better and more systematic approaches to such problems is, as I have said, a major justification for IIASA.

• The fact that these projects are oriented toward the problems of the manager and decision maker has led us to an emphasis in our methods and analyses different from that of many IIASA tasks. Our prime problem is often simply to understand and structure the situation. We make much less use, particularly in the early stages of the research, of large formal models; more emphasis is placed on conceptual understanding and less on mathematical manipulation. This is a difference in emphasis rather than a conflict of ideals; we work in close collaboration, for example, with the System and Decision Sciences Area and many of our staff could be interchanged. Nevertheless, there is a difference and it should be noted.

SOME PRACTICAL STUDIES

Problems of Scale

The problems of scale in our modern society are many. So far as industry is concerned, they are often contained in such questions as "How big should we build the next plant?"; "How does one scale up the present operation to obtain increased output?"; and "How can one cope with the complexity created by the amalgamation of several

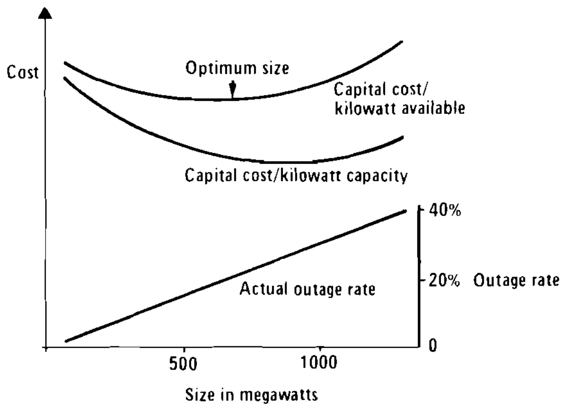

FIGURE 1 Factors determining the sizes of electricity-generating units.

previously separate organizations?". Many mistakes have been made in the past (particularly in building too large); no standard reference books exist that tackle these questions comprehensively, and little serious research appears to be going on or directed toward developing a general methodology.

As we studied the problem, we developed a feeling that, at a certain stage in the development of a technology, the economies of scale that had previously been well established are overtaken by a variety of factors that had previously been thought of as secondary. A startling example of this was given in a workshop in July 1979. One of the largest manufacturers of electricity-generating plants in the USA reported on a study indicating that, in terms of minimizing overall operating costs, they were already building generators twice as large as the optimum. Part of the reason for this can be seen in Figure 1, which we have prepared from his data, and which shows how outage rate and capital costs/kilowatt vary with generator size for a modern generator. Although the capital cost per kilowatt capacity reduced with size, the total cost curve in terms of kilowatts generated has a minimum well below current building sizes. (This was not an obvious result; it was the result of extensive regression analysis.) However, the real picture is much more complicated than that shown in Figure 1, for a number of reasons. One reason is the capacity factor, which is generally larger for smaller generators; a second is the question of learning; and a third relates to the fact that the decision to build a larger generator requires a decision about increased demand further ahead than the decision about a small generator, and consequently there is a much greater chance of a serious error in the demand forecasts. However, the question of learning is illuminated by Figure 2, which shows the reduction in construction costs in the building of four identical

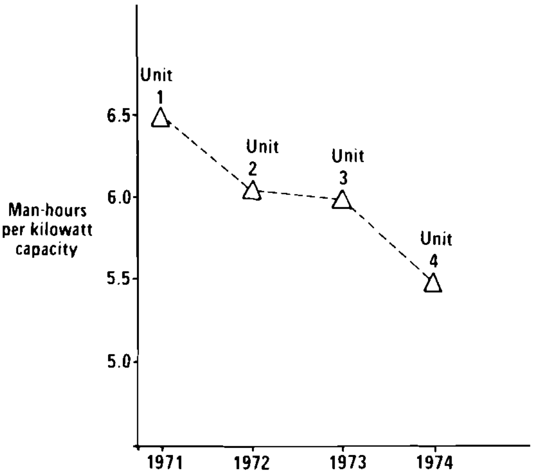

FIGURE 2 The effects of learning on the cost of constructing electricity-generating units.

units on the same site by the same contractor during the period 1971–1974. Although the first unit was considerably more expensive per kilowatt capacity than a unit four times the size built at the same time, the fourth unit was considerably cheaper. The size decision is a complex one.

When we started this work, we hoped to produce a handbook on the question of problems of scale, but we do not now consider this to be practicable at the present stage of knowledge. We are producing a book* based on the workshop that will identify the state of the art and explore, with some thoroughness, the main issues involved. We have also undertaken research on two topics: the question of learning and the question of management decisions in view of an uncertain future.

In addition, we have identified four major factors that must be borne in mind when taking decisions about plant scale. The first of these is the question of flexibility – will the larger plant be sufficiently flexible to meet an uncertain future? The second is the

*J.A. Buzacott, Mark F. Cantley, Vladimir N. Glagolev, and Rolfe C. Tomlinson, editors, *Scale in Production Systems*, Pergamon Press, Oxford, UK, 1981, in press.

question of systems effectiveness – although the larger plant may be more effective as a single unit, does it reduce the overall effectiveness of the system of which that unit is a part? The third is the question of complexity. Increased size almost invariably leads to increased complexity – does this generate increased costs in terms of organization, lack of control, etc.? Finally, the possible lower performance of individuals in very large organizations needs to be considered.

Innovation

Innovation, the process of putting into practical use the basic research ideas produced in the laboratory, remains one of the headaches of modern society – in the developed and the developing worlds, in East and West, in large and small countries. It is now generally realized that traditional sources of economic strength in industry may not be

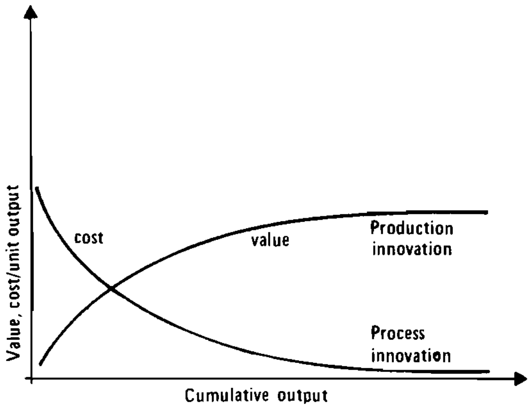

FIGURE 3 A view of the effects of process innovation and production innovation as cumulative output increases.

the ones that will provide an organization or a country with a stable economic future. The questions are: How can a country or an industry change its technological base? How does it decide where to go? What means can it use to change more rapidly in the right direction?

The first step in trying to answer these questions is to understand the process of innovation more thoroughly, and we have been looking at this from several points of view. We have tried to understand the apparent fluctuations in the number of innovations emerging in successive years. We have tried to understand the difference between basic and improvement innovation. Above all, we are trying to understand the relative importance of different kinds of innovation. Many people have pointed out, for instance, that it is necessary to distinguish between production innovation, which improves the product, and process innovation, which reduces the cost of production (see Figure 3).

Professor Heinz-Dieter Haustein, a member of the MMT team, has shown what this can mean, as a result of his research into the lighting industry. Figure 4 shows the annual increase in the amount of light produced by a single lamp; the main product improvements can be seen clearly. Figure 5 shows the main process innovations together with the annual increase in productivity, i.e., the number of lamps per unit cost. When you

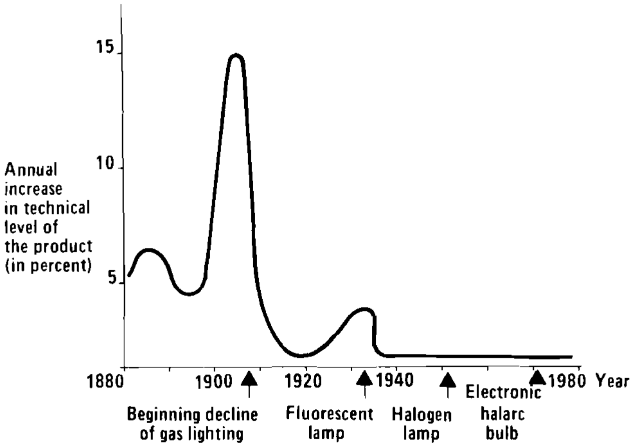

FIGURE 4 Production innovation in incandescent lamps: the annual increase in the technical (light-giving) level of the product.

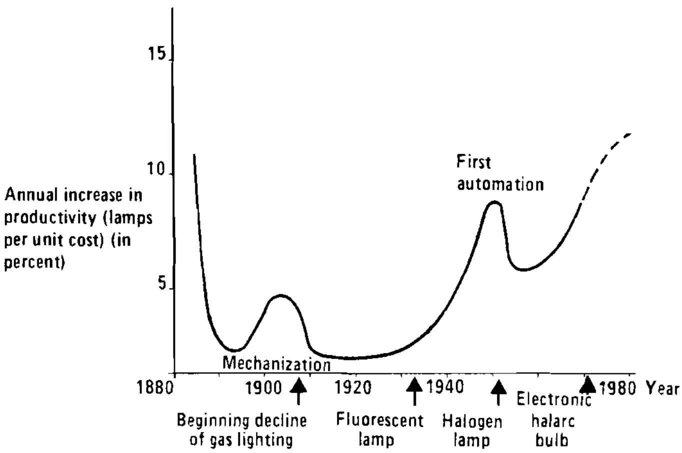

FIGURE 5 Process innovation in incandescent lamps: the annual increase in productivity (lamps per unit cost).

superimpose the two curves, there is no correspondence. Now although one is the learning factor so far as cost is concerned, it is not often appreciated that there is a similar effect with product improvement (i.e., it takes time for people to realize that the new product is better). This is, however, the most important kind of innovation, since it increases demand whilst maintaining product value.

Jennifer Robinson has built this understanding into a systems dynamics model that helps us to follow the overall innovation process more clearly than in the past. We now find it useful to categorize potential innovations on the basis of a 2 × 2 classification, as shown in Figure 6. It is worth noting that the items in the box where innovation would normally have the least chance of success – nuclear energy and coal liquefaction – are those where in the long term the need may be greater. What innovation policies will transform this situation?

This is all to aid understanding – it is necessary for an answer, but it is a long way from the answer to the problem of action or "use" – and does not constitute the bulk

	Large productivity gain	Small productivity gain
Large product improvement	Xerox Integrated circuits	Product dominated Color TV Convenience foods
Small product improvement	Process dominated Automation Adam Smith's nails	Nuclear energy Coal liquefaction

FIGURE 6 A two-by-two classification of innovations.

of our work. We have looked at such questions as the way in which governments decide on the kinds of innovation policies they want, and the effectiveness of the various instruments they may use to further these policies, and we are just about to undertake detailed studies within industries of the barriers and incentives to innovation. This study is expected to continue for some years, always being closely related to management.

The Management/Computer Interface

The traditional centralized computer information system may give managers less (or more) information but it has had surprisingly little effect on the way they actually do their jobs. On the other hand, there are strong indications that, once a manager has a flexible interactive system that he can address, using his own data and asking his own (often not very clearly structured) questions, his pattern of behavior alters. This has major implications for the future of information systems, for management training, and for organizational structure. We need to know what these implications are. One step in finding this out is a task force meeting to be held in June 1980* at which an international group of experts will review the state of the art in decision support systems.

There are, traditionally, two classes of criteria used when considering the design of a computerized information and decision support system. There are the type A criteria concerned with cost: the cost of purchase, of installation, and of the operation of the computer service. Then there are type B criteria, concerned with impact, the behavior and effectiveness of the system in relation to the individual, the group, or the organization. Because of their cheapness and their accessibility, the introduction of small (mini–micro) computers operating within networks is now making radical alterations in the balance between the type A and type B criteria. Before the small computer came in, the type A costs were very much lower for the larger centralized installation, and, as a consequence, the type B considerations were regarded as secondary. Now, however,

*Editor's note: The proceedings of this meeting have now been published: G. Fick and R.H. Sprague, editors, *Decision Support Systems: Issues and Challenges,* Pergamon Press, Oxford, UK, 1980.

computing on the small computer operating within a network can be as cheap as computing on the big central computer, so that type B criteria now become primary.

One of the critical elements that has to be looked at when studying small computers within the network system is the software constraint. Software, if it is to be reasonably cheap and accessible in places where there is relatively little skilled programming support, must, in fact, be mass produced. If such mass-produced software is to be widely used, then there must be a nonprocedural interface between the user and the procedural program. Our research has so far concentrated on looking at the relation between the user and the nonprocedural interface, and a report on this work is available.* We are now looking at the relation between the nonprocedural interface and the procedural program.

Decision Making Under High Risk

The next question is that of management under high risk, and it is particularly concerned with the situation where the risk is the potential for large human and material damages. We first looked at this question in relation to the oil blowout at the Bravo platform in the North Sea, and as a result we were able to make some recommendations that have been adopted by the Norwegian government.

We are currently undertaking a major study comparing the siting decision process for liquid energy gas plants in six, or perhaps seven, countries. However, as we were preparing for this work, the Three Mile Island nuclear accident occurred, and it quickly became clear that there were a surprising number of similarities with the North Sea accident. We have recently had a successful workshop on problems of reactor safety management in which David Fischer, who had been responsible for the work on the North Sea, compared the two accidents. He looked at questions such as the location, the timing, the indirect cause, the initiating events, the reaction and behavior of the supervisors, their accident management, the maintenance program, etc. The results he obtained are given in Table 1; a comparison of the two accidents shows a surprising number of virtually identical features. In both cases, it was a sticking valve that initiated the accident chain, and the maintenance program was deficient. In fact, 17 out of the 29 comparisons made were labeled "same." There are common principles involved in quite different technologies, and the lessons to be learnt are applicable to many different technologies.

Another interesting finding was related to contingency plans for accident management. Table 2 shows the relations of certain elements in the plans prepared before the accident to the situation that actually evolved. For instance, the accident plan states: "Measure the radiation to determine when the dose reaches a certain level." When the accident occurred, the radiation monitors detected such wide fluctuations that the orderly projection of doses assumed by the accident plan was impossible. According to the plan, if the dose exceeded a certain level, countermeasures were to be taken. However, the critical decisions concerned how to avoid reaching a dangerous dose. Accident plans typically assume no significant delays involved in the necessary phone calls. Yet, during the accident a call could take as long as 45 minutes, and it was often impossible to get through at all. The general lesson is that plans have to be flexible

*B. Melichar, *Nonprocedural Communication between a User and Application Software,* IIASA Research Report, 1981, to be published.

TABLE 1 A comparison between the Bravo blowout and the Three Mile Island accident.

Items	Bravo	TMI
1 Location	Norwegian sector of North Sea	Middletown, Pennsylvania, USA
2 Technology	Offshore oil production platform	Nuclear power plant
3 Accident	Oil blowout	Core overheat
4 Timing and extent	Late evening, 8 days	Early morning, 6 days
5 Indirect cause	Maintenance program	• Same
6 Early warning	Fluid leaking from valve (mud)	• Same (water)
7 Initiating event	Valve stuck open (downhole safety valve)	• Same (pilot-operated relief valve)
8 Contributing events	Not ready to install backup valve, and installed it upside down	Did not realize valve was stuck open, and shut down cooling pump
9 On-duty crew	• Could not act on warnings	• Same
	• Could not share information between shifts	• Same
	• No formal engineering education	• Same
	• Lacked experience with events	• Same
10 Supervisors	• Lacked theoretical knowledge	• Same
	• Lacked experience with events	• Same
11 Investigation	Royal Commission of Inquiry on Bravo	President's Commission on TMI
12 Basic cause	Weak organization/administrative systems	Weak organization, procedures, practices
13 Prevention	Preventable	• Same
14 Safety program	• Existed but no details, inspections	• Same
	• No plans for stopping uncontrolled well	• No plans for stopping core melt
15 Accident management	Hindered by design and responses	• Same
16 Maintenance program	• Not detailed or approved	• Same
	• Changed at will, poorly organized	• Poorly organized
17 Communications	Internal communication poor	• Same
18 Damages	• Nil	• Same
	• Lacked off-site monitoring and containment equipment	• Lacked off-site monitoring equipment
19 Liability	• Operators created pooled fund	• Operators sought Price–Anderson Act to limit liability
	• North Sea states agreed to limit liability, except Norway which recognized only unlimited liability	
20 Political impact	Temporary moratorium (on drilling in the North Sea)	• Same (on new plants)

enough to cope with the great uncertainties and unpredictable events that face management in accident situations. There is still a great deal of analytical work to be done in trying to identify the correct structure and scope of such emergency plans.

