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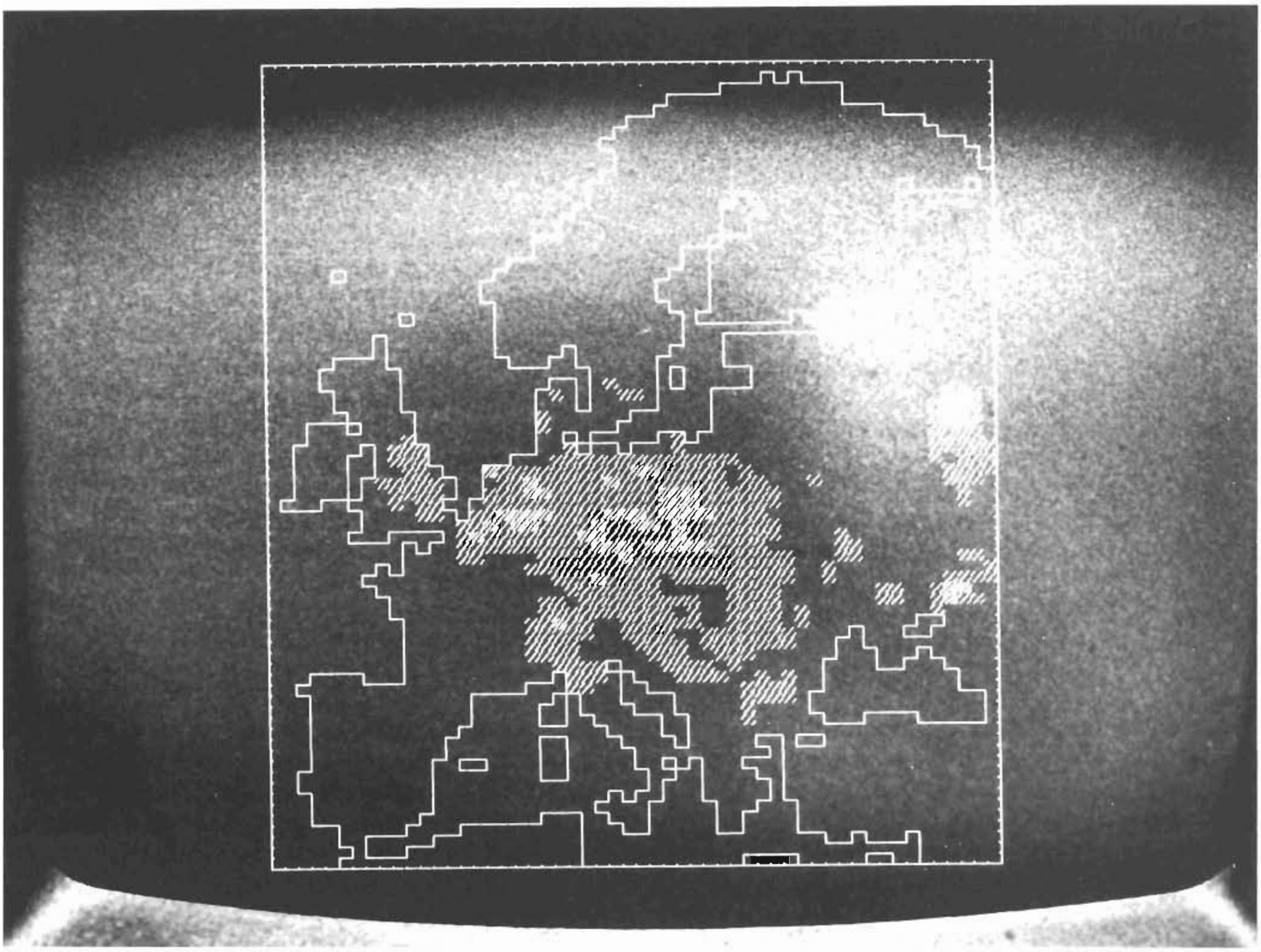

Computer-generated schematic map of Europe comparing areas affected by sulfur deposition in the year 2010 (soil pH below a critical level). The larger area results from a high energy scenario; the smaller area from a low energy scenario with major pollution control measures.

# Acid Rain

IIASA is analyzing control scenarios for acid rain in cooperation with the UN Economic Commission for Europe, which oversees implementation of the International Convention on Long-Range Transboundary Air Pollution.

The damage from acid rain is visible: the German Black Forest trees are turning yellow; fish are absent from thousands of lakes in the northern hemisphere, particularly in the Scandinavian countries and Canada; the gilded roof of the sixteenth-century Sigismund Chapel in Katowice, Poland was so pitted that it had to be replaced; Quabbin the largest reservoir in the United States has had to have neutralizing chemicals added to it since the mid-1970s to protect the drinking water supply of millions of people in and around Boston, Massachusetts, USA.

"Many experts concur that the main problem in Europe is caused by emissions of sulfur dioxide and nitrogen oxides, mainly from the burning of fossil fuels, primarily from power plants," states Dr. Eliodoro Runca, leader of the IIASA research on toxic deposition and acidification until recently. Dr. Leen Hordijk now leads the project. "These oxides remain in the atmosphere long enough to be transported hundreds and sometimes thousands of kilometers from the point of

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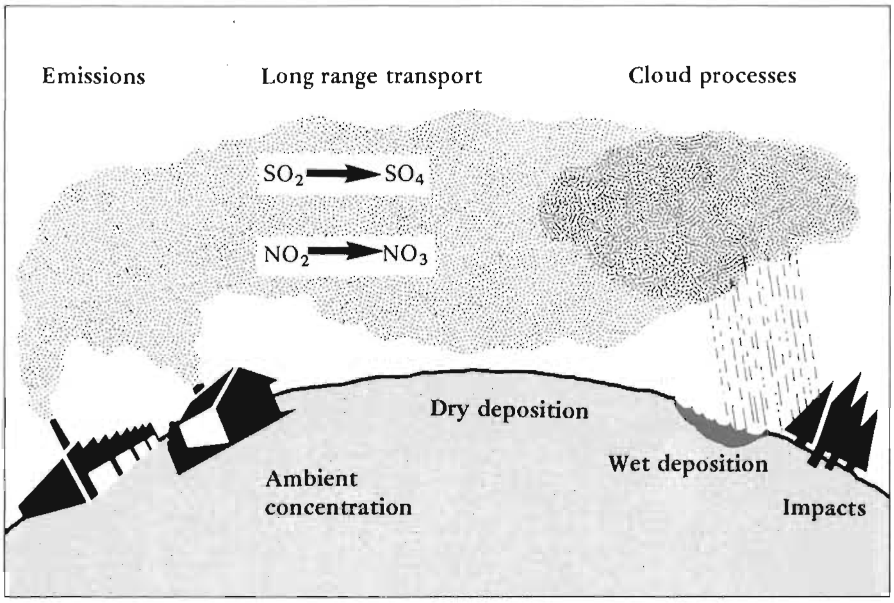
emission. During this time they undergo very complex physical and chemical processes leading to the formation of sulfuric and nitric acids which continue to disperse as small particles or as droplets. Both the emitted oxides and the resulting acids are deposited in due course on the surface. They are either washed out by rain (wet deposition) or they lodge on vegetation and moist surfaces (dry deposition). Dry and wet depositions of sulfur and nitrogen compounds cause the acidification of the environment. European rainwater should have a pH value between 5 and 6, but over large areas it is now between 4 and 5. Since the pH scale is logarithmic, a reduction of one pH unit means that the concentration of acid is ten times greater. A neutral solution is pH 7, vinegar is pH 2.2; most fish cannot reproduce in water with a pH of 4.5; the soil in some parts of central Europe measures pH 4.3 and in the northeastern part of North America measures pH 4.1."