Let us now consider the research into the factors affecting siting decisions for large plants handling liquefied energy gases. Figure 7 describes two examples based on case-study investigations carried out by the team. Typically, a number of sites may be suggested, and various methods used to identify one of them as the best. Detailed risk analysis may then be undertaken to find out whether the site is acceptable on the basis of formal risk criteria. This done, little further progress may apparently be made until external factors force those concerned with the decision to act. In one case stretching over some years, the unemployment factor was finally considered as decisive. The analytical work supporting

TABLE 2 The contingency plans for accident management at Three Mile Island and what happened.

The plans	The accident
How did they help?	
• Measure radiation to determine when dose reaches specified action level.	• Radiation monitors show fluctuations spanning orders of magnitude.
• When dose exceeds 5 R_{wB} take countermeasures.	• Threshold never reached but gas bubble may explode any time leading to major release.
• Telephone seven authorities notifying of incident. (< 2 min per call at rehearsal)	• First call takes ¾ hr, then lines jam with incoming calls.

Conclusions
1. Plans should be less detailed!
2. Plan for uncertainty rather than expect emergency to fit preconceived patterns.

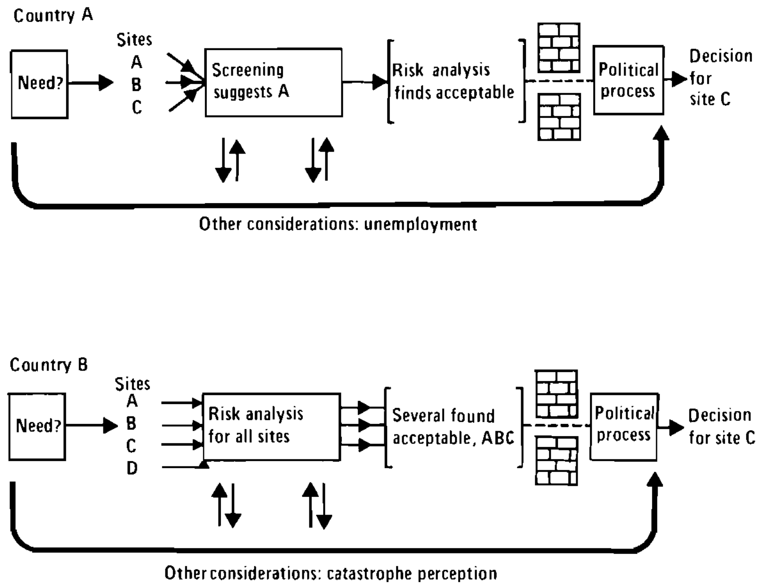

FIGURE 7 Schematic representation of two liquefied natural gas (LNG) siting decisions studied by IIASA analysts.

the final decision was minute compared with that done previously. Now, you might think that the conclusion would be that risk analysis was useful in aiding the designer, but useless in aiding the decision maker, and should be eliminated from siting decisions – but this is not a politically acceptable conclusion. The question is not whether any risk analysis should be done; it is rather to determine what can usefully be done and how the analysis can be incorporated into the overall decision process by finding the best form for presenting results, for example. We are studying this problem with a mixed team of analysts, technologists, economists, and sociologists.

Gaming

One of the key elements in such decisions is the negotiation process, and I must make a brief reference to some work we are doing to explore the use of the operational gaming technique as an aid to both policy making and analysis. Janusz Kindler has already referred to our use of operational gaming in connection with a problem of water cost allocation in Sweden. The game to which he referred has also been played in Italy. The comparison between the behavior of the planners in the two countries using the game was fascinating, but at the end they came to almost the same result. Just how close can be seen from Table 3, which shows the weighted mean-square difference of the allocations made by different methods from the allocations made by various theoretical and other approaches as well as the Swedish game. The agreement between the two experimental games is outstanding and implies that there may be something absolute about the joint answer. It would be erroneous to draw general conclusions from this, but it does appear that operational gaming provides a tool that enables us, not only to study the behavior of policy makers in simulations of real life, but also to test out theory.

TABLE 3 Weighted mean-square difference between allocations made by the Italian game and those made using different methods.

Method	Sum of squared differences (weighted)
Water proportional to demand	15.7
Separable cost/remaining benefits (used in practice)	2.0
Swedish game	0.1
Shapley value	0.6
Weak least core	2.2

Industry Studies: Issues for the Eighties

I conclude this illustrative section with mention of a study that is wholly oriented toward industry. All the work so far described has been concerned with particular problems – real problems facing industry in its everyday life. Nevertheless, we are studying these problems in isolation when, as systems analysts, we should also examine their overall content. Problems in industry are interrelated, and in order to understand both the industry and the way in which the industry may use systems analysis, it is necessary for the analyst to look at the industry as a whole system. Moreover, it is only when the industry looks systematically at the overall use of analysis that it receives full value from it.

We have, therefore, instituted a new class of industry studies, "Issues for the Eighties," and I shall discuss one of them, the forest industry study. At the beginning of 1980, there was a workshop meeting at which forest industry representatives from twelve countries were present. At the outset, the industry representatives gave their views on the major problems facing the industry in the next ten years. Åke Andersson from our

TABLE 4 A summary of issues facing the forest industry in various countries.

Country	Raw material	Energy	Capital	Labor	Environment	Technology	Markets/ products
Austria	Balanced utilization. "Many users"	Conversion to energy forests?					
Canada	From mining to management "Multiobjective forestry policies"	Energy cost sensitivity of process and products	Availability Modernization Taxation	Costs and supply for forestry regional issue	Pollution abatement Tourism–recreation Forestry Forest industry	R & D in forest industry. Support?	World market forecasts Currency problems Protection Transportation competitiveness
Developing countries	From selective mining to plantation management of rare species	Dependence on wood for energy production increase?	Investment scarcity vs. high capital intensity	Labor-intensive technology needed	Heterogeneous forests with unusual trees	Small-scale labor-intensive technology needed	Local vs. world demand Balance of trade
Finland	Availability	Generally energy-intensive sector	High capital intensity, specialization of national importance	Included	Economy vs. environment in forestry	Automation, computerization	World market industry, i.e., include all countries in a bilaterally specified trade analysis
Japan	Import strategies	Transportation cost effects	Comparative investment productivity?	Scarcity of "wood workers"	Water availability	"Moderate" industrial complexes	Trade analysis needed Demand saturation for wood and paper products?

Sweden	Biological vs. economic optimality: regional variation	"Sawing –pulping –burning" proportions	"Competitiveness" Productivity–investments	Regional employment policy vs. productive industry and growth	See Canada and Finland labor environment	–	Optimal adaptation of product mix to demand development Good forecasts of demand or mobility of resources?
UK	Forestry vs. farming, recreation, land use			Regional aspects of forestry policies	Land-use policies	–	Product prices in world market cartels? Product substitution with electronics, plastics, metals, etc.
USA	Availability costs; productivity growth	Availability prices. "Fuel-fiber"	Availability scale, durability decision possibility		Forestry chemicals manufacturing pollution	1. Costs – review of new procedural control technology 2. Packaging technology 3. Chipping 4. Computerization	Product use Produce design for resources – limitation economy
USSR	Better management methods Utilization of biomass		Mechanization	Training policies; social conditions	Environmental problems of new harvesting and production techniques	Industrial complex analysis	Optimal transportation analysis

Regional Development Task has summarized these views; Table 4 is an extract from his summary. It was surprising how the same topics were repeated and how much common realization there was that systems analysis had a part to play. The problems that determine our research were imbedded in use. The workshop also showed that there was much more analytical work going on than any of the analysts realized. There had previously been no common meeting place for them to discuss progress. It was also recognized that there were many major gaps in the analytical work. In particular, much work needed to be done on the world supply/demand situation for the next 20–25 years.

The plan is, therefore, to undertake a collaborative research program with the following principles. The starting point is to identify the main problems facing the industry in the 1980s; this has largely been done already. We shall then establish the state of the art, so far as systems analysis is concerned, and ensure that there is a critical information exchange. This will enable us to identify the major gaps in our knowledge and to undertake joint collaborative research. I should emphasize this word "joint" – the majority of the skills necessary for tackling these problems lies within the industry in the different countries. IIASA cannot match this technical knowledge; instead we have the specific knowledge about systems analysis, and the international environment to undertake studies of this kind. The agreed research work should, therefore, be undertaken in conjunction with a research team in each country, which will be supported by a reference group from the industry in that country. At IIASA we propose to establish a coordinating team to develop and help operate a plan; we shall organize state-of-the-art meetings and help undertake the critical mutual analysis; we shall undertake some special research on topics such as world trade, the use of computers, questions of energy and of innovation. To coordinate IIASA's work there should be an international reference group from the industry.

This proposal is still in the negotiation stage. Since it is an entirely new venture for IIASA, there are many organizational problems to be overcome. But it is clear that we have the support and good will of the industry, East and West, and there is the general intention that we should overcome the organizational problems.

CONCLUSIONS

There are three basic things that need to be said in conclusion. In the first place, however much we wish to help industry, IIASA cannot act as a first-line consultant. It is not our job, nor is it appropriate to our situation. In order to be effective, we must work in connection with research groups in industry, or groups that are closely related to industry in the various NMO countries. Unless these groups exist, there is a very severe limit on what we can do. The work of IIASA may help such groups to get established, but we should be under no illusions as to the time it will take.

Secondly, before we can consider the possible impact of IIASA, we need to analyze the way systems analysis can help industry. Generally speaking, systems analysts help industry and decision makers in industry in three ways:

1. They help the general *understanding* of the environment within which decisions have to be made. Decisions are made by people in organizations, but the way the questions are formulated depends on the understanding of the background situation. Often, wrong answers are the consequence of wrong questions. IIASA undertakes many studies

directly related to developing this understanding. The work of the Energy Systems Program is primarily devoted to ensuring that industry and governments understand the energy situation within which they have to make their decisions. The work we are doing within the innovation task, to understand what the main factors in the innovation process are, is of the same character. So IIASA has a major role to play in promoting understanding.

2. Systems analysis can be of value to industrial decision makers by helping to improve the *process* of decision making. Decisions, of course, are not made at isolated points in time, but as the result of a process that develops the decision over a period. Thus, much of our work is concerned with processes, e.g., the work on management and computers.

3. Finally, systems analysts can help by providing better methods of calculation for certain elements in the process. They can provide forecasting techniques, optimization techniques, etc. Here again, IIASA has the skills and is currently developing techniques that can be used for this purpose.

So IIASA can help strengthen each of these three ways in which systems analysis can help industry – there is no single way.

Finally, we need to consider how we may improve the contacts between IIASA and industry. How can we generate an environment that will help these important associations to grow? There are three ways in which it can be done.

Firstly, there can be what I will call the *IIASA push*. We publish research reports and executive reports, and we have conferences. These are all means by which we can push or communicate our results to industry. The only questions are: Who reads our reports? Who comes to our conferences? Do we have the mechanisms to identify the right people and to make these contacts? When we have asked for nominations to some of our workshops, some National Member Organizations have found it difficult to identify the right people. The people most appropriate did not always easily come to notice, particularly when they were working in industry. So it is not only an IIASA communication problem. This problem can probably only be solved by time, but as yet IIASA's "push" is not sufficiently well directed toward industry.

The second way in which the association may be improved is through *industry pull*. If certain industries have people with the right skills, then they can ensure that they examine IIASA's work, and pull into their industry what is relevant to them. Wolf Häfele's description of the Bulgarian use of the energy work is an example. Czechoslovakia has taken similar action, as have some industrial organizations in the West. This can only be done if there are people with the right skills within the organization.

Finally, and possibly most important, there is cooperation where the relation is neither "push" nor "pull," but *working together*. The Management and Technology Area has a number of people from industry working within it. They contribute as research staff while they are broadening their own experience and obtaining specific information useful to their own industry. This is potentially one of the most useful ways of widening the cooperation. But IIASA and industry can also work together through case studies and in providing information. In this connection, it is important to remember that, in order to provide useful information, you have to understand what it is needed for, so information provision in its own right develops a much closer understanding and exchange with IIASA. Finally, there is actual cooperative research, such as we have discussed in our Issues for the Eighties work. These three ways are all possible; all must be used.

To conclude, I believe that industry, through collaboration with IIASA, can both enrich our studies on national policy, and also serve itself. Let it be clear that cooperation will not happen unless both sides find it to be to their own advantage. I have little doubt that this will prove to be the case.

New approaches

THE CHALLENGE OF APPLIED PROBLEMS TO THEORY DEVELOPMENT

Andrzej P. Wierzbicki
Chairman of the System and Decision Sciences Area

The System and Decision Sciences Area of IIASA serves a double purpose: to consult and collaborate with other IIASA areas and programs on methodological subjects, and to probe frontiers of knowledge in selected methodological problems perceived to be of current or future importance to applied systems analysis.

Figure 1 represents in a schematic way the collaboration of various research tasks in SDS with other areas and programs at IIASA, where ENP denotes the Energy Systems Program, FAP the Food and Agriculture Program, etc. For example, a cross in the intersection of the Human Settlements and Services column and the Optimization row means that there have been researchers in both units – in fact, David Hughes from Great Britain and Evgenii Nurminski from the Soviet Union – working together on a problem of common interest to them and applying advanced methods of nondifferentiable optimization to problems of health care (see Hughes, Nurminski, and Vorontsov 1979). This is an example of our continuing concern with the relations between applied problems and theory development.

System and decision sciences X Collaboration O Consulting	ENP	FAP	HSS	MMT	REN	GEN
Decision and planning theory	X	X	X	X	X	O
Economic modeling	X	O	X	X	O	X
Optimization	X	X	X	O	X	X
Other activities	X	O	O	X	X	X

FIGURE 1 A scheme showing the collaboration between the System and Decision Sciences Area and the other IIASA areas and programs.

A theory of universal character describing the relations between a set of facts of (e.g.) mathematical, economic, social or systems analytical nature can be developed in various ways. One extreme, though often used and well regarded, is the abstract approach, which starts with a set of abstract assumptions and derives the theory. Clearly, the theory should then be checked against applications, experiments, or at least other theories; the success of the theory depends on the skill and taste in choosing the initial assumptions.

Some of the best theories have been developed in this way, when their authors had the intuition to choose the assumptions that reflected, however abstractly, the necessities of the real world. However, these good examples have given a bad incentive to develop all theories in this academic way, and to look for applications only after the theory is fairly well developed. This process results in what we can call "toolism:" a theoretician has his favorite tool and goes around looking for a place to apply it.

At the other extreme, one can start with an applied problem, use any theoretical tools that are already available, and develop a new theory only when the available tools are not sufficient. This problem-oriented approach is clearly much more time-consuming, requires a fair knowledge of existing theories, demands a certain generality and open-mindedness in pursuing interdisciplinary problems, etc. In fact, the problem-oriented approach to theory development is so much more demanding that a theoretician cannot pursue it all the time: after gathering experience from applied problems, he must revert from time to time to more abstract approaches. However, the problem-oriented approach is one of the basic features of modern systems analysis, and the System and Decision Sciences Area has been successful so far in recruiting researchers who follow this approach.

The theoretical problems that have been encountered in various applied areas and programs at IIASA can be exemplified, first, by a group of problems related to decision and planning theory, represented in Figure 2. This figure lists many interesting problems.

Decision and planning theory X Collaboration O Consulting	ENP	FAP	HSS	MMT	REN	GEN
Cost and resource allocations within institutional structures		X	O	X	X	O
Relations between demographic and economic development		O	X			O
Decision making under hazards and risks	X			X		O

FIGURE 2 The use of decision and planning theory in IIASA areas and programs.

For example, the problems of relations between demographic and economic theories (see, e.g., Arthur 1979a, b, 1980) are challenging and interesting, both from theoretical and applied points of view. However, only one of these problems can be characterized here.