The acidic depositions act directly to change the pH levels of lakes, streams, and rivers when they fall directly on them, as they do onto buildings and monuments. Wet and dry depositions are absorbed into the soil where they can break down other naturally present minerals and leach away nutrient sources necessary for the healthy growth of trees, plants, and crops. The acid precipitation finds its way into groundwater and eventually enters nearby bodies of water, often carrying toxic metals such as aluminum that can deform or kill aquatic life. Acidic water, by dissolving lead water pipes, can introduce unhealthy levels of lead in drinking water.




Natural processes such as volcanic eruptions, forest fires, and bacterial decomposition of organic matter also produce acidic sulfur and nitrogen compounds. However, it is widely agreed that the current problem is man-made, a result of industrialization, the use of coal-, gas-, and oil-burning facilities to produce electricity, and our petroleum-based transportation system. The average precipitation today is one hundred times more acidic than 180-year-old ice cores from Greenland.

The term "acid rain" itself was first used in 1872 by chemist Robert Angus Smith in a book discussing damage to vegetation, fabrics, and buildings in Manchester, England. Realization that local deterioration was associated with a distant source came with the work in the 1950s by Professor Eville Gorham, which correlated acidity in the rural English Lake District with fossil fuel combustion in industrial areas elsewhere in Britain. Professor Svante Oden, a soil scientist at the Agricultural College in Uppsala, Sweden, compared data from Europe's first systematic effort to monitor the chemistry of rain, established in the 1940s in Sweden, with data from a network he initiated in 1961 to test Scandinavian waters. Professor Oden reported in the late 1960s that Swedish waters were becoming increasingly acidic and that there were drastic reductions of fish populations as a result of sulfur emissions from central Europe and Britain — long-range transport across national boundaries. He described acid rain as industrial man's "chemical war" against nature.

The Swedish case study on the impacts of transboundary sulfur emissions was presented at the 1972 United Nations Conference on the Human Environment. The UN Declaration on the Human Environment, adopted by the Conference, states that nations "have the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond the limits of national jurisdiction."

Norway, alarmed by the findings of the largest multidisciplinary research project in the country's history that fish had disappeared from more than half of its southern lakes, joined with Sweden and Canada to press for international cooperation to control acid rain by reducing emissions. This culminated in the 1979 Geneva Convention on Long-

**The International Institute for Applied Systems Analysis**
is a nongovernmental, multidisciplinary research institution supported by scientific organizations in sixteen countries. IIASA's objectives are:

- to promote international cooperation in addressing problems arising from social, economic, technological, and environmental change
- to develop and formalize systems analysis and the sciences contributing to it, and to promote the use of the analytical techniques needed to address complex problems
- to inform policy advisors and decision makers about the application of the Institute's work to such problems

**OPTIONS**
**ISSN 0252-9572**
is produced quarterly by the
Office of Communications, IIASA.

A-2361 Laxenburg, Austria
Telephone 02236 71521 0; telex 079137

Editor: Roberta Yared
Managing Editor: Derek Delves
Designer: Martin Schobel
Photographer: Franz-Karl Nebuda
Printed by Novographic, Vienna

Range Transboundary Air Pollution which came into force in January 1983. The Convention states that countries "shall endeavor to limit and, as far as possible, gradually to reduce and prevent air pollution." The UN Economic Commission for Europe, comprising thirty-four countries from eastern and western Europe and North America, coordinates implementation of the Convention.

Joseph Alcamo of IIASA notes the irony involved: "It was earlier efforts to reduce local pollution through the construction of tall stacks at power stations, refineries, and smelters that resulted in the increase of long-range transport of pollutants. We moved the pollution from one place to another, and while we know what is happening, scientists cannot yet identify which specific factory or generating facility is responsible for the damage resulting elsewhere."

## What Can be Done

Controlling emissions so that less sulfur reaches the atmosphere is the solution generally accepted as the most practical, most efficient, and quickest way to avert continuing damage. There are basically four methods to reduce sulfur dioxide emissions in existing plants, with newer technologies available for those to be constructed. "Scrubbers" can be installed in smokestacks. A switch can be made to fuels with a low sulfur content. Fuel can be desulfurized by chemical or physical "washes" before combustion. Lime Injection Multistage Burning (LIMB) during combustion neutralizes the sulfur emissions before they reach the stacks.

These methods all cost a great deal of money. A study by the twenty-four nation Organisation for Economic Co-operation and Development calculated in 1972 that the US$2.7 billion annual costs of cutting emissions by half in western Europe would be roughly equivalent to the amount of savings from healthier crops and forests, improved fishing conditions, lower health-care expenses, and less corrosion of exposed metals. The State of Baden-Wurttemburg in the Federal Republic of Germany alone reported in November 1983 that it had suffered an US$80 million loss in wood production due to forest damage. It cost US$1 million yearly for neutralizing chemicals to be added to the Quabbin Reservoir in central Massachusetts, USA.

Rather than remove sulfur emissions after they are produced by power plants or industrial boilers, another strategy would be to reduce the amount of fuel burned. Energy conservation therefore has an important role to play in controlling acid rain in the long term.

1910 1930 1970

" Art and Labor", Basilica of St. Mark in Venice, Italy.
Reprinted from G. Amoroso and V. Fassina, *Stone Decay and Conservation*. Elsevier-North Holland, 1983

## What IIASA is Doing

"IIASA's objective is to create a practical, easy-to-use analytical computerized framework so that different strategies and options can be evaluated and assessed," says Dr. Runca. "In an effort to 'codesign' such a system with potential users, we presented and discussed an early version of our 'decision support system' for acid rain control with a group of governmental and international policy makers and advisors at IIASA in November 1983. Additional meetings will be held with the group during 1984 as part of a continual process of model review and revision."

"The basic point is that users can specify energy sources and flows with different control alternatives and see graphically where sulfur emissions will be deposited throughout Europe and what the resulting pH level would be," explains Maximilian Posch, who did most of the computer programming with Moniruzzaman Khondker. "Work done at IIASA in developing a dynamic interactive decision support system using multicriteria stochastic optimization techniques can be used in the system of models for the analysis of acid rain control scenarios," states Professor Manfred Grauer at IIASA from the Technical University of Leuna-Merseburg in the German Democratic Republic.

IIASA's analysis could also be directly tied in to a cost-benefit analysis which could help decision makers balance the costs of emission control with the costs of damage.

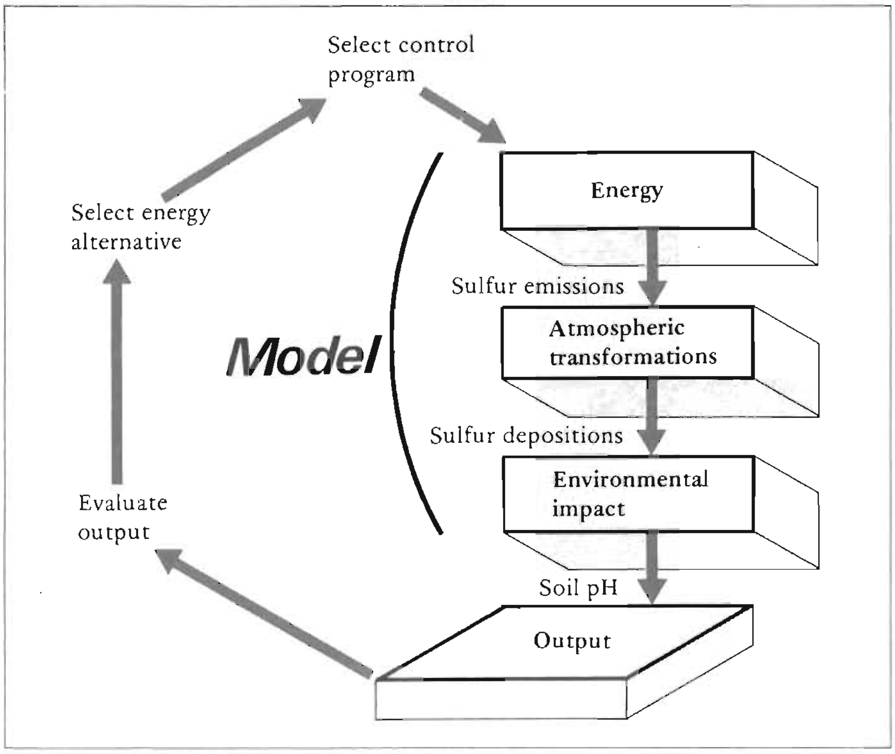
"We've used three submodels," continues Mr. Alcamo. "These deal with energy, atmospheric transformations, and the environmental impact shown in soil pH levels. The diagram shows how scenarios are currently generated for evaluation: energy sources, fuel characteristics, and chosen control alternatives in one or a grouping of any of the twenty-seven European countries give rise to sulfur emissions, which are transformed, transported through the atmosphere, and deposited, with the resulting acidification of soil."

"This may seem over-simplified, but current knowledge is incorporated and the information generated provides a rational basis for decision making and action. We wanted to show that it is possible to link available data, theories, and models in a framework for an objective analysis of acid rain control actions," affirms Dr. Runca. "The effectiveness of the approach adopted is that all the information is graphically represented on the screen of the computer terminal. The user can interactively select isolines of sulfur deposition for a given strategy, and compare changes of deposition patterns and extension of areas with a pH below a given threshold for various control policies. Other procedures are being explored by the IIASA Acid Rain Group as well."

The energy and atmospheric submodels were developed by IIASA scientists Joseph Alcamo, Maximilian Posch, and Eliodoro Runca, with the assistance of Dr. Januscz Bartnicki of the Institute of Meteorology, Warsaw, Poland.

The energy submodel was based on the most recent forecasts of the UN Economic Commission for Europe (ECE); the atmospheric submodel consists of a source-receptor matrix which adapts the long-range transport model developed by Dr. Anton Eliassen within the Cooperative Programme for Monitoring and Evaluation of Long-Range Transmission of Air Pollutants in Europe (EMEP), under the auspices of the ECE and the UN World Meteorological Organization. The soil pH submodel was developed by IIASA scientist Pekka Kauppi in cooperation

Dr. Eliodoro Runca has led IIASA research on air pollution since 1980. He had previously taught at the University of Padua, Italy and the University of Louvain-la-Neuve, Belgium and was with the IBM Scientific Center in Venice, Italy. Dr. Runca is returning to his native Italy as a manager with Technitel International General Engineering S.P.A. The work at IIASA is now led by Dr. Leen Hordijk, who joined the Institute from the Free University of Amsterdam in the Netherlands.



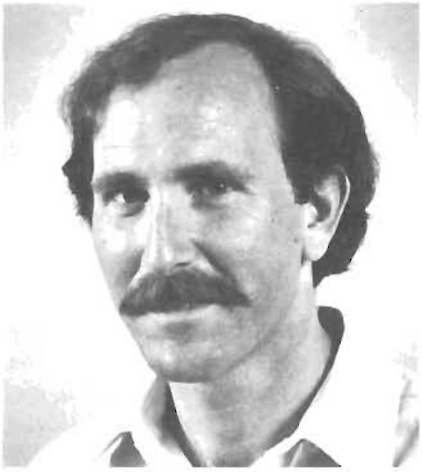
with the University of Göttingen, FRG, Dr. Lea Kauppi of Finland's National Water Board, and Juha Kämäri of the University of Helsinki. The assumptions adopted have been checked and discussed both at IIASA and outside with the institutions of a collaborating network that extends from North America to the Soviet Union.

"Our present system," continues Dr. Runca, "is sulfur-based, tracing sulfur emissions and depositions. It will eventually be expanded to include nitrogen and perhaps other gases and particles of toxic metals emitted, as well as the impact on aquatic systems. Reduction of sulfur emission is the present major international policy issue. For historical reasons the knowledge on sulfur dispersion and transformation and its harmful effects is more complete, and there is nearly unanimous agreement that reduction of sulfur emissions will arrest the present acidification of the environment."

## Environmental Impacts

"While it was relatively easy to work out the cost of controls in terms of tons of sulfur removed, it was more difficult to select one aspect of potential environmental damage that would be universal yet could be quantified," recalls forest ecologist Pekka Kauppi. "Soil pH levels, related to forest damage, were chosen to indicate ecological impact since it is known that risk of forest damage increases substantially below a certain soil pH level. This section of the system predicts when and where critical soil pH values could appear."

This was accomplished by dividing Europe into 1500 grid squares, each 50 by 70 kilometers, and detailing the percentages of each of seven soil types present in that square. The soil types are important because certain naturally occurring chemicals act as "buffers" to neutralize and stabilize acidity. The amount of the neutralizing chemical in the soil is the buffer capacity: the buffer rate is the maximum rate of the neutralization process that chemical provides. The sulfur depositions, on an annual basis, are compared with the buffer capacity and rate of release in



Joseph Alcamo
Civil Engineering Department
University of California (Davis), USA

Maximilian Posch
Technical University of Vienna, Austria

Pekka Kauppi
Department of Silviculture
University of Helsinki, Finland
Dr. Kauppi is now with the Forest Research Institute in Helsinki. Juha Kämäri, a limnologist from the University of Helsinki, is joining the IIASA Acid Rain Group.

each grid. Five buffer ranges are used in the submodel: carbonate range, silicate range, cation exchange range, aluminum range, and iron range. Conceivably, any buffer can be "used up" in the neutralizing process and disappear completely, leaving that soil defenseless against acid deposits. Soils and waters without buffer capacity have no protection, unless neutralizing chemicals are artificially added.

There is a time lag between a sulfur deposition "dose" and the soil pH response. "There is no simple dose/pH relationship because the soils and any buffers present differ so widely," notes Dr. Kauppi. Nonakaline soils, and the trees and plants they support, face the most danger. "One very alarming fact is that all trees, young and old, are affected," states Dr. Kauppi.

Dr. Wolf-Dieter Grossmann, at IIASA from the University of Hamburg, FRG, says "since forests absorb pollutants more than other lands, we can only guess at the consequences" of this damage. "Forests are a source of manifold environmental services as well as jobs and incomes and psychological renewal. It is difficult and expensive to restore, restock, and reseed forests when buffers have been lost, the soil has been changed, and the microorganisms necessary to recycle nitrogen and carbon have been affected."

## Choosing Strategies

"There are still some unknowns and much uncertainty involved in the acidification process," according to Dr. Runca. "However, some European governments have already pledged to cut emissions. IIASA's approach and efforts are aimed at showing how various feasible energy options and control strategies quantitatively relate to pollution emissions and depositions and the effects on the human and natural environment. The impact of any control measure can readily be seen, and alternative policies easily compared, as effects are shown graphically on computer screens as well as in printed form. This should assist those responsible for decisions and action in this field."

Roberta Yared

# Information Systems for Regional Planners

How does regional planning use computer-based information systems – and how could the process be improved?

The oil crises and worldwide recession that followed the rapid industrial growth of the 1960s and early 1970s brought serious upheavals to many countries, altering the very structure of their national economies. Within the nation, these upheavals, coupled with changing population patterns, have translated into greater problems for some regions than for others, as traditional industrial sectors have declined, local firms have become more specialized, and the service sector has grown in importance. Consequently, the economy of a region has become more vulnerable to changes in other regions of the same country, as well as to international trade and politics. Faced with such issues as migration, unemployment, and environmental pollution, the regional planner needs more information on a wider range of concerns in order to understand the dynamics of the regional system and to detect new trends in its development.