Let us consider the problem of cost and resource allocation within institutional structures. This issue is of basic interest to many areas and programs; the strongest cooperation that exists is between SDS and the Resources and Environment Area, with further assistance of the Management and Technology Area, with regard to a study of water-investment projects in southern Sweden.

Costs and resources are often allocated, not according to purely competitive mechanisms, but rather under the heavy influence of institutional considerations. For example, if several municipalities in southern Sweden decide to finance a major water-supply investment jointly (see Figure 3), allocating costs among them constitutes an institutional agreement to form an association, and this agreement may be different in various situations. What are equitable ways of allocating costs among the members of an association?

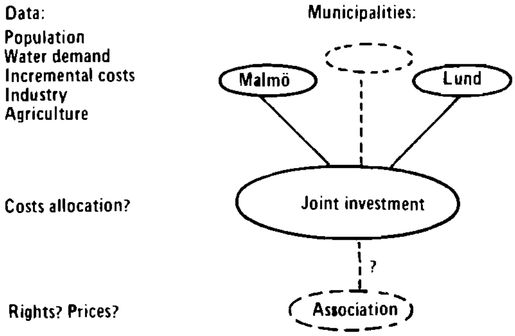

FIGURE 3 Issues in water-investment projects in southern Sweden.

Should the cost allocation depend on population data, on water demand by municipality, on incremental costs of supplying a municipality with water, on industrial development level, or on agricultural use of water? Should the members endow the association with some rights? If yes, what prices for water can the association charge? (See Young, Okada, and Hashimoto 1979.)

The problems of taking into account institutional aspects in decision making are complex and only partly understood, even on a conceptual level. SDS has been interested in finding mathematical tools to help answer such questions. There are many tools that can be applied to such problems – game theory, utility and value theories, hierarchical optimization, etc. However, no one of them quite describes these problems adequately. For example, agreements may be reached, or people may form an association and endow it with some rights, even though there is no apparent game-theoretical justification for such a course of action. Developing the existing theory further to fit this important class of problems is a challenging task. We are pursuing two possible approaches to this task: extending the concepts of game theory, including hierarchical aspects (see Young 1979) and testing the actual behavior of decision makers in suitably devised operational games (see Ståhl 1980).

Let us reflect for a moment on the issue of the use of such theoretical research. We collaborate with applied areas and programs, and seeing that our research helps to solve their problems is a reason for satisfaction. However, more important is the outside use: through interaction with decision makers from various countries, the research becomes a vehicle for promoting a better understanding of such problems. We do not try to substitute for decision makers in solving their problems; rather, we show alternative ways of approaching these questions. While doing this, we learn more about which problems are perceived as significant and which are not, which helps us to validate our theoretical results and develop them further.

Another group of problems that have either been encountered in applied projects at IIASA or perceived as of future importance is related to economic modeling. It is represented in Figure 4.

Economic modeling X Collaboration O Consulting	ENP	FAP	HSS	MMT	REN	GEN
Interdependence of national economies in global development	X	O	O	X		O
Energy strategies for small open economies	O		X			X
Growth models of national economies	O	O	X	O	O	X

FIGURE 4 The uses of economic modeling in IIASA areas and programs.

Some results of IIASA studies in this field have also been applied outside the Institute. For example, several national models of dynamic input–output type, incorporated in the so-called INFORUM System, have been developed in collaboration with various National Member Organizations (see Almon 1979, and Nyhus 1980). The results of the study on energy strategies in small open economies are being transferred to Bulgaria and Hungary and have actually been applied during preparation of the recent referendum on nuclear energy use in Sweden (see Bergman and Pór 1980, or Bergman 1980). This illustrates the diverse meaning of the use of theoretical results: sometimes we are satisfied that other scientists use our work, or that our work is helpful in understanding or solving applied problems, but it happens also that our work helps in problems of immediate relevance to an actual user. However, let us concentrate for a moment on a problem that has been of increasing importance to IIASA and may deserve even closer attention in the future: the problem of the interdependence of national economies.

We all know that international economic exchange makes national economies interdependent, or, at least, interrelated. This fact has been clearly taken into account in IIASA's Energy Systems Program and Food and Agriculture Program. For example, the FAP system of models is coordinated by a model of international trade, where the trade equilibrium is reached through making world market prices depend on surpluses of agricultural commodities offered for trade. In fact, SDS has been instrumental in solving this model by providing a nondifferentiable optimization algorithm (see Keyzer, Lemarechal, and Mifflin 1978). However, we also know that the trade in agricultural commodities is never quite free. Most of the developed countries try to protect their farmers by various subsidies, import quotas, custom taxes, or other barriers and regulations. All this can be taken operationally into account in the FAP system of models; but this example leads to a more general and interesting question.

The uneven dynamics of development in various countries, the increasing scarcity of old and development of new resources, the possibilities of forming international cartels or using other economic weapons, the transfers of technology and shifts of industrial potential among countries present all of them with a common problem: that of choosing a strategy of economic and industrial development. In order to determine a desirable and attainable future structure of its national economy, a country must take into account future international resource markets, industrial product markets, technology transfers, etc.

However, our understanding of how these markets function is by no means complete: we all hope that suitable international agreements will be of common benefit to all countries, but we do not know what those agreements will be – recall the attempts and failures by developing countries to formulate principles of a new economic order. Here is an important issue that IIASA can usefully contribute to, at least to the point of a better understanding of these problems.

Another related problem is that of an advantageous implementation of a development strategy: given a desirable future structure of a national economy and its dependence on international trade, what mechanisms best serve the restructuring process? In the theory of market economy, interventionism is bad, but in practice each government uses various interventions to encourage or protect certain sectors. If we face reality, not theory, then what are the best areas of government intervention: a goal-oriented educational program, support of research and development, participation in investments? And what are the best tools: tax exemptions, governmental purchases of products, direct subsidies? In a planned economy, is direct governmental investment the best and only tool for restructuring? In other words, how can developing sectors be supported without endangering their competitive efficiency? These and related questions do not have full answers in existing economic theory.

However, the coming decades will be characterized by major structural changes in many national economies, and the question of the adaptability of an economy is a challenging theoretical problem. IIASA has several advantages over other institutions in this field: our interdisciplinary heterogeneity that encourages research even on unconventional questions, and our tradition of addressing even controversial questions jointly by researchers from both East and West in a detached scientific manner. Thus, we can at least serve as catalysts, and hope to contribute more significantly to an understanding of this important problem. Most of the efforts of the Economic Modeling Task in the SDS Area – for example, the Conference on Global Economic Modeling to be held in July 1980, the study of labor supply and unemployment issues (see Coen and Hickman 1980), the study of economic indicators of resource scarcity (see Barnett and van Muiswinkel 1980), or an aggregate global economic model (see Klein 1979) – are related in some sense to this problem.

The third group of theoretical and methodological problems of basic importance for applied projects at IIASA is related to model solving and optimization. As can be seen in Figure 5 these problems are encountered in most of IIASA's projects. I will comment on only two of them: the problems of model linkage and nondifferentiable optimization.

The problem of linking several models, often distributed in space, according to various types or degrees of aggregation, etc., into one coherent system is quite fundamental

Optimization X Collaboration O Consulting	ENP	FAP	HSS	MMT	REN	GEN
Large-scale optimization Linkage of models	X	O	O	O	O	X
Nondifferentiable optimization Inclusion of uncertainty	O	X	X		O	X
Stochastic optimization	X		O	O	X	O

FIGURE 5 The uses of model solving and optimization in *IIASA* areas and programs.

in systems analysis and has many variants. We have seen one of its examples: the mathematical aspects of modeling international trade in agricultural products. There are also various approaches to this problem: via large-scale optimization techniques, via dual and primal coordination (see Kallio, Orchard-Hays, and Propoi 1979), and via nondifferentiable optimization (see Nurminski 1979, 1980). This is the reason for using broken lines in Figure 5: the linkage of models is related both to large-scale optimization and to nondifferentiable optimization.

Let us analyze this last connection – see Figure 6. Consider two optimization models that maximize objective functions f_1 and f_2, which sum to a common objective. The decision variables x_1 and x_2 in these models are separate and separately constrained, except for one variable in each model, v_1 and v_2, that represents, for example, the use of a jointly bounded resource V. We can express the way this resource is allocated by a single parameter v and can solve the optimization models for each level of the allocated resource.

If the level of the allocated resource increases, at some point it ceases to influence the optimal value of the objective function $\hat{f}_1(v)$, simply because other constraints do not permit making use of a larger amount of the resource. Therefore, there usually is a sharp corner in this graph. The graph of the sum of the objective functions also has corners, and the maximum of the sum is very likely to occur precisely at such a point of nondifferentiability. Thus, when linking more complicated models in a manner described by this simple example, special algorithms of nondifferentiable optimization must be used; the more classical types of algorithm do not work for such problems.

Since 1977, the System and Decision Sciences Area has been pursuing research on basic theory, computational aspects, and applications of nondifferentiable optimization. Moreover, IIASA has become a meeting ground for two schools with different approaches to nondifferentiable optimization: the Western school, exemplified by the works of such researchers as Wolfe, Balinski, and Rockafellar, and the Eastern school, which actually started this research earlier than the Western one, at the Institute of Cybernetics in Kiev, by Glushkov, Michalevich, Ermolev, Shor, and others. Research on nondifferentiable optimization at IIASA has succeeded in merging these approaches; all of the scholars I have mentioned have either worked in SDS or keep close contact with us, and many others have joined the research.

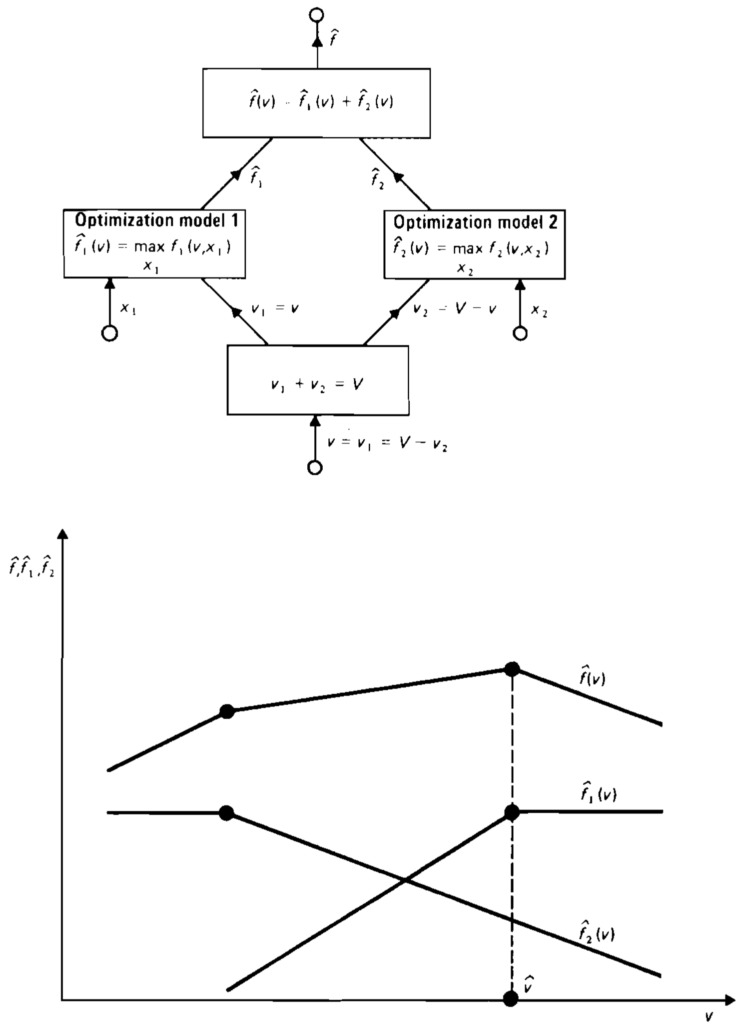

FIGURE 6 Model linkage and nondifferentiable optimization.

This international scientific cooperation has not only brought many interesting theoretical results – such as necessary conditions of optimality or saddle point theorems for nonconvex nondifferentiable optimization (see, e.g., Mifflin 1976, Lemarechal and Mifflin 1978, Nurminski 1978) – but also resulted in practical algorithms and computer codes for various applied problems of systems analysis, such as the problems of solving models of international trade, or linking models of regional development or health-care systems. The research on nondifferentiable optimization is a good example of the response of theory development to the needs of applied problems: motivated by the needs of modern systems analysis, the research is both theoretically challenging and important for applications.

The fourth group of various problems, represented in Figure 7, includes some other research activities related to the needs of applied systems analysis. For example, we have recently begun exploratory research on model validity and credibility – a problem fairly

Other activities X Collaboration O Consulting	ENP	FAP	HSS	MMT	REN	GEN
Organizational aspects of decision making Inclusion of human judgment in formal modeling	O		O	O	X	X
Model validity and credibility	O	O	O	O	X	O
Operational gaming in systems analysis		O		X	X	O

FIGURE 7 The uses of miscellaneous technical methods in IIASA areas and programs.

well understood in the case of descriptive econometric models, but very poorly understood in the cases of normative optimization or equilibrium models, or models for scenario analysis. As in Figure 5, the broken lines in Figure 7 indicate that there are strong connections among some of these problems.

I would like to comment in slightly more detail on one possible approach to the problem of including human judgment and institutional aspects in systems-analysis models, simply because it is related to my current research interests and will thus serve as a more detailed example of our approach to theoretical problems.

Starting with the needs of applied systems analysis, we can observe that, in many areas – for example, in the Regional Development Task or the Energy Systems Program – there is a difficult problem of linking several models of widely different types into one system of models (see Figure 8). We cannot expect the solutions of these models to fit precisely the solutions of, say, an aggregated, top-level model; thus, we must soften the requirements of the more typical approaches to model linking described above. Moreover, we should include somehow the user's judgment on how the solutions of these models fit together. We could try to use the theory of human organizations as a blue-print for organizing such a system of models. However, the existing theory of organizations given,

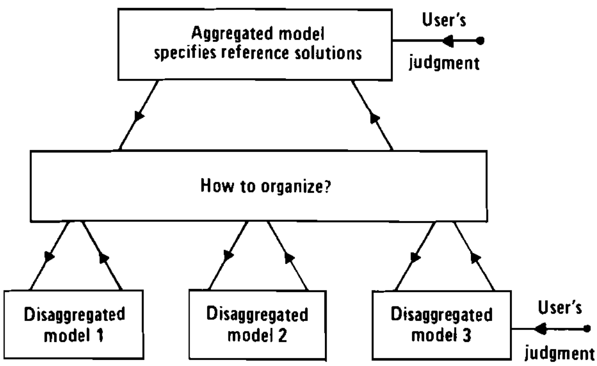

FIGURE 8 The soft linkage of models in systems analysis.

for example, by March and Simon (1958) or Arrow (1974), is mostly conceptual and descriptive, not mathematical, and we need a mathematical description for organizing a system of computerized models.

It is known that one of the functions of a staff in an organization is to generate reasonable alternative plans of action in response to the boss's requirements. If we had a mathematical description of this process, we could organize better the interaction between a model, interpreted as the staff, and the user, interpreted as the boss (see Figure 9).

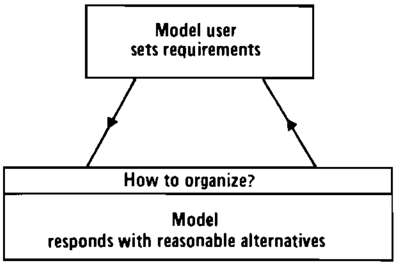

FIGURE 9 Generating alternatives interactively.

However, until now, there has been no mathematical description of even a simple organization consisting of a boss and a staff, or of the processes that generate alternative plans in such an organization.

Another complication is that plans are often dynamic in their nature and the user's requirements are likely to be formulated in terms of entire paths or trajectories. For example, an economic modeler might be interested in checking whether trajectories of desired GNP growth rate and reasonable inflation rate are attainable through varying policies in an economic growth model, or whether the model could predict even better outcomes – see Figure 10. These questions are usually approached by trial-and-error procedures – how could we organize these procedures better, and make the model respond to the user's wishes?