Plans for regional development were originally made in response to local conditions or events, and not as part of any comprehensive long-term national policy. But since the end of the last century, and especially since the Second World War, many governments have tried to influence regional activities and living standards in order to promote national economic efficiency or reduce inequalities between regions.

The spread of computers and communication systems has of course made it easier, in theory, for planning authorities to collect, process, and distribute information, and so make their planning more effective. Scholars of the Integrated Regional and Urban Development Group at IIASA and from the Department of Economics at the Free University of Amsterdam in the Netherlands have jointly been studying the information systems used by planners and decision makers at the regional level, in the light of these technical advances.

## Regional Data: Too Little...

The information needs of planning offices can vary between regions and over time within the same region, giving rise to the question of whether information collection and production should be regionalized or centralized. According to Börje Johansson, Professor of Regional Economics at the University of Umeå in Sweden, who heads the group at IIASA, "In most countries today, decentralized, heterogeneous demands for information from the regional planning level are basically met by a centralized, homogeneous supply."

In Italy, for example, most regional data are collected from local authorities but are published only at the national level by a central body. This "divorce between knowledge and government" has been eased recently as the number of decentralized government bodies has multiplied, but there has not been a similar proliferation of local data bases. In the developing countries too, where resources for information systems are scarce, planners are concerned that the economic data supplied to them are of limited application because insufficient thought has been given to the regional dimensions of national development.

"The primary aim of information systems in regional planning has traditionally been to store data for various uses in large computer systems," says Professor Johansson, "but the data aspect has been stressed at the expense of planning relevance. These developments are partly explained by a persistent lack of contact between designers of information systems and planners using the information."

## ...Too Late

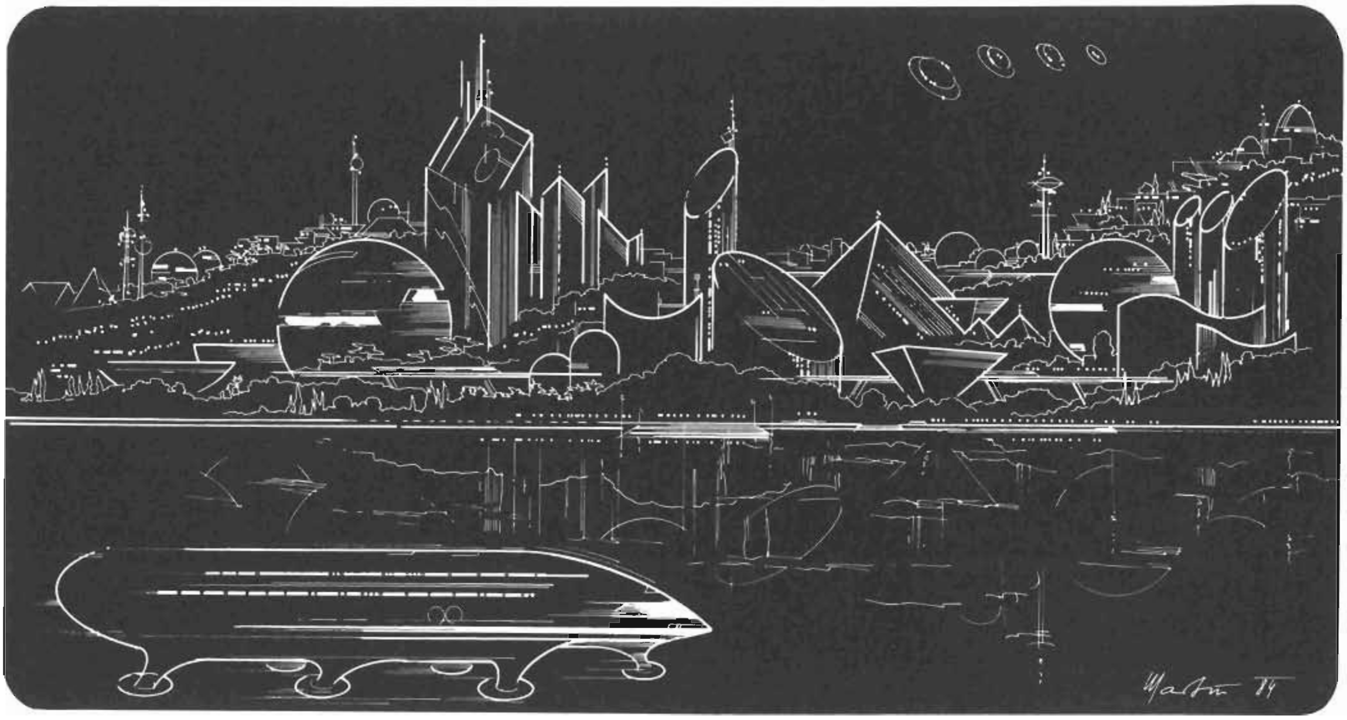
Very often there is such a long delay between a government survey and official release of the results that these are ultimately of little value at lower planning levels because they contain no record of recent events, such as factory closures. This problem has been encountered, for instance, by regional planners in Sweden, where the central bureau collects some of its regional figures from five-yearly Population and Housing Censuses. This information is badly needed for adjusting population projections, since these are greatly affected by patterns of interregional migration. However, the latest housing data available to regional planners in 1982 were the 1975 census results.

One solution, made feasible by developments in microcomputers and systems expertise, would be to allow local planners to produce their own statistics more frequently on decentralized data bases. In such an arrangement the central agency would remain responsible for establishing standard definitions to help integrate the various parts of the information system.

## Privacy and Power of Information

When data collections from different sources are combined, there is a chance that information could be traced to individual citizens or firms. Many countries try to prevent this invasion of privacy by prohibiting the public release of information on individual units. For example, official statistics on the annual profits of firms may have to be combined in such a way that no single firm can be identified. Peter Nijkamp, Professor of Economics at the Free University of Amsterdam, who has been leading the joint study of regional planning and information systems, points out that "The loss of information due to aggregation is an issue that has never been attacked consistently. A reconsideration of confidentiality rules is undoubtedly a necessity."

Regional analysts have devised methods to minimize this information



loss and to present the data in as informative a way as possible. One procedure, based on an examination of critical threshold values for production and wage levels, allows a single firm to be modeled without revealing sensitive information. "Since many individual firms in an economy exert a significant influence on the evolution of the regional system," says Professor Nijkamp, "this procedure may be a useful one to consider. Although, in general, individual firms attach great importance to the confidentiality of data they give to statistical offices, usually the same data can be obtained from annual reports of firms, trade journals, and even newspapers."

Retention and control of information also represent a considerable source of influence at the disposal of the planner. Information exchange, seen from this perspective, is not so much a technical problem as a political matter of power distribution. For this reason alone, a comprehensive "supersystem" of data banks, operating through the exchange of information between different administrative bodies, might be difficult to establish and control.

## Spatial Awareness

Statistical data made available to the regional planner are often unsuitable because they describe economic variables at the national level or for specific industrial sectors. Another problem is that discrepancies between administrative and socioeconomic areas can lead to lack of agreement between the spatial scale on which the information is based and the scale appropriate to the planning issue. It may also prove difficult to combine spatially oriented information systems that have been set up independently of one another.

In fact, spatial referencing of regional information did not receive proper attention until the late 1970s, but since then many techniques and software packages have been designed for managing and analyzing geographic data. One particular application of computerized map-making techniques, called geocoding, has made it easier to adapt information systems to the needs of urban and regional planners. By this method, information on all intersections of the national transport infrastructure can be digitized so that a corresponding network of nodes, connected by segments, is defined.

Geocoding has been used for INSYRON, the information system of the National Physical Planning Agency in the Netherlands. INSYRON integrates land-use classifications, information on housing, and public utility access points, and also includes information on traffic flow and other activities. Because the side of a street can be represented by one geocoded segment, encoding of all segments allows the planner to examine the distribution of public facilities, for example. The advantage of storing data at this level of detail is that it offers flexibility: data can be aggregated to different scales according to the planner's requirements. The availability of a coherent data set has also meant that different government agencies in the Netherlands now use basic data more consistently.

The disaggregated spatial data of the Dutch system are stored in regional data bases that are maintained by regional authorities. Dutch planners claim that this decentralization has resulted in greater efficiency of information flow and is cheaper than a centralized information system, which would normally have to be much bigger and more complex to hold data on the geographic locations of physical objects, and would thus cost more in terms of storage capacity and computer processing time.

An outstanding weakness that has been observed in regional information systems is the lack of information on flows within and between regions. In general, there are some figures on physical flows, of people and commodities, but Professor Nijkamp points out that they are inadequate in many countries. "Consequently, the distributional impacts of many public policy measures are very hard to judge. Especially note-

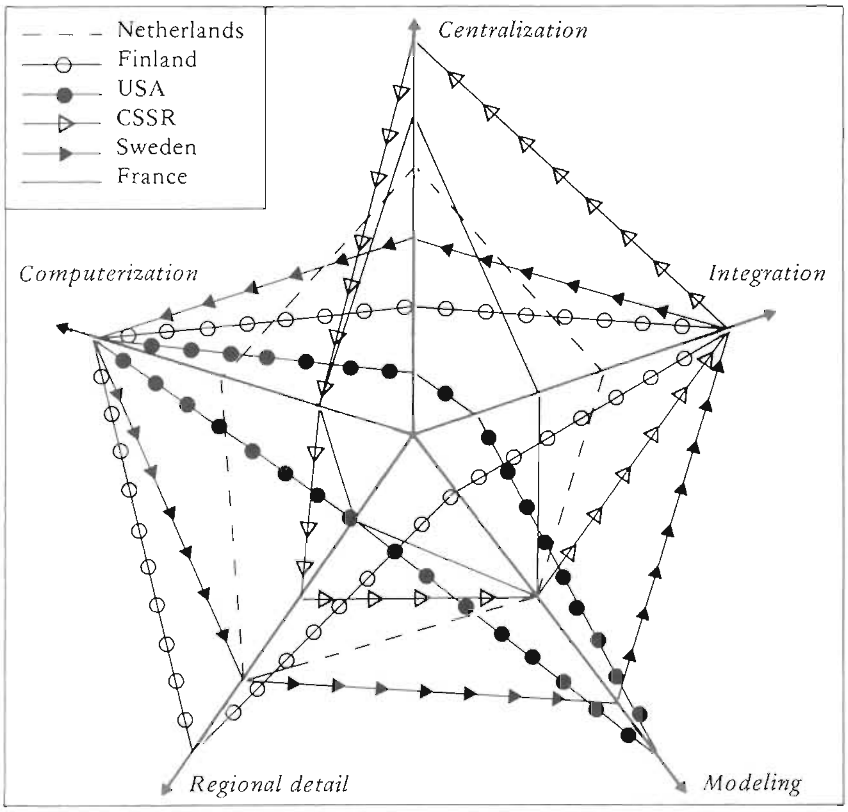
## International Comparison

The work undertaken at IIASA included a comparative study of regional planning and information systems in six countries having different geographic characteristics, socioeconomic patterns, and planning traditions: Sweden, France, the United States, the Netherlands, Czechoslovakia, and Finland. The regional planning systems were compared in terms of five main characteristics, as were the regional information systems. Because of the small number of countries involved and the large number of variables affecting the different features of these systems, the results could only be tentative, and have been expressed as ordinal rankings. The diagram shows the results of the comparison of the information systems.

*The degree of centralization* of information systems seems to be lowest in the USA, where most states have developed their own regional economic models. In contrast, regional initiatives for building information systems appear to be small in France and Czechoslovakia. In the other countries, some steps have been taken toward decentralization. The extent of decentralization in each country certainly seems to reflect the level of decentralization of the planning systems.

*The degree of integration* refers to the production of synchronized and standardized information on the various planning components (such as housing and transportation) at each planning level. Of special interest are Finland and Sweden, whose information systems are based to a large extent on administrative register systems, which can be linked by means of codes that identify all statistical units, such as persons.

The ranking of the countries by this attribute corresponds roughly to the order found for the degree of "horizontal" coordination of different planning components at each planning level. For example, both the planning and the information systems at the regional level appear to be well integrated in Czechoslovakia, whereas those in the USA are rather fragmented.




*The role of modeling* in helping regional forecasts or production of impact statements is strongest in the USA and Sweden, but very modest in Finland. Throughout the regional modeling community in general, it has been observed that the majority of operational (multi)regional models have not been subjected to rigorous validation tests. In addition, there appears to be a serious lack of models for *ex post* evaluation of policy performance. This would indicate that regional planners are generally not paying enough attention to lessons that can be learned from the past.

*The degree of regional detail* that is appropriate depends on the particular planning component as well as the spatial level. For instance, high detail is necessary for land-use planning at the local level, but less detail is necessary for local economic and industrial planning. In Finland regional detail is generally very high, and data are available at the local or county level. In Sweden and the Netherlands county or provincial data are normally available, and in France and the USA the average size (by population) of the corresponding region is even greater. It appears that the larger the population, the lower the degree of regional detail.

All six countries have problems with confidentiality of information.

*The extent of computerization* of regional information systems has increased rapidly in the last two decades. This is most evident in data storage and processing, and less so for data input and output, though Finland, Sweden, and the USA have on-line connections to their administrative data bases for the major users. The ranking of the countries is the same as that for the role of modeling, with the exception of Finland, which indicates that progress in one does not necessarily imply advances in the other. In view of the high demands imposed by regional planning systems in some countries, computerization and modeling appear to be underdeveloped in information systems at the regional level.

Börje Johansson

Peter Nijkamp

worthy is the lack of information on nonphysical flows, such as finance and knowledge, in regional planning." Since regional accounting systems are generally poor and regional activities are becoming increasingly internationalized, Professor Nijkamp believes that more thought needs to be given to interactions between the interregional and the international economy, not only in terms of commodity trade, but also through migration, capital movements, and flows of information itself.

## The Planning Process

The need for more flexible information systems has accompanied a growing realization that planning should be treated as a process. Planning practice in several countries is thus moving from a "blueprint" mode, whereby the final state is prescribed, to one in which a continuous watch is kept on how plans are functioning in relation to actual developments. This implies less focus on the plans themselves and more on planning procedures and interactions with policies of other agencies, and on their consequences. The attention that planners are presently giving to monitoring stems to some degree from the inability of plans to deal with change and uncertainty.

One approach to handling uncertainty is to construct different scenarios in order to establish the range of possible changes with which a regional plan may have to contend. Over the long term (ten to twenty years) regional trends could be affected as much by national as by local factors; by a similar argument, national economies cannot be isolated from activities on the international scale. Therefore, trends are considered at each spatial level in turn. Scenarios can then be constructed that project possible long-term futures, but in different directions depending on the assumptions made about energy supplies, food production, or technological progress, for example. Using these scenarios, planners can try to determine the implications of global and national trends for their region.

Several kinds of uncertainty can also be treated by "early warning systems". Originally designed to aid decision making in business, they have been adapted, using the latest decision support systems, to help in regional planning.