Between the existing approaches to decision making, utility and value theories are not applicable to such problems because they do not describe the generation of plans by the staff in an organization. The theory of satisficing decision making, introduced by

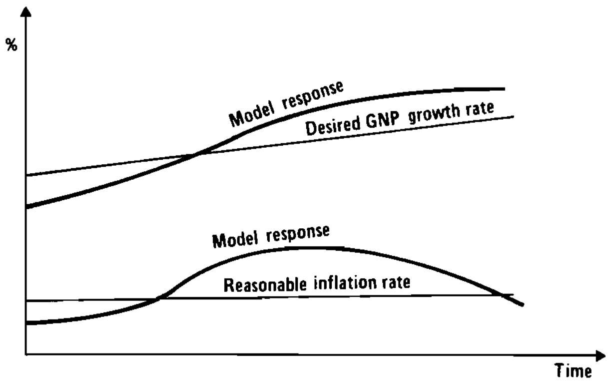

FIGURE 10 Trajectories as user requirements.

March and Simon, is applicable, but only conceptually – it has not been, as yet, expressed mathematically. Mathematical goal programming in multiobjective optimization is applicable, but only in a restricted sense – it does not answer all the problems discussed above. Therefore, we need a generalization of the goal programming approach or, actually, a mathematical basis for satisficing decision making.

Such a mathematical basis has recently been obtained – see Wierzbicki (1980). We analyze first the process of generating plans of action in a simple organization, composed of a boss and a staff. There are three possible types of outcome of plans proposed by the staff. Firstly, the requirements of the boss, called aspiration levels, are not too high; then the staff proposes how to exceed them. Secondly, the aspiration levels are too high; then the staff proposes how to come close to them. Finally, the boss may have specified just-attainable aspiration levels; then the staff proposes how to meet them and does not bargain with the boss about changing the aspiration levels (this is, clearly, a somewhat idealized assumption).

We can describe this process mathematically and obtain, as a result, an additional axiom to the general value theory that expresses the rationality of staff proposals, restricted by the boss's requirements. Thus, we construct a bridge between seemingly contradictory theories – the satisficing decision making and the value theory – by introducing a class of modified value functions, called achievement scalarizing functions, that describe the preferences of the staff in an organization.

This abstract theory is also pragmatic: it responds to the needs of applied systems analysis and makes it possible to construct interactive systems of models using the pattern of an organization. On this basis, an interactive technique for analyzing development paths for the Finnish forest industrial sector has been developed and checked practically (see Kallio, Lewandowski, and Orchard-Hays 1980). This technique is also applicable to other problems, and we are continuing to work on its applications in the Energy Systems Program and in the Resources and Environment Area.

Finally, the mathematical basis for satisficing decision making changes our perception of the role of optimization in systems analysis qualitatively. Instead of proposing prescriptive, so-called "optimal" solutions that maximize either one objective or a utility function aggregating several objectives, we generate by this method alternatives that respond to the requirements of the decision maker or model user. The role of optimization is restricted to eliminating inefficient, dominated alternatives and to responding to the user's wishes (see Wierzbicki 1979).

I have outlined here the challenges that applied problems of systems analysis pose for a theoretician, with examples of current IIASA research. From many possible examples, I have chosen only four to comment on: resources and cost allocation within institutional structures, interdependence of national economies in global development, model linkage via nondifferentiable optimization, and inclusion of human judgment and institutional aspects in systems-analytical models. In all of these examples we have seen how theory development responds to the needs of applied problems.

If we turn our thoughts to future IIASA research, we should be guided by the principles of the IIASA Charter and, even more generally, by the ethics of the development of science (see, for example, Boulding 1980). We live in troubled times, on the wave of a transition period for the entire world (see Figure 11); this period may last another one or two hundred years. Science is responsible, to a large extent, for initiating this transition; science should therefore contribute to stabilizing its dynamics.

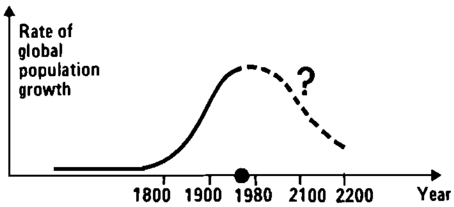

FIGURE 11 A period of global transition.

This can be achieved by seeking and promoting a better understanding of the stabilizing factors of global development. There are several areas of human activity that can exert either stabilizing or destabilizing effects on global development. Among others, these are international trade, education, communication, and transportation.

If we understood better, for example, what aspects of contemporary education are likely to help stabilize global development or what the possible destabilizing aspects of modern mass communication are, we would have greater hope for a better future for our world. This hope is a basic principle that should direct our research. As much as a researcher can be attracted by the aesthetic features of a general theory, or by scientific fame, the final test of the value of our results is whether they serve humanity.

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THE EVOLVING CRAFT OF SYSTEMS ANALYSIS

Hugh J. Miser
Executive Editor of the Survey Project

Even though the roots of systems analysis go back over four decades, it is as yet a relatively young activity. While its past achievements are significant – sufficiently so to prompt the founding and support of this Institute – its potential is as yet largely unrealized, particularly for the classes of problems with which IIASA is concerned. Thus, IIASA includes in its portfolio of work, not only studies of specific problems (of the sort the earlier speakers have dealt with), but also research on conceptual and professional issues. This research and its products are aimed at broadening the scope of systems analysis, improving its quality, and making its results more useful, both here at IIASA and elsewhere.

My purposes here are to comment on some of these conceptual and professional issues, and to sketch some of the work we are doing on them.

THE POINT OF DEPARTURE FOR SYSTEMS ANALYSIS

A new field of science and technology emerges when workers identify a context, discern problems in this context, and devise an approach to them. Systems analysis emerged from three such steps.

1. *A context was identified.* As summarized in the program for this meeting, this context, as it emerged from early systems-analysis work, can be described briefly in this way (see Appendix B for further discussion):

> Many of the functions of society involve structures that can be thought of as systems combining people and the natural environment with various products of man and his technology.

Historically, many examples of this context have been identified and investigated fruitfully: fire-department operations, regional water-supply systems, blood-bank operations, flood-control systems, and large business and government operations. Too, previous speakers at this Conference have identified many other realizations of this context that have been studied here at IIASA: Kindler's lake systems, Tomlinson's industries, Rabar's food and agriculture systems (both national and global), Rogers's communities, Albegov's regions, and Häfele's world energy system.

To make this background accessible to persons interested in it, particularly new workers in the field, we have prepared a short introduction to the field (see Miser 1980) and a sketch of its intellectual history (see Majone 1980).

2. *Systems within this context exhibit many problems.* For example, blood-bank operations in the United States have been characterized in recent years by a high level of wastage (20 percent of the blood collected from donors) and a high cost of ensuring adequate supplies at the points of use. Similarly, for the systems you have heard about from the earlier speakers, you will recall problems of ensuring an adequate supply of energy at prices society can afford, of feeding the world's population adequately, of ensuring water quality and supply, of planning for continuing industrial strength and variety, of managing communities and regions.

These examples make it clear that the context of systems analysis contains many important problems.

3. *An approach was evolved.* Early work in systems analysis suggested that a complete study might well contain these elements (as quoted from Appendix B):

> . . . Applied systems analyses:
>
> - Marshal both the evidence relating to the problem and the scientific knowledge bearing on it, where necessary gathering new evidence and developing new knowledge.
> - Examine critically the social purposes — of both persons and institutions — relating to the problem.
> - Explore alternative ways of achieving these purposes, which often include designing or inventing new possibilities.
> - Reconsider the problems in the light of the knowledge accumulating during the analyses.
> - Estimate the impacts of various possible courses of action, taking into consideration both the uncertain future and the organizational structures that must carry these courses of action forward.
> - Compare the alternatives by applying a variety of criteria to their consequences.
> - Present the results of the study to all concerned in a framework suitable for choice.
> - Assist in following up the actions chosen.
> - Evaluate the results of implementing the chosen courses of action.

There are several points to be made about this approach, based on experience elsewhere:

1. While it captures in systematic form key elements of systems analysis, individual systems-analysis studies seldom conform to it as an ordered process:

> . . . . there is almost always a great deal of recycling of ideas and analysis; for example, the impacts of the chosen courses of action may dictate reconsidering the social purposes, the analysis of the chosen alternatives may generate new and more interesting ones for consideration, and so on. Nor do all systems analyses carry out all of the steps; the user may need only some of the steps carried out. Since the world does not stand still while the work is going on, its changes may dictate major changes in content and approach, or, since user representatives must work with the analysis team throughout if the work is to be effective, early results may get translated into action or policy quickly. All of these influences may change the pattern of the work. (Miser 1980)

2. The approach sketched in the list implies a reasonably well focused decision-making apparatus: a single decision maker or a consortium of decision makers with well established

responsibilities and powers and the ability to work together toward coherent courses of action.

3. This decision-making situation, in turn, implies that the underlying situation to be dealt with in the analysis is sufficiently coherent to make choosing courses of action possible, and that such courses can have beneficial effects.

While we can imagine such decision situations as implied by the discussion so far in Tomlinson's industries, the picture gets murkier when we turn to Kindler's lakes, then to communities and regions, and finally to world problems such as those dealt with in the IIASA energy analysis.

4. Thus, while the approach I have sketched is classical – indeed, we are using it as the point of departure both for this Conference and for the *Handbook of Systems Analysis* (see Quade and Miser, to be published) – it can only serve as a somewhat distant point of reference for much of IIASA's work. Rather, IIASA must find its own approaches, program by program, area by area, appropriate to the problems being treated and the related decision and control apparatus.

The Institute is engaged in the early phases of this search now. This Conference was designed to focus attention on issues related to how to make systems analyses done here effective in practice – in other words, at the "use" end of the Conference theme. You have caught glimpses of the Institute's evolution toward use in some of the talks: Häfele spoke of the dissemination work of the Energy Systems Program, and its involvement with various groups working toward policy decisions; and both Kindler and Wierzbicki spoke of how the work in the Skåne region of Sweden bore on policy issues; and so on. The Consultative Sessions at this Conference are designed to elicit your help in exploring these matters further. However, it would be foolhardy for any of us to try to predict the outcomes of our search at this early formative stage.

SOME OF THE DIFFICULTIES WE FACE

Beyond these difficulties about the ultimate focus and use of our work, we face some others that should be mentioned here. I pass over such fundamental difficulties – obvious to you, I suspect – as selecting the appropriate system configuration for study, clarifying and identifying its problems, and understanding the mechanisms underlying these problems. Rather, I will discuss three others: the dependence on perceptions, the necessity of working with functioning systems, and the difficulties of making changes in them.

1. *Perceptions.* As I have said, the starting point for a systems analysis is a problem emerging from a context. However, our sense of a problem emerges from our perceptions of both problem and context.

While our perceptions arise from our sense of reality, as we begin to come to grips with them intellectually, we begin to formulate intellectual constructs, somewhat removed from reality, to replace the original perceptions. We have seen this process at work here:

- Hunger is Ferenc Rabar's dominating perception. How does he measure it? How does it enter his calculations? What system is it embedded in? How can changes in this system help to appease hunger? What should these changes be?
- Declining water quality is one of Janusz Kindler's key conceptions. How does he measure it? What systems must be dealt with to respond to this perception? And so on.
- Several of my colleagues have begun their talks with the world's population growth as a key motivating perception. How did they use it in their analyses? What role did it play in their work as they described it to you?

To carry the discussion one step further, consider the abstract nature of such systems-analysis concepts as costs, needs, poverty, effectiveness, equity, the amenities of life, and so on – not to mention many variables that have been used by my colleagues in their talks. How "real" are our intellectual constructs – our variables and the rules by which they interact – that represent our conceptions of reality?

Indeed, the history of systems analysis records that it has often been so difficult to formulate a measurable construct to represent a conception that we have retreated to a proxy – an obviously inadequate measure that the analyst hopes is well correlated with the real perception. A commonly quoted example is the use of infant mortality as a measure of the quality of a health-care system, a proxy clearly inadequate as a representative of the myriad complications of such a system. Scattered through our work are such proxies, not so extreme as infant mortality as a representative of health-care quality, but proxies nevertheless.

Yet these proxies are what our analyses deal with: we get data about them to use as inputs. We theorize about them, and build models in which they are the structural elements. We devise options involving them. We compare these options and choose preferred ones on the basis of abstract criteria (or, indeed, combinations of such criteria) that are themselves often proxies. We even, on occasion, urge our results on decision makers and other parties at interest.

These issues urge on us a central question for systems analysts:

> How can we be sure that all of this work on structures somewhat removed from perceptions can be carried back into reality with what we and others will perceive to be happy effect?

2. *Working with functioning systems*. The difficulties of working with functioning systems – familiar to medicine, biology, and the social sciences – are new and special ones for the majority of systems analysts, who come to their work from the physical sciences or mathematics. They find they must face such difficulties as these:

- While the systems analyst's systems betray many aspects of persistent regularity – a property that charmed many of us into this field in the first place – they also exhibit sharp shifts from time to time (sometimes described as uncertainties). There are many familiar examples: the heightened response to ecological concerns over the last two decades; the major shifts in the prices of many forms of energy; the change in the public attitude toward nuclear energy in the face of radiation hazards; political shifts in other contexts; and so on.
- Experimentation, always difficult with functioning systems, may be impossible. For example, Kindler cannot experiment with his lakes, except, possibly, very guardedly; nor will society allow a very large nuclear plant to be built next to a city to see what the radiation effects might be.
- Equity issues become important, perhaps controlling. They are clearly a central issue in the thinking about hunger and the world food supply, as Rabar's comments show. The IIASA work on allocating costs of water-resource development in the Skåne region of Sweden shows that this difficulty can be approached rationally, as a central issue should be.
- The imperative of taking steps to be very sure of avoiding unknown evil effects may be very strong, particularly where science cannot produce good evidence or adequate theory on which to base predictions, and where time or other factors are known to bar such certainty of knowledge – in others words, where what is involved is trans-science (to

use Alvin Weinberg's term). The outstanding current example is the very cautious public thinking about nuclear energy as posing risks to future life and climate, both areas of trans-science; in the United States, there are similar approaches to the problems of potential carcinogens.

3. *Achieving changes.* By now it must be clear to you that the systems-analysis approach that I outlined above was evolved at a time in the development of the field when the problems, the systems they involved, and the relevant decision and policy apparatus were relatively simple compared with what we are talking about today. Indeed, if you have been trying to match this approach with the talks you have been hearing, you have undoubtedly been having some difficulty. For example, to achieve change it is desirable to have an appropriate and effective administrative control apparatus – but what this is is neither obvious nor simple for the Institute's two major programs in food and energy.

Thus, a major focus of this Conference is to ask you, particularly in the Consultative Sessions, to help us consider this problem.

Beyond the issue of how to achieve change there lie a number of others. A few examples will suffice to suggest the thicket confronting the analyst:

- Experience with systems analysis results has shown that, if change is not very carefully carried through, it can often go awry. Indeed, it always brings new problems for analysis and decision, so that the analytical work during implementation may turn out to be more extensive than the original work that began the change process.
- A change in a complicated sociotechnical system frequently alters many matters at a distance from the original central concern, and these alterations may have deleterious effects. As an example, Kindler told us that agricultural fertilizers were introduced into the watershed of Lake Balaton to raise the productivity of the growing agricultural activity in this region, but that these fertilizers have had an unfortunate effect in speeding the eutrophication of the lake.
- Long times from treatment to response may inhibit our knowing and controlling the effects of a program, even if it is entered into in an adaptive mode. The forest-management techniques evolved from IIASA's work in adaptive environmental management – popularly known as Holling's "budworm work" – are still seriously handicapped by this problem (see Holling 1978).
- The system may be so complicated that extraneous-variable changes may mask the effects of control programs, making the reading of indications of program effectiveness difficult, if not impossible.

THE CRAFT OF SYSTEMS ANALYSIS

How can we deal with these difficulties?

The classical positivist approach to the scientific method would say that we simply observe phenomena, model them, use the model to predict consequences, and check the predictions against what happens in the real world (in others words, step to the laboratory next door) – and then continue this cycle.