The progress of a plan is typically measured against standard quantitative indicators, such as employment and population figures. But there is some skepticism among planners about measuring performance in this way because of the difficulty of separating the effects of policy from influences beyond the planner's control. Even in the plan-making process itself, negotiations, habit, and "muddling through" have been known to be more persuasive than the figures computed using a mathematical model. And because the information needed in monitoring is so diverse in terms of type, source, and spatial and temporal scales, there is a widely felt need to handle not only numerical but also qualitative information.

Qualitative information, such as planning proposals, or even public opinion, may indeed seem difficult to convert to policy-relevant form, but computer technology is providing increasingly sophisticated means of collating and studying combinations of statistical and textual material. Planning issues that are complicated by conflicting objectives and criteria can be rationalized with the aid of interactive decision-making methods that employ user-friendly hardware and software to help the planner make better use of all relevant information, regardless of its nature.

## Planning of Information

Today's planners are faced with an overabundance of some kinds of data, so the real predicament in modern regional planning appears to be not the supply but the evaluation of information. Professor Nijkamp sums up the situation in this way: "Our era is indeed the era of information. But, at the same time, the identification of meaningful structures and patterns in the mass of information that confronts us is fraught with many problems. The need for better information for planning has evolved into the need for better planning of information.

"It is clearly more important to increase the speed of response to, or recognition of, conditions that call for planning action, and to broaden the range of variables considered, than to increase the amount of data on each variable," Professor Nijkamp notes. "It should be realized that improvements in the design and use of modern information systems for regional planning will lead to better decision making and thus to higher social benefits."

**Steven Flitton**

Key issues of information systems for regional development planning, as well as the six-nation comparative study, are treated fully in a new book by Peter Nijkamp and Piet Rietveld (Editors): *Information Systems for Integrated Regional Planning* published by North-Holland, Amsterdam, in the Contributions to Economic Analysis Series (Volume 149).

# Scientists and Policy Makers in an International Context

**Harvey Brooks** argues that research in science for public policy must be broadened to include implementation problems and distributional effects of policy recommendations.

Much current writing from the scientist's perspective is about how to make the most rational and informed choices in support of the common good. In this view the task of research is to help to determine the most rational course of action, which ideally should emerge in a compelling fashion from the proper marshalling of the "facts". The difficulties of implementing this course in the real political or economic world are often seen as a problem for the policy maker or administrator, rather than the analyst or researcher. If the world can be shown to be embarked on a self-destructive course, the demonstration and clear explanation of this, it is argued, should suffice to convince key decision makers of the folly of their ways and thus alter the undesirable course of events. To stop the nuclear arms race, for example, it should be sufficient to demonstrate the mutually suicidal nature of even a small nuclear exchange. To induce national governments to reduce sulfur dioxide emissions from their power plants it should be sufficient to project convincingly the cumulative destructive effects of these emissions on the environment of their own or nearby countries.

While there is no question that accurate and convincing forecasts of the consequences of pursuing various policies encourages decision makers towards more rational choices among alternatives, such information is seldom sufficient. Basically the problem is that the scientists and policy makers necessarily have different agendas. Unless this is recognized and taken into account on both sides, they are likely to talk past each other.

The conventional wisdom is that the failure of politicians and decision makers to listen to scientists is the source of the problem. But this is a dangerous oversimplification. The failure of communication is two-sided; neither politicians nor scientists are sufficiently prepared to understand the constraints under which the other operates. The blame may lie especially with scientists and analysts who belittle the constraints of the politicians and managers and do not address their concerns seriously.

There is almost no application of science in the real world that is completely neutral in its distributional effects, in the sense that it benefits or injures everybody equally. Indeed, a typical application of knowledge may be one which benefits a great many people a little bit, but has substantial adverse consequences for a few, or vice versa. Thus the scientific notion of "benefit to the human species" is in practice constrained by notions of equity or justice in the distribution of benefits and costs among individual members or subgroups of the species, such as nations, classes, regions, corporations, institutions, professions, or associations of like-minded individuals. Even when there is almost universal agreement on the net benefits of certain policies or actions, there is no agreement on how the costs or risks of taking these actions should be shared among the people affected. If the existing state of knowledge were capable of providing a confident prediction of the consequences of particular policies or actions, including the distributional effects for various groups, "objective" knowledge would still be incapable of providing a basis for arriving at a consensus concerning which consequences were most desirable or acceptable.

> **"There is almost no application of science in the real world that is completely neutral in its distributional effects, in the sense that it benefits or injures everybody equally."**

Policy makers must consider the possible adverse consequences of any course of action on the varied constituencies to which they are accountable. They try to strike a balance between the contending interests and value preferences of these groups, as well as those of their decision-making colleagues who may frustrate their preferred policies and goals in other arenas.

In an international context, the willingness of policy makers to accept findings calling for policies adverse to the interests or strongly held beliefs of powerful national constituencies is greatly reduced when the apparent benefits of the policies being pressed upon them appear to accrue mainly to citizens of other countries or to humanity as a whole.

By and large, past attempts to use scientific networks, national or international, to influence national political decisions have often bogged down because of their failure to be sufficiently sensitive to the problems of implementation arising out of national or subnational constituency interests. It is not that knowledge itself should be altered by the interests involved, but rather that in spelling out the consequences of policy, analysis must identify not only the macro benefits but also the micro costs to particular interests, if only so that these interests do not become a surprise rallying point for opposition. Policy research should pursue the implications of the implementation of recommended policies in much greater depth than has been traditional. It should attempt to indicate in advance the likely points of resistance by identifying affected interests and recommending implementation designs that will mitigate opposition through compensation and other devices.

## Transcending National Interests

A common ideal for the application of science in our contemporary world has been encapsulated by Professor William Evan in his book *Knowledge and Power in a Global Society*: the "rationality of pursuing power through the pursuit of national interests will have to be replaced with the rationality of pursuing science and applying scientific knowledge on behalf of the human species." I think this could form as good a motto as any to express the ideals and purposes which lay behind the creation of IIASA, and which still provide one of the most attractive drawing cards for its staff.

Professor Evan goes on to say that "if any segment of society can possibly contribute to transcending the 'ideals of the tribe' it is the community of scientists, engineers, and professionals whose work brings them into recurrent contact with colleagues the world over." In this respect institutions such as IIASA provide an ideal setting for the realization of the benefits of that "recurrent contact" among colleagues because it encourages much more sustained interaction and actual collaboration than the usual international meetings, conferences, laboratory visits, correspondence, and "invisible colleges". These networks are important, but they cannot provide the intensity of interaction necessary to work problems through comprehensively and in detail.

The idea of a research institution capable of addressing, as Professor Evan puts it, "global problems outside the framework of warring national interests and ideologies" has a great deal of appeal, but the translation of its scientific findings into concrete policies and actions by individual governments — and, even more, many governments acting in concert — is fraught with difficulties. There are grounds for hope, nevertheless, that transnational associations, networks, or multinational scientific institutions, especially if nongovernmental or at least partly independent of governments, can divorce themselves more completely from parochial or national interests. Even if their "objective" conclusions are the same as those of national institutions, they may have higher credibility, especially among those who consider themselves as potential losers.

Harvey Brooks is Benjamin Peirce Professor of Technology and Public Policy and Gordon McKay Professor of Applied Physics at Harvard University, USA. He has served on the President's Science Advisory Committee from 1959 to 1964, was a member of the National Science Board from 1962 to 1974, and served as the second chairman of the Committee on Science and Public Policy of the US National Academy of Sciences. He is also Chairman of the Committee for IIASA of the American Academy of Arts and Sciences, the US National Member Organization.