However, this physical-science approach – while it has given us the tremendous store of knowledge that is the cornerstone of our work – is only partially useful in the systems-analysis contexts. Majone (1980) puts the matter concisely:

> . . . the most significant similarities between [physical] science and systems analysis are to be found not in the *outcome*, but in the *process* of research,

> more precisely, in the craft aspects common to all forms of disciplined intellectual inquiry. The actual work of the scientist requires knowledge that is acquired only through practice and precept and that therefore is not scientific in character. This craft knowledge is a repertoire of procedures and judgments that are partly personal, partly social. Thus, when a scientist decides whether a batch of data is of acceptable quality, he applies standards that derive from his own experience, but also reflect the professional norms of his teachers and colleagues, as well as culturally determined criteria of adequacy. Personal and social judgments are also involved in data manipulation, in the choice of tools and models, in the selection of evidence, and in the construction of an argument.
>
> The importance of craft knowledge and experience is even greater in . . . [systems analysis]. Because the conclusions of a systems study cannot be proved in the sense in which a theorem is proved, or even in the manner in which propositions of natural science are established, they must satisfy generally accepted criteria of adequacy. Such criteria are derived not from abstract logical canons . . . but from craft experience, depending as they do on the special features of the problem, on the quality of the data and limitations of the available tools, on the time constraints imposed on the analysts, and on the requirements of the sponsor and/or decisionmaker.
>
> In short, craft knowledge – less explicit than formalized theoretical knowledge, but more objective than pure intuition – is essential for doing systems analysis as well as for evaluating it . . . close attention to the fine structure of the analyst's task is what is required for serious evaluation.

In sum, systems analysis must build a body of craft knowledge to guide both the internal competence of its work and its external effectiveness through the shared experience of the entire community of systems analysts and the users of their work.

The craft knowledge of internal competence will deal – as it already does to some extent – with such issues as problem setting, using data as evidence, choosing models, tools, and methods, dealing with costs, choosing alternatives, formulating findings, and doing these things with a view to the ultimate effectiveness of the work.

The craft knowledge of external effectiveness will deal – as our limited current knowledge suggests – with such issues as having a detailed knowledge of the context of the problem, knowing the decision-making environment, developing an approach that is intrinsically persuasive to nonscientists, shaping findings to make them effective, considering implementation issues as part of the analysis of the problem, and following through to work extensively with implementation activities.

IIASA'S WORK ON THE CRAFT OF SYSTEMS ANALYSIS

Thus, as it must be, IIASA is concerned with the craft aspects of systems analysis. It demonstrates its concern in two ways: by working to exhibit good craft practices in its work, and by carrying out a research and publication program aimed at systematizing the knowledge of this craft, both to inform its own work and to aid analysts elsewhere. Internal criticism and outside review of our products help us with the first of these concerns, and the Survey Project, with its very small staff, works on the second concern with the aid of many consultants and colleagues scattered throughout the NMO countries.

The work of the Survey Project – which will be renamed the Craft of Systems Analysis in 1981 – has three thrusts currently, with the fourth to be added next year: publishing the *International Series on Applied Systems Analysis* (a series of books dealing with models for systems-analysis use, accounts of cases, and craft issues, with nine published, six in editing or review, and twenty being prepared); preparing the *Handbook of Systems Analysis*, which will appear in three volumes; research on craft issues; and engaging in a number of educational activities.

In connection with the *International Series*, two items are relevant to this discussion:

- Majone and Quade's volume on *Pitfalls of Analysis*, just published, focuses attention on a variety of craft issues in systems analysis, and an accompanying Executive Report makes some of the key points of this book more readily available for the general reader.
- The 35 volumes currently listed for the *International Series* involve over 75 authors or editors from 16 countries (not counting the large number of other contributors to several of the volumes). These figures evidence our effort to bring together the international experience in systems analysis.

CONCLUSION

In sum, IIASA is working to exemplify high craft standards in its work on systems problems, and to develop and disseminate explicit knowledge of craft procedures and standards for systems analysis, to the end that this approach to systems problems will grow in strength and usefulness throughout the world, thus giving concrete expression to the faith of the Institute's founders and supporters.

The great economist–philosopher Kenneth Boulding visited us recently and gave us a challenging lecture about issues to which our craft must respond. There is neither time nor space to summarize his points, but underlying them is what he said in the closing paragraph of his retiring Presidential Address to the American Association for the Advancement of Science in January 1980 (Boulding 1980):

> . . . the heritage of science is a heritage of hope. By greater understanding, not only of the physical and biological worlds but also of ourselves and the world of human society, we can push the evolutionary parameters toward human betterment and build a happier world for the human race even out of the fires of catastrophe. But, if this hope is to be realized, the scientific community itself must evolve. It needs a renewed sense of its mission and its ethic. It needs to develop a pattern of appropriate epistemological methodologies, and to gain a sense of the unity of human knowledge bridging the present "two cultures" gulf between the sciences and the humanities. It needs to develop within it a discipline of "normative science" that will take the study and critique of human valuations seriously. It needs a livelier sense of itself as a world-wide movement transcending values of nationality and culture, but also concerned to preserve national and cultural variety as one of the keys to human evolution.

By understanding the science and technology of systems analysis and the craft that puts these elements to work on problems, we here at IIASA are responding to Boulding's challenge.

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Integrating sessions

Reports from the consultative sessions

PUTTING THE RESULTS OF THE IIASA ENERGY SYSTEMS PROGRAM TO WORK

Dr. James F. Young
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The objective of this session was to examine how the results of the recently completed IIASA energy study could be put to work.

The enthusiasm of the session discussions and the sense of the participants indicated that IIASA can be proud of the product of its Energy Systems Program. Frequent comments indicated that the publication and wide distribution of its report, *Energy in a Finite World*, will promote a favorable image. The publication will be of special value to energy analysts and energy researchers. A shortened version is desirable for decision makers, and the participants were pleased to hear that work is under way at IIASA and in the Federal Republic of Germany on such a version.

The presentations at our session provided examples of the guidance the results have given to regional and national studies. Assistance in identifying trends, crucial choices for transition, the nature of technical problems, and topics for initiating research and development programs were mentioned specifically. It was also noted that the Program's report has helped to insure consistency in local studies, and provided a mechanism for aiding international cooperation and joint-venture collaboration. This, of course, offers prospects for avoiding duplication on major developments through pooling big project resources. In these ways, the Energy Systems Program's report provides a platform and perspective.

The discussions brought out a number of lessons that have been learned. For example:

- Transition of energy systems to new supply forms will be a slow evolution – a gradual transition. There are no easy solutions. Conservation will be essential, but nations cannot conserve their way to prosperity or, in some cases, even to survival.
- The IIASA work has put the prospects for renewable sources into perspective. Thus, nations and regions are encouraged toward wise use of their indigenous wealth of energy resources.
- Energy supply cannot remain static if the needs of population growth and aspirations for upward mobility are to be met, even in a minimum way.
- Transition to new energy supply systems implies a great deal of change in technology and its infrastructure. The transition will be paced in part by the resources required

to meet the new needs, then the replacement of obsolete systems, and, finally, the displacement of existing energy-scarce systems. The magnitude of the transition and its interactions will deserve assessment from time to time.

- Direct work with IIASA has been the most effective way to use the Program's results. In the Latin American study, the IIASA report helped define the capability required. The European Community study, modeled on the IIASA report, showed that energy supply is more crucial than national models had shown. At this planning stage, aspirations exceed potentials. Studies by some less developed countries showed some cost optimization differences that need resolution.

The discussions also brought out a number of potential areas for future inquiry. The main examples were

- Extension and formalization of the energy models. These should continue, aiming for verification and reproducibility. It would be useful to illuminate the relationship between input and output data.
- Transfer of the global findings into regions – i.e., portrayal of the implied entities in each region versus the global model.
- Further study of uncertainties. This effort would examine what constraints on supply are reasonable, and how capability matches desires. Some participants urged consideration of a longer time horizon to see if it posed new constraints.
- Large-scale use of unconventional fuels. It may be timely for IIASA to take on a study in this area, especially of coal gasification or coal liquefaction.
- Use of the Program's data base. There was little discussion emphasizing the value of the global energy model data base: it is unique. Consideration should be given to the question of data-base access and to periodic updates.

There are a number of examples of use of the Program's report by regional organizations, by ministries at the national level, and by at least one industrial company. This experience reinforces the importance of wide distribution of the publication. It also stresses the importance of continuing to insulate IIASA from political policy and political decision making.

Feedback from users will be especially important for formulating the next steps for IIASA's energy efforts. While this phase of the Program is nearly complete, feedback can refine areas for counselling and can help define areas that will deserve continuing effort. The geographic, demographic, technological, and infrastructural aspects of energy sufficiency will remain major global concerns deserving continuing incorporation in IIASA planning.

It has been a privilege to chair the sessions on energy and to make this presentation on putting the monumental achievements of IIASA's Energy Systems Program to work.

FOOD AND AGRICULTURE SYSTEMS: GLOBAL AND NATIONAL ISSUES

Professor Wouter Tims
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The session focused on the global and national issues addressed by the Food and Agriculture Program. The Program is at an intermediate stage: some economic models for selected countries are now in the advanced stage; others are progressing; and a new task in the field of resources, technology and the environment is presently being formulated. As a result, three major topics appeared in the discussions:

- The experience with the use of some of the national models developed in the context of the Program's efforts;
- Prospects for the future use of the Program's system of models, and limitations of the system;
- Possibilities for further development and extension, including the most desirable way to dovetail economic and technological modeling.

The use of four national models was discussed.

Applications of the Hungarian model for policy analysis were examined and the following conclusions drawn:

- The model is useful for national planning, including the planning of international trade in agricultural products;
- The detailed description of production is useful for simulating future development.

Applications of the model have pointed to some improvements that can be made to add to the practical usefulness of the next-stage model.

The experience with the Indian model was reviewed. Against the background of the specific problems of the Indian economy, it was shown how the model could be and has been used. Emphasis was put on the capability of the model to specify the policies required to achieve the government's objectives in agriculture and thus to check the feasibility of the current five-year plan for India.

The structure of the Polish model was described with respect to both private and state-owned farms. The model is expected to be useful for a wide range of issues faced by decision makers for planning in this country. Work on the model has not been completed, but it will be geared principally to the main agricultural policy issues that are presently observed in Poland.

The use of the Swedish model was discussed, with particular attention given to the analysis of interactions between the agricultural sector and the rest of the economy. Users considered the model worth while, as it gives interesting new insights. Extensions to the model are under consideration, particularly for the purposes of distinguishing the energy sector and analyzing land use for meeting energy needs.

In general, the discussion showed that

- There is growing practical experience of a positive nature with the use of the models;
- The problems addressed and analyzed by using the models are different and country-specific; but
- The models are found to be useful and relevant, especially since they can be linked into a global system.

Concerning future use and limitations, the discussion suggested a variety of possible extensions of the models that could enhance their usefulness:

- Inclusion of technological developments
- Disaggregating the *n*th (nonagricultural) sector
- Considering energy explicitly
- Incorporating environmental effects and feedbacks
- Maintaining the potential of the system and developing it further over time in order to ensure the fullest possible use of the efforts already invested in the work
- Intensifying exchanges with decision makers about the work on the models.

The difficulties of the interdisciplinary modeling work needed for proper integration of economic and technological/environmental analysis were underlined.

Particular attention was given to the way in which the two tasks – the modeling efforts and the studies on the interaction of resources, technology, and environment – under the Program can be made to benefit fully from each other. The need for both approaches and their validity were generally endorsed, particularly when it could be assured that the two would be mutually supportive and reinforcing.

MIGRATION, URBANIZATION, AND DEVELOPMENT

Professor Walter Stöhr
Director, Interdisciplinary Institute for Urban and Regional Studies, University of Economics, Vienna, Austria

Of the six tasks comprising the Human Settlements and Services Area – health care systems, migration and settlement, public-facility location, manpower analysis, urban change, and population resources and growth – the consultative session discussed primarily the first two, which are the oldest.

The reports concentrated on the theme of *IIASA Conference '80*, "From Problem through Research to Use" although the discussions inevitably extended to a broader issue, "from problem through research to *problem solution*," as the *use* of a model was considered not equal to the *solution* of the real problem.

It was widely agreed that IIASA's work has stimulated research and planning in most National Member Organization countries. However, so far it is not known to what extent this research and/or planning is actually able to influence actual problem solutions. For one National Member Organization country, for instance, it was reported that recent health planning and policy work, sophisticated and of considerable magnitude (though not based on IIASA research), was in fact not able to change the actual state of health of the population; in a pointed way the discussant stated that the health planning system had very little to do with the actual state of health of the population. Similar indications were made for various countries regarding the effectiveness of policies aimed at influencing migration patterns and/or urban development. It was not possible in the short discussion period available to conclude whether these facts are due to the inherent difficulties of some of the problems addressed, to the methodologies proposed for their solutions, or to the interrelations between researchers/model builders and decision makers in individual countries. But it was felt that this might be an important topic for further investigation.

Let me now deal in more detail with the two major tasks discussed.

The Health Care Systems modeling group is working on developing a family of submodels simulating different parts of the health care system, including variables such as population morbidity, manpower, resource allocation in health care services, etc. The discussion pointed out that it may be desirable to introduce more differentiated variables of the life cycle, rather than merely birth on the one end and death on the other, e.g., different degrees of handicap of certain population groups. The health models are oriented to different levels of the health care system, namely national, regional, local, and hospital or individual facility level, but deal also with problems at the supranational level of the health care system, e.g., those related to international agencies such as the World Health Organization.

The consultative session reported particularly on progress in collaboration. Specific examples are the collaboration between IIASA and Canada, Czechoslovakia, and the UK. Each of these countries represents a different system of health care planning: Canada, a market system; Czechoslovakia, a planned system; and the UK, a semi-planned system. Such a comparative approach between different types of health care planning systems was considered particularly instructive.

The panel discussion heard reports by representatives of Czechoslovakia and the UK, discussions of practical applications of the work developed by the health care team, and responses by users. In all cases, the comments were favorable, with the prospect of an increasing involvement between the Health Care Systems Task and the National Member Organizations. In the UK, the usefulness of IIASA's work in the health care field was recognized in the government by the Minister of Health. In Czechoslovakia, the Ministry of Health has formed a special scientific group to develop and implement IIASA's health care models. It was also noted that there is much potential for further and closer collaboration with other institutions, such as the World Health Organization.

The ensuing discussions commented particularly on the value of IIASA's work with regard to developing the health care model further. It was suggested that in the next generation of models increased emphasis should be placed on the behavioral aspects of the interrelation between demand and supply in the health care system. It was noted that in many cases it is difficult to reach a reasonable degree of coverage between the implementation of new health care facilities and the target groups for which they are meant. Another suggestion urged institutional support for self-care in the health sector, in addition to services provided by institutions directly to the consumer.

It is expected that further research in developing new methods will be promoted through close cooperation between the Health Care Systems Task and other tasks at IIASA. For example, the health care task and the public-facilities task of the Area plan to investigate the behavioral aspects of health care demand over space and time.

The Migration and Settlement Task was the second task discussed in the consultative session. It was reported that the method developed by the Area, called demometrics, has been applied in some 17 National Member Organization countries so far; reports and analyses of almost all the individual countries are available. Detailed reports were made in the session by representatives of Hungary, the Netherlands, and Poland. All of these countries are using population distribution as a major policy variable. The Netherlands defines population distribution targets as a basis for its territorial planning. Hungary and Poland use population distribution variables as inputs to their national planning process.

With regard to further development of the work on demometrics, two alternatives were discussed:

- To increase the number of countries to which the demometric model is applied beyond the 17 countries where it has been worked with so far.
- To deepen the model, particularly to relate migration more explicitly to economic and social variables, or to such variables as the sectoral structure of urban economies and changes in international relations between industrialized and developing countries as they affect the growth and structure of urban economies and migratory flows. Another suggestion was to focus particularly on the determinants and causes of migration from a behavioral point of view.

The tendencies in the discussion seemed to favor deepening the existing model. It was further suggested that, if additional countries are selected for application of the model, they should preferably be from the group of developing countries, where the problem of migratory pressure on very few urban areas with unsatisfactory economic structures is most urgent.