## Knowledge and Power

Knowledge may be cultivated for many different purposes. Ideally it is often thought of as divorced from the exercise of political power, but if it is at all applied, or just potentially applicable, its generation is inevitably affected by assumptions regarding its ultimate use. It is thus, implicitly or explicitly, cultivated to support some kind of exercise of power. The agenda for applied research is therefore influenced by the purpose for which the knowledge it creates is expected to be used.

The power to be exercised may be mainly national power, for example, in direct support of military power, or to enhance the national "image" and thereby the political influence of the nation through the demonstration of scientific or technological prowess, as in the space programs of the USA and the USSR. The source of this influence may ultimately derive from the popular belief that technical prowess is an essential ingredient of national military strength or economic competitiveness. To the extent that the cultivation of technical knowledge supports national military or economic power against other nations it may be viewed as violating the universalistic norms of science; nevertheless, nationalistic aims have become deeply embedded in the practice and institutions of scientific and technological research, and have indeed been a main driving force for technological progress in the past. This can be expected to change only slowly.

Knowledge may also be cultivated for the support of the exercise of power at the national level for purposes which are, at least in initial intent, humanitarian and universal. Such is the case, for example, with research in support of environmental, health, and safety regulation, designed to protect society from the possible adverse effects of technology. Despite the fact that this use of knowledge is in principle more compatible with the universalistic norms of science, the exercise of power which it supports inevitably confronts narrower interests.

Knowledge in support of regulation is especially crucial in the American political system, where the strong emphasis on "due process" in the legal regime means that almost all regulations are subject to challenge in the courts by the interests affected. Regulators, to withstand this challenge, must be in a position to show that their decisions are adequately grounded in scientific evidence. The character of the evidence required for regulations to withstand challenge in the courts has a major influence on the agenda of research related to the environmental, health, and safety effects of technological activities. In this sense science is, perhaps, a more important source of the legitimacy of political authority in the American system than in any of the other western industrial democracies. For rather different historical and philosophical reasons science is also a major source for the legitimacy of political authority in the countries with centrally planned economies.

In the case of regulatory science there is something of a paradox in that knowledge developed to undergird the exercise of regulatory authority may have greater credibility — and hence legitimacy in the political or judicial process — if it is perceived to have been developed free of all prior influence of policy orientations. For this reason, for example, knowledge developed in truly international research institutions may carry greater conviction to affected national constituencies than research performed either by national regulatory agencies or by the industry which is a potential candidate for regulation.

## Global Problems

Many, including Professor Evan, have argued that the "absence of an infrastructure of scientific and technological research institutions with a mandate to study global problems" results in a "failure to integrate knowledge with power on behalf of global society." Those who argue for this point also maintain that such a scientific infrastructure may be a prerequisite to the emergence of a matching sociopolitical infrastructure that is capable of carrying knowledge into application outside the framework of purely national interests.

There is a considerable proliferation of nongovernmental scientific networks, including multinational corporations, several multinational research institutes such as IIASA, and international agricultural research centers. There are also the specialized agencies of the United Nations system which, despite the political polarization that has plagued some of them in recent years, have chalked up some of the most successful accomplishments of the UN. Although they do not do much original scientific research, they have succeeded in integrating existing knowledge and understanding in certain fields of global significance, such as food, health, and environment. This part of their work often gets less attention from the media than the more dramatic political confrontations which make more arresting reading.

Regional groupings such as the Organisation for Economic Cooperation and Development, the European Community, or the Council for Mutual Economic Assistance have tended to take on an increasingly scientific complexion. These form an "infrastructure" whose potential has not been fully realized, but they serve as a continuing reminder of the universalistic ideal for the utilization of knowledge. Despite the fact that most science and technology today has been co-opted by national rather than more inclusive human interests, the universalistic vision exercises a powerful countervailing influence not only on scientists themselves but also on political leaders.

> **"Research can broaden the agenda of policy options while narrowing the specific areas of conflicting interest."**

International or multinational research institutions can contribute most to the solution of global problems, problems which are inherently international, interlinked with each other (such as food and energy), and multidimensional. The biggest limitation in the contribution that science and analysis can make to the solution of global problems lies in their distributional dimensions. Problems of balancing the total supply and demand for resources such as energy and food are almost surely soluble by means of science and technology, even for considerably higher population levels than are now contemplated in most projections. What is not soluble by technical means alone is the distribution of these resources among nations and groups. However, analysis should be capable of generating a consensus on the most probable distributional consequences of various policies, thus narrowing the political focus on choice among consequences rather than on hopelessly entangled political *cum* technical arguments. What appeared initially as an irreconcilable technical disagreement can frequently be reduced to a difference in perceived interest, or to an argument over the sharing of risks or costs. Furthermore, science and analysis can often uncover policies where mutual gains are possible, replacing what was originally seen by politicians and administrators as a zero-sum game by a positive-sum one. Research can thus broaden the agenda of policy options while narrowing the specific areas of conflicting interest. The experience of IIASA seems to show that even global issues that are inherently political can be partially depoliticized and analyzed dispassionately, given the right environment. This environment must be carefully designed to enhance the universalistic ideals of science, including Robert Merton's four norms of "universalism, organized skepticism, disinterestedness, and communality."

## Global vs. National Stewardship of Resources

One of the major areas of conflict in the world arises over the control and management of natural resources, both renewable and nonrenewable. In one sense this is not different from other environmental issues, because a clean environment can be regarded as a finite natural resource in its own right. However, there is a long societal tradition of national sovereignty over natural resources which does not apply in the same measure to the environment. That the environment belongs to the global "commons" is much more accepted than that resources in the ground or on the land should. On the other hand, the whole international community has a stake in the wise management of all the world's resources because of the "spillover effects" in other countries arising from the mismanagement of resources in one country. For example, the felling of forests on the steep hill slopes of Nepal causes flooding in India and Bangladesh, and affects the supply of hydropower in those countries. Pricing and production of oil and gas in various regions that control large resources of these can have profound economic effects around the world. The genetic resource base for many important cash crops on which particular countries depend may lie in other countries; 40 percent of the world's coffee crop, for example, is said to depend upon germ plasm found only in the forests of Ethiopia.

Not only does each sovereign nation have a responsibility to safeguard key resources under its control for the benefit of mankind as well as its own future, but the rest of the world has a reciprocal responsibility to provide whatever support lies within its capability to help other nations in managing their resources wisely. As in many other instances, the problem of wise management of resources may come into collision with the concept of fairness and equal sacrifice. What is generally acknowledged to be in the collective interest of all may nevertheless fail to be implemented because of disagreements over what constitutes a fair method of sharing benefits and costs. The claim of sovereignty over resources tends to be taken as implying a principal obligation on the part of the sovereign nation, but each nation in turn feels it unfair that it should have to bear the full cost of reducing spillover effects from the exploitation of its own resources that mainly affect other nations. Frequently interdependence among nations on the use of resources is not appreciated or understood by the actual people who exploit the resources. The farmers of Nepal do not understand the problems their activities create downstream.

The summoning of the political will necessary to insure exercise of the reciprocal responsibilities among nations and groups within nations for the husbanding of key resources depends on wide diffusion of understanding of the consequences of various actions and policies; and this in turn depends on convincing scientific information, which, however, is a necessary but not a sufficient condition for arriving at a consensus among all those whose behavior affects ultimate outcomes. The reason it is not sufficient is that no scientific information can deal completely with the sharing problem. The most that scientific information by itself can hope to achieve is to help identify the magnitude of the stakes involved in *not* arriving at an accommodation in relation to the sharing of the burdens of constructive action. International research institutions should have a comparative advantage in developing and certifying scientific information and analysis which will have credibility among the wide variety of commercial, industrial, regional, and national bodies that must act, and in persuading them that it is in their ultimate self interest to cooperate in maintaining the natural resource/environmental base which in the last analysis sustains all economic activity.