Another point discussed in relation to the Migration and Settlement Task was the scale of territorial units at which analyses are performed. The advantages of large regional or territorial units are that analysis can be made operational more easily, and data are more readily available, but the disadvantage is that some of the key social problems, particlarly with regard to the causes of migration, are not detected. A lowering of the scale of analysis to microregional and, where possible, even to urban levels, would be desirable.

It was suggested that the description of the structure of the demometric model and possibilities for its further development should be made available to all countries in the form of a manual describing the requirements and procedures.

To conclude, I would like to mention two reactions by representatives of international organizations: the representative of the United Nations Population Division, New York, stressed that in his opinion the work of the Migration and Settlement Task is the most advanced policy-oriented work in comparative international studies in the field of migration and settlement; he found particular value in the data bank that has been established on these issues here at IIASA, containing, as it does, data that not even the United Nations has access to at the moment. The second suggestion was that contacts with international agencies working in similar fields, such as HABITAT in Nairobi, should be intensified further.

REGIONAL DEVELOPMENT: FROM CASES TO GENERALIZATION

Professor Andrzej Straszak
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I am honored to present to you the results of the consultative session on Regional Development. From the beginning of this second IIASA Conference we have had an opportunity to become familiar with outstanding results obtained in this field at IIASA during the last four years. First, the Director's report gave us a comprehensive description of this line of IIASA activities, and Professor Murat Albegov, the leader of this area of research, has added details. Hence I will not repeat, but rather add some points.

IIASA's regional development work has concentrated on case studies supported by methodological research. Four regions have been chosen: Silistra in Bulgaria, Notec in Poland, Skåne in Sweden, and Tuscany in Italy. It was therefore essential for us to examine in depth the experience with using IIASA's work in these National Member Organization countries.

The consultative session gave us an opportunity to hear direct reports from Bulgaria, Italy, Poland, and Sweden on this subject. The presentations during our session showed that this IIASA work has reached its potential clients: regional decision makers and their staffs, as well as analysts and the scientific communities. Of course, research on regional development problems is not new in Bulgaria, Italy, Poland, or Sweden, or in other National Member Organization countries. However, IIASA has contributed a new concept to this area of research, as was stressed by Dr. Levien in his opening summary. This new concept – integrated regional development – emerged as a result of generalization of previous IIASA retrospective case studies undertaken in the USA, the USSR, and Japan at the beginning of IIASA's work. The first international assessments of three world-famous large-scale regional development programs, for the Tennessee Valley Authority in the USA, the Bratsk–Ilimsk Territorial Production Complex in the USSR, and the Shinkansen Railway in Japan, as developed by IIASA, gave a unique opportunity to examine goals and strategies, organization and planning, models and computer utilization, environment and resource management, and technology for development. *Ex post* international assessments of the effectiveness and efficiency of these development programs showed the effectiveness and comprehensiveness of the programs – but the integration of the programs was still a weak point.

However, nearly all present and future regional development programs are and will be faced with scarcities of resources, conflicts, and multitudes of constraints, and they must cope with them.

The applied systems analysis of regional development undertakings is distinct from routine regional planning, and, therefore, the integrated regional development concept arose naturally. It is "integrated" that is the key word.

As many of you know, there were some doubts at IIASA about whether IIASA could initiate such a complicated line of research and obtain successful results in the near future. The existence of huge interlinkages and interdependences in the integrated development approach made many fearful that this new venture could not be undertaken successfully.

Today, however, after three years of extensive in-house research at IIASA, which has built up a network of cooperating research institutes and organized several methodological workshops and task force meetings, and, of course, performed actual case studies of real problems in the Silistra, Notec, Skåne, and Tuscany regions, some breakthroughs have occurred. IIASA has responded to the problems, and seen how to tackle their complexities and how to avoid the huge dimensionality issue by launching the so-called "top-down" and "bottom-up" approaches. Both a hierarchical structuring of the regional development problématique and guidelines for modeling specific issues and interlinking models have been proposed. During the consultative session these constructs have been carefully considered from the points of view of implementation and their universal features.

There is no doubt that these two IIASA constructs have a great potential for implementation, as well as widespread use. This follows from the already existing partial implementations performed in the Silistra and Notec cases. It was stressed several times during our discussions that, to manage any regional development problem, more forecasting, planning, and control are required than are required in the usual managerial activities. Thus, it is necessary to define the optimal regional specialization from the point of view of resource efficiency as regards all sorts of resources: material (productive), manpower, and natural (environmental). Since inefficient uses and scarcities of resources occur in both rich and poor countries, it is imperative that regions become more self-reliant so as to keep the present energy and material crises on national and global scales from becoming more severe.

There is no doubt that, after several years of extensive research, IIASA has gained a substantial amount of knowledge in regional development and integration of at least some subregional issues, such as agriculture, water, and population. Moreover, industrial, land-use, settlement, and other issues are now being considered. The participants of our consultative session view the roles of IIASA as follows.

First, IIASA should demonstrate through a series of case studies that it can and will elaborate a general methodology of regional problem formulation and solution in such a way that it will be straightforward to proceed to analysis and design for each particular case.

Secondly, IIASA should take the opportunity to study and analyze a wide range of issues and questions in individual cases, so that more justified and broadly applicable generalizations can be formulated.

However, it should not be forgotten that, in reality, each region and its related program are unique, differing from the other ones geographically, historically, culturally, socially, economically, and methodologically – and that a direct transfer of experience is, therefore, limited.

Nevertheless, even in such different case studies as Silistra, Notec, Skåne, and Tuscany some similarities have been found. The integrated regional development approach is still so complex that no one has enough experience and knowledge to solve this issue alone, and hence exchanges of experience will be fruitful for all the interested parties.

The main features of the integrated regional development construct are: widespread use of models and model interlinkages; the analysis of goals, their consistency and priorities, and conflict resolutions; and integration with respect to objects, subsystems, and values.

It was stressed several times during our deliberations that IIASA can and should play a more important role in the field of regional development. However, much more research effort should be added to that of IIASA by collaborating institutes. As is recognized, IIASA's experience and knowledge in energy, agriculture, population and settlements, water, and other resources, as well as in environment and industry issues, give it a unique world-wide opportunity to construct integrated regional development research. As a matter of fact, regional development issues have been reported by all the IIASA area leaders during this Conference. The participants in the regional development consultative session strongly support this line of IIASA activity and advocate program status for this field of IIASA research.

It has been stated – and it is of considerable importance – that the scientific communities as well as decision makers and planners in many National Member Organization countries have reached a level of experience about IIASA's goals and research methods that can stimulate further collaboration. All four regional development case studies are well imbedded in their national settings and play, to a large extent, a pilot role, with a potential for further use in other regions. During our deliberations, we found that, when some questions are answered, others arise, and – as usual in research done well – IIASA has generated more questions than answers. But this can be considered a good prospect for the future.

TOWARD INTEGRATED POLICIES FOR RESOURCE AND ENVIRONMENTAL MANAGEMENT

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The Resources and Environment Area studies water, air, land, and mineral resources and the environmental consequences of their utilization. Prepared statements relating to the mission of the Area were made by the following members of the Conference: Professor Z. Kaczmarek (Poland), Dr. C.S. Sinnott (United Kingdom), Acad. G. Kovacs (Hungary), Professor C.S. Holling (Canada), Professor V.A. Kovda (USSR), and Dr. I. Gouevsky (Bulgaria). There was a wide-ranging discussion of each of these statements by various members of the group. Most of the discussion centered on present and past case studies in the Area.

It was agreed that the summary report should relate to the question of *global* versus *universal* problems as discussed by Dr. Roger Levien at the opening session. Universal problems are those specific to a given region, usually within one country, but which have aspects that are common to other regions and countries. It was further agreed that the report should focus on the appropriateness of treating universal problems through the mechanism of the case study, in particular, on the process by which IIASA selects such case studies and how it decides the amount of its resources to be devoted to such studies.

The following advantages of the case study approach were discussed. It provides:

- A *real* problem.
- *Access* to existing data. A problem in the Area is the regional variability and scarcity of resource and environmental data.
- *Interaction* with the users' staffs. This provides a degree of relevance of results to the user or decision maker.
- The opportunity to *influence* future data collection. Existing data are usually not sufficient for modeling efforts. In general, the methodologies used generate new data needs.
- *Research* opportunities in the development and comparison of alternative models and methodologies. IIASA has a unique role to play in *comparing* the results of alternative models and methodologies applied to the same set of data. Important trade-offs and benefits of simple models versus complex models can be gained in this manner.
- *Training* for users and decision makers through their association with the case study, either at IIASA or in agencies of IIASA's National Member Organizations.

The following problems of the case study approach were identified:

- The role of IIASA as a *consultant*. While cooperation with the user is essential to the success of the case study, IIASA must maintain its independence to conduct research and to compare alternative approaches to the analysis of the problem.
- The impression that IIASA will make the *decisions*. It should be clear that IIASA can only provide tools, analyses, and information to the user or decision maker.
- Lack of understanding of the *universal* nature of the case study. More attention should be given to emphasizing the common features of a case study to National Member Organization outside the case study area.
- Recognition of the time and cost of *technology transfer* and *implementation* of case study results. It should be recognized at the outset of a case study that IIASA's capabilities and resources in technology transfer are limited.

Our group concluded that case studies have been effective in generating new methodologies and in promoting applications of IIASA's work.

We recommend that:

- IIASA develop *criteria* for selecting future case studies. These criteria should be based on assessments of the effectiveness of earlier case studies.
- IIASA *decide* how far it wants to go in transferring technology and implementing case study results.
- IIASA *decide* on the proper balance between case studies and other activities such as global studies, in-house basic research, workshops, and state-of-the-art reviews.

We conclude by noting that the IIASA alumni present at the meeting are an enthusiastic and loyal group. We request that Chairman Gvishiani convey our appreciation to Professor Oleg Vasiliev for his effective leadership of the Area during the past three years. We are also pleased by the smooth transition of leadership under Dr. Janusz Kindler.

The Chairman would like to express his appreciation to the Cochairman, Professor Genady Golubev, for his assistance in planning the meeting.

SYSTEMS APPROACHES TO INDUSTRIAL PROBLEMS

Academician Evgeny Mateev
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During the Management and Technology Area's consultative session five topics were discussed. The main points for each topic are given below.

IIASA must be interested in industry and industry must be interested in IIASA. In most countries industrial growth is a major issue, either because existing industries are declining or because new ones are not being created fast enough to maintain or amplify the quantity of employment or to improve the well-being of the population. This is a serious problem. Political leaders, industrial managers, and the people themselves need sound, scientifically based advice to help them solve this industrial problem. IIASA intends to provide such guidance. Important aspects of the problem are: how to manage the introduction of new technology, how to apply new technology to improve the ability to manage, and how to design a future that is based on well-managed industrial growth on such a large scale that the patterns of living may be changed everywhere. The Area should be particularly concerned with these issues. A particular case, arising in three mountain states of the USA, was outlined by Dr. Sol Penner and discussed.

The problems are many but the resources are limited. Some participants said that the Area's research programs have tended to be too numerous, so that resources have been spread too thinly, and to lack a common theme to link them together. This has reduced the practical usefulness and timeliness of the results. The number of elements in the research program should be reduced and the available resources concentrated.

Others believed that to concentrate on fewer tasks might lead to over-specialization; and neither IIASA nor the Area can compete with other institutes in specialized, in-depth research. The Area should do what other, specialized individual research groups do not do. That is, it should discover universal rules, i.e., rules that are common to many specializations and illustrated by many real-world cases. The Area should therefore always be looking at several problems. It was agreed that these should usually have some common theme. And, of course, the shortage of in-house resources must be offset by collaboration with industrial organizations, government agencies, and other research institutes. Joint programs and the secondment of people to work at IIASA are essential and should be encouraged.

IIASA should not just be an information clearing house. It was stated that industry in market economies is interested in profitable results, not in idealism. Global models and generalities without specific application will attract neither their support nor their interest. This attitude was also expressed by representatives of government and industry in planned economies. It was agreed that, while it is nice and quite useful for IIASA to act as an information exchange center and as a meeting place for discussion, this is not enough. The Area in particular should aim to produce significant, useful *results*, directed toward customers who can be clearly identified in advance. The answer to the question, "Who is the customer?" should be "The man who wants the answer and who will help us find it."

For the Area, it is just as important to choose the right "customers" for its work as it is to choose interesting problems. This means that the Area's researchers must make and keep contacts with senior managers in government and industry as well as with scientists. We discussed how to do this at some length.

A very significant technology that is affecting all of us more and more is informatics. The Cochairman of our session, Alec Lee, prefers, like the French, to call it *télématique* (or telematics) to emphasize the importance of the communications media. The Area is soon going to assume responsibility for this work at IIASA. Two tasks will probably be organized to deal with the technology. One will concern itself mainly with technical questions, including technological forecasting in telematics. It is proposed that the other task study systematically, during the next few years, the impact of developing information technology on foci of organization, styles and techniques of management, and patterns of living. It will be necessary to obtain cooperation and participation from many firms and government agencies in this work. It was, however, generally seen as not only of immense importance in itself, but as something that would tie together the other tasks of the Area, such as innovation, problems of scale, management of complex organizations, and even risk. Although some industries may be unwilling to share their knowledge and experience with IIASA in these tasks, others – both in market and in planned economies – will do so willingly.

THE CHALLENGE OF APPLIED PROBLEMS TO THEORY DEVELOPMENT

Professor Michel Balinski
School of Organization and Management, Yale University, New Haven, Connecticut, USA

The emphasis of this Conference has been on the uses of IIASA's work in the various areas in which it is engaged. Accordingly, the System and Decision Sciences Area organized a panel around "the challenge of applied problems to theory development."

Two principal questions were addressed:

- What guiding principles should be followed to ensure that methodological research is useful?
- What are the uses of methodological work?

These seemingly simple questions elicited an interesting and spirited debate that delved into specific Area projects, past and present; into the history of IIASA's choice of research projects; the challenge of applied problems to theory development; and, indeed, the challenge of theory development to applied problems, for it should not be forgotten that new theory may restructure the way we think about problems. With so many scientists in both this room and that in which we held our debates I can report confidently to you the truth of Mark Twain's observation:

> There is something fascinating about science. One gets such wholesale returns of conjecture out of such a trifling investment of fact.

Instead, therefore, of attempting to review the many fascinating points that were made in the course of our discussion, I would like to give you several views concerning taste and style in undertaking work and using its results, which I found arresting, and which I hope this larger audience will find interesting too.

The first view borrows from words used by John von Neumann some years ago in discussing the state of mathematics.

An idea or a theory of systems science, or mathematics or economics, originates in empirics although the genealogy is sometimes long and obscure. But once conceived, it begins to live a life of its own. As it travels further from its empirical sources, or still more, if it is a second or third generation indirectly inspired by ideas that come from "reality," it is beset with very grave dangers. It becomes more and more purely aestheticizing, more and more purely *l'art pour l'art.* At a great distance from its original empirical source, the subject is in danger of degeneration. While at its inception the style may be classical, when it shows signs of becoming baroque then the danger signal is up.

In my view, the danger signal is up when it comes to the majority of the established scientific disciplines of our day, from mathematics to economics to political science and also other subjects. "Good science" unfortunately means baroque science: complex, difficult to achieve. sophisticated, overbred . . . in the long run all too often insignificant. IIASA, I b[illegible]ers a rare opportunity – in a manner that academic institutions do not – o[illegible]ting return to the source: the reinjection of empirical ideas. These should be taken from global issues – issues that go beyond individual nations – for IIASA is unique in the ability to do so. It is the process of grappling to *understand* real empirical issues that can lead to truly new and innovative insights and new methodologies. IIASA has a potentially fundamental role to play for science.

Using the results of system and decision science research raises the image of elaborate techniques used to solve complicated, large-scale models. And such is one real sense of what it means to *use* the results developed by the Area. But there are many meanings that can be attached to the word "use." A perhaps less evident, but no less real, use of methodological research is the establishment of new scales of reference – of a new language – of a new way of talking and thinking about a class of problems . . . even if the model behind the thought itself is never "used," in the sense that none of the specific solutions it may suggest is ever actually taken into practice. The same thought is expressed in the observation that it is the basic, indeed the *primitive*, ideas of a methodology that have greatest impact and not the elaborate constructs. A prominent economist, known principally as an excellent and insightful technician, when asked what methodological tools he used while serving in a prestigious policy role, is reported to have thought for some ten minutes, then answered, "the concept of opportunity cost." The Area is clearly doing work that is useful in all these senses.

Methodological work is best when kept honest by empirical demands. Yet the whims of the ephemeral phenomenon that is the creative urge must be nurtured. And this means that critical masses of researchers with common disciplines must be formed. It seems that a delicate balance between the calls of reality and the disciplinary needs of creative research must be established and maintained. The attempt is well worth the investment. These words, from the *RAND Twenty-Fifth Anniversary Volume* (1973), are particularly revealing:

> [The methodological ideas] were not there when we started. And many of the modern ones are in widespread use today because RAND invented or developed them . . . In the long run, it is this creative work that may be RAND's most lasting achievement.

Basic new ideas are indeed the only ones that are lasting.

Conclusion of the Conference

THE IMPORTANT THEMES OF THE CONFERENCE

Roger E. Levien
Director of the International Institute for Applied Systems Analysis

This second IIASA Conference has been an intense experience for all of us. IIASA staff have been preparing it for many weeks, and you have listened with patience and attentiveness to three days of presentations. It has been a very rewarding experience as well, for it has admirably served the purposes set forth in the Charter:

> The Conference of the Institute is the major forum for providing broad scientific and technical advice to the Council and the Director; for encouraging the programmes of the Institute and linking them with the research efforts of other national and international institutions; and for fostering understanding of the work of the Institute.

In line with these purposes, we have provided opportunities for you to help us to identify the directions that we should follow in the future. However, I would also welcome letters from those of you who have ideas about the content and the shape of IIASA's research program that you have not yet been able to express. Because we have thus far learned a great deal from your comments, the Conference is already a success; we look forward to further benefits as we receive your letters.

My opening remarks used the concepts of problem, research, and use to structure IIASA's past and future activities. Now I shall use them to structure my initial reactions to what I have heard, and sometimes to what I have not heard, during these past three days.

PROBLEM

The message with respect to IIASA's choice of problems was implicit rather than explicit. Since I heard no suggestions for substantial change, I gather that you agree generally with the Institute's agenda, even though many of you no doubt have the feeling that it is an exceptionally ambitious one. I hope we have been able to convince you that our approach to this ambitious agenda is reasonable; while keeping in mind the wide range of issues of international importance that should be addressed by this uniquely constituted Institute, we proceed by concentrating our attention on specific sectors, intending eventually to bring the results together in a comprehensive picture.

The ideas for new themes, new approaches, or new emphases that I did hear centered on the industrial sector. Both in the Conference sessions and in private discussions, a number of voices have urged IIASA to strengthen its contacts with industrial research organizations and industrial decision makers, and to turn its attention to the problems that all nations face in shaping their industrial futures. These are problems that have come about because of rapid growth in factor prices, particularly energy prices; because of new technologies, which threaten to change factor proportions in the production process; because of the shifting geography of resources and industrial production; and because of the growing populations and needs of the developing countries. This confluence of changes is forcing every country to restructure its industry. How can this restructuring proceed in a way that is complementary rather than destructive? This is one of the key questions of the coming decades. I feel that you have advised us to turn the Institute's attention to this problem.

RESEARCH

You have also advised us about the practices that our research should follow.

One of the ways in which systems analysts formalize their understanding of phenomena is by building computer models. A major theme of your comments concerned models – our theories and our tools.

First, I have heard you caution us to pay greater attention to the uncertainties that necessarily enter all such models and not to be fooled into believing that precise numbers represent reality precisely.

Second, I have heard a call for extending, formalizing, and documenting the models we already have, particularly our Energy Systems Program models and our Food and Agriculture Program models. However, as systems analysts we must be aware of the other danger: extending models beyond the limits of understanding and use. We must be sensitive to the balance between complexity and usefulness.

Third, and even more important, is the suggestion that we establish a firmer base for continuity in our modeling efforts. I understand fully the concern expressed by Professor Wouter Tims about the Food and Agriculture Program's system of models. In this case, we have groups in 14 countries now, and in additional countries in the future, working with us to develop national models to be linked through IIASA's system of models. If the IIASA system is terminated in 1982, much of the work that went into the national model development could be lost. However, I assure you that IIASA will not terminate a successful effort in midstream because of some arbitrary principles of program planning. Rather, we feel an obligation to plan for the continuity of the Food and Agriculture Program model sets, just as we do for the Energy Systems Program models, and for other successful ventures. But we do face difficulties. The turnover of staff and changes in research programs are greater at IIASA than at national institutions. Therefore, we must find some means by which to establish continuity of effort, even while we do not have continuity of staff. I do not think this is an insolvable problem. In fact, we have solved it in certain cases already; but it is a problem that underlies planning for the future of our modeling efforts.

A fourth suggestion is for IIASA to have increased contact with decision makers while building its models. The mutually beneficial effects of such relations are a lesson that many systems analysts have learned. In the USA, and perhaps in other countries, formal mechanisms have been established through which decision makers and modelers can work together. I think the establishment of such a mechanism (for example, a forum meeting regularly) might be useful for IIASA, too. However, it is hard for the Institute, which is distant from the decision centers of most of its National Member Organization countries, to bring decision makers to its site. A more feasible approach might be for the Institute to use its network of collaborating institutions to help establish those contacts. Indeed, this has been one of the successful outcomes of the Food and Agriculture Program's network, whose participating national groups generally have close contact with their national decision makers. Improvement is possible in this aspect of our work; it should be a priority for each of our groups.

Finally, I was pleased to see that you share our recognition of the important role that IIASA can play in bringing about the linkage of national models. Our Food and Agriculture Program model set is again an example here, but there are others that have a similar character. The function of IIASA, given that many groups are building national policy models, is to establish a common structure that enables these models to be linked, giving to each model a dimension that it otherwise could not achieve, to the mutual benefit of the participants and those concerned with international policy.

Another major topic of your comments concerning research was case studies. Professor Donald Harleman, among others, raised the issue in his remarks. I agree that to gain the maximum benefit from case studies, we must be sensitive to their prospective dangers. Prominent among them is the possibility that IIASA may come to be viewed as, or in fact become, a consulting firm. So we have to be aware of the precise use and usefulness of our case studies. In this sense, Professor Harleman's recommendation that we base a policy of developing case studies on an examination of the case studies we have carried out so far is a wise one, and we will attempt to do so.

I think it is useful, too, to be aware of one of the important roles that he mentioned for IIASA case studies: the comparison of alternative approaches. For example, in its Lake Balaton study IIASA has provided the setting for trying out different approaches, developed in different countries, with the same base of real data. Such comparisons are difficult to make within a single nation; consequently, IIASA has made a significant contribution.

You have also cautioned us to be careful to build into our case studies an effective transfer and implementation mechanism; otherwise, the general value of the work may be lost. Unfortunately, IIASA has neither the expertise in the many different local situations, nor the talents in languages, nor the time, to do a considerable amount of implementation work. This is the reason we have chosen the style that we call "second-order consulting," working with analytical groups in the nations, who in turn have the responsibility for direct contact with the decision makers.

A third topic of your comments on research was data bases. I must admit that they pose difficult problems for us. However, we are going to have to solve these problems in the near future. In the course of our studies, we have by necessity created data bases, several of which are "unique and valuable." Dr. James Young described the data base in the Energy Systems Program as a unique world resource. A similar comment was made about the data bases of migration and settlement patterns in the Human Settlements and Services Area, and the same can be said for several of our other data bases. Their existence poses a challenge to IIASA similar to the one posed by the models we have developed. IIASA's staffing pattern does not readily produce the continuity of effort and focused expertise required to build up and maintain data bases. Therefore, we must examine the role IIASA can play in providing data bases, how they will be funded, and how access to them will be provided. It seems to me that, if we establish a publicly available data base, we have a responsibility to keep it up to date; this requires clerical and programming skills, as well as scientific ones.

To avoid diverting IIASA's resources away from science and analysis, it will probably be necessary to find additional funding and to charge for data-base use in order to support data-base services. These ideas, however, have not yet been carefully explored. On the basis of your comments at the Conference, we shall pay greater attention to this issue.

We also received some comments on IIASA's research "style." Academician Evgeny Mateev cautioned that IIASA should not fall into the trap of becoming simply a clearinghouse and an information exchange mechanism. I agree fully with this view. It is natural for us in the early stages of developing a research topic to use conferences and workshops for planning and organization. Later on they can be used for progress reporting and review, and dissemination. But while meetings perform an essential function, they are a means to a larger end. We recognize that IIASA must have substantial and important research underway. Indeed, without this solid base, the attractiveness of IIASA as a clearinghouse and as an information exchange mechanism would be lost.

Professor Michel Balinski called our attention to the essential roles of "taste" and "style" in the choice and conduct of our research. In his view, IIASA offers theorists an opportunity to be in touch with real global and universal problems, and this opportunity, if taken, should lead to new and exciting theories of wide usefulness. He also challenges IIASA to keep things simple; to seek elegance and economy in theory development and in methodology, in contrast to the tendency of many systems analysts to try to achieve realism through great detail. We accept this challenge.

USE

Achieving the successful use of IIASA's results is the central topic before us at this Conference. As we have gained experience and matured, we have produced a growing number of potentially useful results. We hope to make them even more useful in the future. This is where your guidance, your assistance, and your perceptions have been, and will be, valuable to us. Your comments confirmed the three types of use of IIASA results that I described in my opening remarks: to improve understanding, provide methods, and suggest strategies.

- Words such as "guidance" and "perspective" were used to describe the benefits that the global energy models can provide to decision makers at the national and regional levels. This is precisely what we mean when we say "IIASA's work can improve understanding."
- We heard that the Food and Agriculture Program's models have been useful in decision making in India, in Hungary, and may soon be used in Poland; and that the Health-Care Systems Task's models have been helpful in health-care planning in the UK and Czechoslovakia. Thus, our discussions have confirmed methods as a second benefit of IIASA, a second form of output.
- The most dramatic and clear-cut example of the third type of benefit, i.e., strategies, is the Energy Systems Program's perspective for the future, which has been applied by, among others, the European Community.

Thus, your comments neither add to nor subtract from the types of benefit that IIASA's work can provide.

With respect to the audience for IIASA's results, you urged us to develop effective methods for communicating with decision makers. This is high on the agenda of the Institute at this moment. I want to call your attention to our new publication series, *Executive Reports*, addressed to the decision-making community and the public. These are distinct from our *Research Reports*, which are aimed at the scientific and analytical communities. The first two *Executive Reports*, based on IIASA research, have been prepared by Bradley H. Hitchings, a writer who comes to us from *Business Week*, a US magazine addressed to decision makers. We are also considering other methods of reaching this audience through visits, briefings, seminars, and so on. We would welcome your suggestions concerning how a relatively small research institution, in a somewhat isolated location, can have an impact on decision makers, with busy schedules, spread around the world.

I also heard the suggestion that we strengthen our relations with other international organizations. I agree; indeed, we already have good contacts with many of them. They play important roles in the world, quite different from ours, yet they are concerned with many of the problems that IIASA is studying. Thus, both IIASA and the other international organizations have much to gain from strengthened linkages and an improved two-way information flow.

Professor Walter Stöhr struck a note that sets an appropriate concluding tone to this discussion of use. He urged us to be "realistically modest" in our ambitions to affect societal systems such as the health-care system, the migration system, or the settlement system. Many policies have been tried in many countries to affect the behaviors of these systems, with more failures than successes. These systems are complex – and it may be that we are at a stage where the most that IIASA can hope to achieve is improved understanding, rather than improved strategies. So we have to choose our targets appropriately and to aspire, depending on the nature of the system, to the benefits that seem feasible: understanding and methods more often than strategies.

IIASA Conference '80 has more than achieved our goals for this second IIASA Conference. This fact is due in some measure to the efforts of the IIASA staff. But it also owes a great deal to your constant attention and patience, for which we are very deeply grateful. I know it has been difficult for each of you to take these three days from your own activities, especially for a meeting whose primary aim is to benefit IIASA. Therefore, I wish to express my deep and wholehearted appreciation for your active participation and for your efforts on IIASA's behalf. I hope that you will retain your contact with the Institute, come back often, and give us the continued benefit of your experience and wise guidance.

THE SPIRIT OF IIASA

Jermen M. Gvishiani
Chairman of the Council of the International Institute for Applied Systems Analysis

Our Conference is over. I believe that during the past days the participants – among whom were representatives of National Member Organizations, and scientific and business communities – had an opportunity to get acquainted with the progress of the Institute's research and its applications. We hope that there was an opportunity to make constructive inputs, both into increasing the practical use of the research results and into mapping out the future paths of the Institute's development.

As was repeatedly stated during the Conference – and as the structure of its agenda reflects – the main purpose of the Conference was to ensure a maximum of interaction between the participants and the research staff of the Institute. We expect that these interactions will result in an impulse to the Institute's research, will enrich our understanding of contemporary world problems, and will encourage a more practice-oriented focus in IIASA's work.

We have heard the reports of the chairmen of the consultative sessions. I think they fully justify our hopes and expectations with respect to the results of the Conference. Of course, finding how to reflect these views in concrete ways in our research plan will require special efforts by the Institute's staff, and can be done only after a thorough analysis of the Conference documents and reports. The Council of the Institute, which had its regular semiannual session during the Conference, decided to give special attention to incorporating the most valuable contributions of the Conference into this plan at its November meeting, when the final approval of the next five-year research plan will be made.

Nevertheless, in the process of our meetings and discussions it has already become evident that IIASA is developing in the right direction, that it is fulfilling its aspirations, and that it is producing valuable analytical and applied scientific results. There is no doubt about the fact that IIASA in practice demonstrates high efficiency in international cooperation among scientists, representing different countries as well as different scientific areas, schools of thought, and approaches.

What are the specific features of this stage of IIASA's development as we can see them now? And what are the preliminary conclusions of IIASA's second Conference?

First, we must note that new steps have been made to develop the *methodology* of applied systems analysis. The novelty here is that we see a maturing qualitative–quantitative approach in research on complex objects and events. To overcome a one-sided, narrow, purely formal scientific apparatus, it is important to exercise wider judgment, built not just on abstract thinking and theorizing, but also on judgment supported by new analytical techniques that apply logico-psychological procedures and modeling, and modern techniques of man–machine interaction. This opens up new opportunities for IIASA, since it raises the levels of reality and adequacy in its research.

The second new feature is the strengthening of the interdisciplinary aspect of the research, which enables the Institute to integrate and interlink various disciplines, scientific areas, and methodologies organically. IIASA now proves that the difficult route from the systems approach as a concept to the systems approach as a practical instrument for organizing and conducting analytical research on important problems facing mankind is now being successfully traveled.

The third feature peculiar to IIASA's recent development is the transition from considering separate models, reflecting the status and evolution of the investigated objects, to considering the interactions and interdependence that reflect the complex processes of reality. This is a higher stage of research, and an important advance in systems analysis.

As the fourth feature I should note the gradually growing scale of the problems investigated. They have broadened in scope to truly global and universal levels. Thus, IIASA's activity has become more comprehensive in its international character. This transition from separate phenomena to complex problems vitally important for all humanity is a recent feature, reflecting a tendency to make systems studies deeper, rather than just to widen them without proper foundation.

Finally, the Institute has built up significant scientific potential and successfully achieved the completion of several important stages of research. This moves into the forefront the task of implementing the scientific results; in other words, we must now pay more attention to completing the cycle "from problem through research to use." The notion of "applied systems analysis," which we chose for the name of our Institute, has become more tangible.

These five features – to which we point with satisfaction – should not make you think that we have achieved everything. Rather, each of these new developments constitutes a trend, a tendency in development. We still have some research tasks not oriented adequately toward application, or of rather limited importance. We are aware of this and consider these phenomena to be inevitable features of the searching process that must continue if we aspire to a healthy evolution of our Institute in scientific, methodological, and practical directions.

We share fully the views expressed by many Conference participants that to create IIASA was a farsighted action. The Institute is a practical result of mutual understanding, and, as a feedback, is an important means for its further progress. Here we have a demonstration, not only of the will to cooperate, but also of an effective, mutually beneficial form of joint effort by the international community of scientists, analysts, and decision makers.

Summarizing the results of the first IIASA Conference back in 1976 we spoke about the evolution of a new phenomenon, the "IIASA spirit." Now this has become an integral, indispensable feature of our life and work in IIASA: it focuses our knowledge and will to attack the urgent problems of mankind.

We feel confident in our expectations because of the impressive composition of the Conference participants. The fact that so many distinguished representatives of academia, research establishments, universities, government, and industry have been actively involved in the Conference gives us confidence in our endeavors and provides us with an important stimulus for the future.

I should like, on behalf of the Council, to express my thanks to all participants in the Conference, especially to those of you who have traveled a very long way to be with us. We wish you a good journey back to your homes. Thank you for your contribution to the ongoing development of IIASA. We hope you will come back to see us again.

I should like also to express special appreciation, on behalf of all participants, to the IIASA staff members who have worked hard to make the Conference a success. I am sure you realize that such a large meeting as this, in such a relatively new facility, requires a lot of organization. I believe that the staff has shown, as well as a fine application of the principles of systems analysis, an outstanding effort in the true spirit of IIASA.

Appendixes

APPENDIX A

The Details of the Conference Program

Monday, 19 May 1980

OPENING PLENARY SESSIONS

15:00 Inauguration of the Laxenburg Conference Area
For the City of Vienna: Mr. Hubert Pfoch, First President of the Vienna Provincial Assembly
For the Province of Lower Austria: ÖkR. Andreas Maurer, Governor of the Province of Lower Austria
For the Republic of Austria: H.E. Dr. Rudolf Kirchschläger, Federal President of the Republic of Austria

15:45 Opening of the Conference: Dr. Hertha Firnberg, Minister of Science and Research of the Republic of Austria

16:00 Opening Address: Academician Jermen M. Gvishiani, Chairman of the IIASA Council

16:30 Intermission

17:00 Applied Systems Analysis: From Problem through Research to Use: Roger E. Levien, Director of IIASA

18:00 Reception and banquet
Banquet Address: Prof. Howard Raiffa, Founding Director of IIASA

Tuesday, 20 May 1980

INFORMATIVE SESSIONS: OVERVIEWS OF IIASA ACTIVITIES (Roger E. Levien, Chairman)

09:00 *Global Issues*
Putting the Results of the IIASA Energy Systems Program to Work: Wolf Häfele, Leader, Energy Systems Program
Food and Agriculture Systems: Global and National Issues: Ferenc Rabar, Leader, Food and Agriculture Program

10:50 Intermission

11:10 *National and Regional Issues*
Migration, Urbanization, and Development: Andrei Rogers, Chairman, Human Settlements and Services Area
Regional Development: From Cases to Generalization: Murat Albegov, Leader, Regional Development Task

13:00 Lunch

14:30 Toward Integrated Policies for Water-Resources Management: Janusz Kindler, Chairman, Resources and Environment Area
Systems Approaches to Industrial Problems: Rolfe Tomlinson, Chairman, Management and Technology Area

15:50 Intermission

16:10 *New Approaches*

The Challenge of Applied Problems to Theory Development: Andrzej Wierzbicki, Chairman, System and Decision Sciences Area

The Evolving Craft of Systems Analysis: Hugh J. Miser, Executive Editor, Survey Project

17:30 Adjournment

Wednesday, 21 May 1980

CONSULTATIVE SESSIONS

The agenda for each of these consultative sessions was organized around this framework:

1. Actual experiences of use: several short talks by persons from National Member Organization countries who have been involved in using IIASA work.
2. General discussion among attendees of
   - lessons of the use experience so far
   - potentials for further use
   - how IIASA's work can be shaped to be useful
3. Discussion of problems of use from national points of view.
4. Identifying principles for IIASA to follow as it seeks to ensure that its work is used.
5. Other subjects of interest to the attendees.

The seven Wednesday morning consultative sessions ran from 09:00 to 13:00 in parallel, with the participants listed below.

PUTTING THE RESULTS OF THE IIASA ENERGY SYSTEMS PROGRAM TO WORK

Chairman: Dr. James F. Young, Vice President and Staff Executive, Technical Resources, General Electric Company, Fairfield, Connecticut, USA

Cochairman: Juan Carlos di Primio, IIASA

Dr. Laszlo Kapolyi, Deputy Minister, Ministry of Heavy Industry, Budapest, Hungary

Academician Michail Styrikovich, Committee for Systems Analysis, Presidium of the USSR Academy of Sciences, Moscow, USSR

Dr. Christov Marinov, Director, Perspective Development, Research and Technical Progress Division, Ministry for Energy, Sofia, Bulgaria

Dipl.-Ing. Hans Carsten Runge, Member of the Board, Deutsche Shell A.G., Hamburg, FRG

Mr. Ernst Römberg, Commission of the European Communities, Brussels, Belgium

FOOD AND AGRICULTURE SYSTEMS: GLOBAL AND NATIONAL ISSUES

Chairman: Prof. Wouter Tims, Center for World Food Studies, Free University of Amsterdam, Amsterdam, The Netherlands

Cochairman: Jaroslav Hirs, IIASA

Dr. T. Morva, Director, Institute of Economic Planning, Budapest, Hungary

Kirit Parikh, IIASA

Leon Podkaminer, IIASA

Prof. Ulf Renborg, Dean, Department of Economics and Statistics, The Swedish University of Agricultural Sciences, Uppsala, Sweden

Prof. Victor I. Nazarenko, Director, All-Union Research Institute for Informatics in Agricultural Technology, Moscow, USSR

MIGRATION, URBANIZATION, AND DEVELOPMENT

Chairman: Prof. Walter B. Stöhr, Director, Interdisciplinary Institute for Urban and Regional Studies, University of Economics, Vienna, Austria

Cochairman: Evgenii Shigan, IIASA *(Health Care)*

Cochairman: Piotr Korcelli, IIASA *(Migration and Settlement)*

Health Care

Pavel Kitsul, IIASA

Leslie Mayhew, IIASA

Prof. Jan Rusnak, Director, Research Institute of Medical Bionics, Bratislava, Czechoslovakia

Prof. A.G. McDonald, Department of Health and Social Security, London, United Kingdom

Dr. Branko Z. Nizetic, Regional Officer for Research, Promotion, and Development, World Health Organization, Copenhagen, Denmark

Migration and Settlement

Andrei Rogers, IIASA

Prof. Paul Drewe, Department of Architecture and Urban Planning, University of Technology, Delft, The Netherlands

Dr. Laszlo Lackó, Deputy Director, Division for Physical Planning and Regional Development, Ministry of Building and Urban Development, Budapest, Hungary

Prof. Kazimierz Dziewonski, Institute of Geography and Spatial Organization, Polish Academy of Sciences, Warsaw, Poland

Dr. Robert Jones, Human Settlements Officer, Research and Development Branch, United Nations Centre for Human Settlements (Habitat), Nairobi, Kenya

REGIONAL DEVELOPMENT: FROM CASES TO GENERALIZATION

Chairman: Prof. Andrzej Straszak, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland

Cochairman: Åke Andersson, IIASA

Dr. Ognyan Panov, Deputy Director, Institute for Social Management, Sofia, Bulgaria

Prof. Dr. Roman Kulikowski, Director, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland

Prof. Agostino La Bella, The Center for Automatic Control and Computer Systems Studies, National Research Council, Rome, Italy

TOWARD INTEGRATED POLICIES FOR RESOURCE AND ENVIRONMENTAL MANAGEMENT

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Cochairman: Genady Golubev, IIASA

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Prof. Dr. Othmar Preining, Institute for Experimental Physics, University of Vienna, Vienna, Austria

SYSTEMS APPROACHES TO INDUSTRIAL PROBLEMS

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Cochairman: Alec M. Lee, IIASA

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THE CHALLENGE OF APPLIED PROBLEMS TO THEORY DEVELOPMENT

Chairman: Prof. Michel Balinski, School of Organization and Management, Yale University, New Haven, Connecticut, USA
Cochairman: Peyton Young, IIASA

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Prof. Lars Bergman, Stockholm School of Economics, Stockholm, Sweden
Prof. Clopper Almon, University of Maryland, Inter-Industry Forecasting Project (INFORUM), College Park, Maryland, USA
Brian Arthur, IIASA

INFORMATIVE SESSIONS: DETAILS OF IIASA ACTIVITIES

The eight Wednesday afternoon informative sessions ran in parallel from 14:30 to 17:30. They afforded the conferees the opportunity to interact with members of the IIASA staff; subjects were chosen from the variety of IIASA research activities. The detailed programs of these sessions are shown below.

ENERGY SYSTEMS PROGRAM

Cochairmen: Mr. L. Gouni, Director of General Economic Studies, French Electricity Board, Paris, France
Wolf Häfele, IIASA

14:30	Introduction – The Cochairmen
14:50	Energy Strategies in Developing Countries – the Case of Latin America – Juan Carlos di Primio
15:25	European Energy Strategies – Wolfgang Sassin
16:00	Intermission
16:20	IIASA's Energy Systems Program and the Work of the German Federal Parliament's Enquiry Commission on Future Nuclear Policy – Wolf Häfele
16:55	The Impacts of Energy Strategies on the Economy – Didier Launay
17:30	Close of the session

FOOD AND AGRICULTURE PROGRAM

Chairman: Kirit Parikh, IIASA

14:30	The General Thrust of the Food and Agriculture Program – The Chairman
15:00	The Linked System of Models – Günther Fischer
16:00	Intermission
16:20	The National Models: Poland – Leon Podkaminer Egypt and Brazil – Desmond McCarthy Japan – Haruo Onishi The Netherlands – Wouter Tims
17:30	Close of the session

HUMAN SETTLEMENTS AND SERVICES AREA

Chairman: Andrei Rogers, IIASA

14:30	Introduction – The Chairman
14:40	Manpower Studies – Robert Coen
15:30	Normative Location Modeling – Giorgio Leonardi
16:20	Intermission
16:40	Urban Change – Piotr Korcelli
17:30	Close of the session

REGIONAL DEVELOPMENT TASK

Chairman: Murat Albegov, IIASA

14:30	Introduction – The Chairman
14:40	Applied Regional Systems Analysis – Some Methodological Considerations – Åke Andersson
15:20	Rural Settlement Patterns – Ryszard Domanski
16:00	Intermission
16:20	The Computerized System of Regional Models – Boris Mihailov
16:55	Software for Regional Water-Supply Systems – Alexander Umnov
17:30	Close of the session

RESOURCES AND ENVIRONMENT AREA

Chairman: Janusz Kindler, IIASA

14:30 Introduction – The Chairman
14:40 Water-Resources Development under Demand and Supply Uncertainty – Donald Erlenkotter
15:10 Beyond the Problem of Planning: Water-Quality Management – Bruce Beck
15:40 Harmful Effects of Agriculture: Global and Local Aspects – Genady Golubev
16:10 Intermission
16:30 Application of Models to Controlling Air Quality – Eliodoro Runca
17:00 Systems Aspects of Energy and Mineral Resources – Michel Grenon

MANAGEMENT AND TECHNOLOGY AREA

Chairman: Rolfe Tomlinson, IIASA

14:30 A continuous poster exhibition of projects in this Area on these subjects:

- Management of technological change
  - innovation
- Organizational management
  - computers and management
  - operational gaming
  - problems of scale
- Management under uncertainty
  - technological accidents
  - problems of siting
- Issues for the eighties: industry studies
  - forestry
  - coal

17:30 Close of the session

SYSTEM AND DECISION SCIENCES AREA

Chairman: Andrzej Wierzbicki, IIASA

14:30 Introduction – The Chairman
14:40 Applications of Nondifferentiable Optimization – Evgenii Nurminski
15:10 Applications of Large-Scale and Multiobjective Linear Programming – Markku Kallio
15:40 Solving Multisector General Equilibrium Models – Andras Pór
16:10 Intermission
16:30 Allocating Costs in Public Enterprises – Peyton Young
17:00 Applications of National Economic Growth Models – Robert Coen
17:30 Close of the session

INFORMATICS TASK

Chairman: Aleksandr Butrimenko, IIASA

14:30 A continuous demonstration of computer connections between IIASA and remote computer facilities:

- The Budapest line
- The connection with the International Atomic Energy Agency
- The Pisa line
- The TYMNET/TELENET connection
- The European Space Agency/ESRIN connection

17:30 Close of the session

Thursday, 22 May 1980

INTEGRATING SESSIONS

09:00 *Reports from the Consultative Sessions*
Putting the Results of the IIASA Energy Systems Program to Work: James F. Young, Chairman
Food and Agriculture Systems: Global and National Issues: Wouter Tims, Chairman
Migration, Urbanization, and Development: Walter B. Stöhr, Chairman
Regional Development: From Cases to Generalization: Andrzej Straszak, Chairman
Toward Integrated Policies for Resource and Environmental Management: Donald R.F. Harleman, Chairman
Systems Approaches to Industrial Problems: Evgeny Mateev, Chairman
The Challenge of Applied Problems to Theory Development: Michel Balinski, Chairman

10:30 Intermission

11:00 *Conclusion of the Conference*
The Important Themes of the Conference: Roger E. Levien, Director of IIASA
The Spirit of IIASA: Jermen M. Gvishiani, Chairman of the IIASA Council

12:00 Adjournment

APPENDIX B

The Argument behind the Theme of the Conference

Many of the functions of society involve structures that can be thought of as systems combining people and the natural environment with various products of man and his technology, Such complex systems abound in modern society, and their operations present many problems.

The elements of such complex systems exhibit many forms of complicated behavior. However, it sometimes happens that regularities in this behavior can be discerned, and scientific scrutiny has yielded much knowledge about these regularities. Thus, many problems that arise in these systems can be addressed by focusing such knowledge in appropriate ways by means of the logical, quantitative, and structural tools of modern science and technology. The craft that does this we call applied systems analysis; it brings to bear the knowledge and methods of modern science and technology, in combination with concepts of social goals and values, elements of judgment and skill, and appropriate consideration of the larger contexts and uncertainties that inevitably attend such problems.

Thus, the central purpose of systems analysis is to help to solve the problems of complex systems by generating information and marshaling evidence bearing on these problems, and, in particular, on possible actions that may be suggested to alleviate them.

Systems analysis can be applied to a wide range of highly diverse problems, and the patterns of analysis exhibit a corresponding diversity, depending on the context, the possible courses of action, the information needed, the accompanying constraints and uncertainties, and the positions and responsibilities of the persons who may use its results. In a rare case, a problem may fall within the sphere of responsibility of a single policy maker; however, it is far more usual for the relevant responsibilities to be diffused among many persons, often with significant portions of the problem lying outside existing authorities.

While applied systems analyses may exhibit as much variation as the problems that prompt them, there are nevertheless a number of steps that a prospective user of such work can expect to find in it. Applied systems analyses:

- Marshal both the evidence relating to the problem and the scientific knowledge bearing on it, when necessary gathering new evidence and developing new knowledge.
- Examine critically the social purposes – of both persons and institutions – relating to the problem.
- Explore alternative ways of achieving these purposes, which often include designing or inventing new possibilities.
- Reconsider the problems in the light of the knowledge accumulating during the analyses.
- Estimate the impacts of various possible courses of action, taking into consideration both the uncertain future and the organizational structures that must carry these courses of action forward.
- Compare the alternatives by applying a variety of criteria to their consequences.
- Present the results of the study to all concerned in a framework suitable for choice.
- Assist in following up the actions chosen.
- Evaluate the results of implementing the chosen courses of action.

In practice, of course, not every systems analysis does all of these things; it not infrequently happens that a user may need only some of these elements. Nor do the steps always follow this order.

In sum, the central goal of the applied systems analyst is to bring his results to bear on the functions of complex social systems with a view to improving them; he helps those with relevant interests and responsibilities to change these functions. His analysis activities are aimed at assuring himself and others, to the extent possible, that the changes will have the desired results.

APPENDIX C

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