**"Problems of balancing the total supply and demand for resources such as energy and food are almost surely soluble by means of science and technology . . . What is not soluble by technical means alone is the distribution of these resources among nations and groups."**

This article is adapted from Professor Brooks' presentation at the IIASA International Forum on Science and Public Policy in January, which he chaired together with Professor Pierre Aigrain of France and Academician Nikolai Emanuel of the USSR.

### IIASA International Forum Science and Public Policy

Forum participants, currently or previously involved in setting policy and government actions on issues with technical considerations, focused on how to make the scientific contribution to the policy process more effective. Improving collaboration between the political and scientific communities is a matter of concern to the two groups and the public: the Forum addressed what scientists can do.

Providing scientific information and counsel to national policy makers is usually the function of science advisors, serving as a bridge between the politicians and bureaucrats and the researchers and analysts. This is also the role of IIASA, given its scientific concerns and international perspective. The Forum participants frankly described the difficulties in acting as the "communications link" between the two communities with their different traditions and agendas. Their experiences demonstrated the need for scientists able to present social as well as technical implications of policy recommendations. Two examples of public issues with scientific components served as the framework for the Forum: acid rain and the warming of the earth through an increase in concentrations of carbon dioxide in the atmosphere. Problems associated with the regulation of carcinogenic, toxic, and hazardous substances were also discussed. Scientific uncertainty and lack of consensus regarding such problems is precisely why they become issues of public concern to be resolved through the political process, and why scientific findings and insights are a necessary part of the process. One debate at the Forum was whether research specifically dealing with these types of problems is a new branch of science, with science advisors to the policy community as a new profession.

Proceedings of the Forum will be published shortly by IIASA, and a book on science for public policy is planned.

# News from the Institute

## Profile: IIASA Deputy Director, Boris Segerstahl

Professor Boris Segerstahl has joined the Institute as a Deputy Director from his post as Director of the Research Institute of Northern Finland. He has been actively involved in research management, in industry, and in university teaching over the past two decades.

He became Director of the Research Institute of Northern Finland at Oulu in 1975, and since then has also served as Vice Chairman of the Academy of Finland, Chairman of the Research Council for Technology, and Secretary General of the Science Policy Council.

Professor Segerstahl has taught control engineering and systems analysis at Tampere University of Technology, the Swedish University of Turku, and the University of Oulu. From 1970 to 1972 he was Director of the Research Institute for Biotechnology at Tampere.

He gained "hands-on" experience in the design and installation of large-scale computer-controlled production processes for various industrial plants while Chairman of the Board of Industrial Control Ltd. from 1969 to 1978, and was also a member of the supervisory board of Televa Ltd. from 1976 to 1981.

Professor Segerstahl will make use of this practical experience in fulfilling one of his responsibilities at the Institute: the development of a new research program dealing with the relationships between science, technology, and society, which will feature problems relevant to industry and the impacts of technological change.

Having represented the Finnish National Member Organization on the IIASA Council since 1979, Professor Segerstahl is not a stranger to the problems and achievements of IIASA. He is "very optimistic" about the future of IIASA and promises to "do all I can do to assist the Institute as it enters its second decade."

## Meetings

Scientists investigating "long waves" to identify underlying causes of economic depressions and upswings met in Florence and Siena, Italy to consider several theories recently put forward and to examine policy implications. This was the first occasion on which proponents of all but one of the leading theories had met together. The consensus was that as the role of innovation is central to all theories, policies should focus on minimizing social costs while encouraging the diffusion of innovations. Nobel laureate Jan Tinbergen stressed that this includes institutional and social, as well as technological, innovations. IIASA and the Institute of Regional Economic Planning of Tuscany (IRPET) organized the meeting, hosted by the Monte dei Paschi of Siena and the authorities of the Tuscany region and the cities of Florence and Siena. A book is being prepared.

The Second North American Conference on forest sector modeling met in Arlington, Virginia, USA, sponsored by IIASA, the US Forest Service, the Canadian Forest Service, the US forest industry, and Resources for the Future. IIASA is coordinating national and regional modeling efforts for the development of a global model of forest resources, production, and trade to analyze the structural changes under way in this industry. Another meeting at IIASA brought together the European scientists working on national forest sector models and an European trade model.

Procedures and software recently developed to solve computational problems involving uncertainty were presented at an Institute workshop devoted to numerical methods for stochastic optimization. Significant progress has been made in this field, in large part due to IIASA's effort in setting up a network of scientists that interact on a more or less regular basis. IIASA is preparing a volume on computational stochastic programming, including descriptions of codes developed at IIASA and a number of collaborating institutions; test problems and a few applications will also be included. New computational, as well as theoretical, results reported at the workshop will be published as a Mathematical Programming Society Study by the Committee on Stochastic Programming (COSP), founded at the IIASA meeting.

A Japan/IIASA Seminar at the Institute featured system analyses undertaken in connection with the planning and development of Kansai International Airport, urban core-cities, metropolitan transportation, and water resources in Japan. The scholars explaining their projects and the methodology they used came from Kyoto University, the Nagoya Institute of Technology, and Tottori University.

Factors influencing the level and geographic location of mineral exploration by mining corporations, the agencies of several governments, and international organizations were examined at a meeting on the economics of mineral exploration held at IIASA. A book on the subject is planned as exploration affects the future availability and price of minerals, the viability of mining in various regions, and international trade flows.

Strategic and long-term planning in innovation management was discussed at a meeting in Budapest, Hungary sponsored by IIASA, its National Member Organization the Hungarian Committee for Applied Systems Analysis, and the Ganz Electric Works. The experiences of various enterprises, particularly in the field of electrical engineering, and theoretical concepts were presented and will be published shortly by IIASA.

The reporting of findings from a world wide survey of economic–

ecological models and their applications conducted by IIASA and the Institute for Environmental Studies of the Free University in Amsterdam, the Netherlands was a feature of a jointly sponsored workshop at IIASA. The emphasis was on the use of such models in policy setting and management of, for example, natural resources and regional planning. A book is being prepared on this new form of modeling and its relevance for policy making.

The impact of agricultural trade liberalization on different countries, groups of consumers, and farmers was analyzed at an IIASA workshop through the system of linked national agricultural policy models developed at IIASA and collaborating institutions. Removing currently applied protectionist practices for some or all commodities, by some countries or groups of countries demonstrated the interdependence of nations in the world food system.

## New Titles

**Risk Analysis and Decision Processes: Siting of Liquefied Energy Gas Facilities in Four Countries**. Howard C. Kunreuther and Joanne Linnerooth, with John Lathrop, Hermann Atz, Sally MacGill, Christoph Mandl, Michiel Schwarz, and Michael Thompson. Foreword by Mary Douglas. 308 pp. Published by Springer-Verlag. (German edition also available.)

Guidelines are presented to improve risk assessments and the political process by which decisions are made as to "how safe is safe enough?", when dealing with new technologies which promise benefits to many, but where there is a low probability of a large-scale catastrophic accident. A particular emphasis is on compensation and insurance schemes for sharing potential gains and losses among those affected.

These findings resulted from the IIASA study of the decision processes associated with the location of liquefied energy gas facilities in Wilhelmshaven, Federal Republic of Germany; Rotterdam and Eemshaven in the Netherlands; Mossmorran, Scotland, United Kingdom; and California in the United States of America, described in the book. More than fifteen risk assessments commissioned and used in these case histories were compared by the IIASA scholars; the institutional and cultural settings of the decision process in each of the countries are delineated.

A point stressed by the study is that contending views about the distribution of risks and benefits among people cannot be "solved" by objective scientific facts, but represent a political and cultural problem. Risk analysis, including the standardized guidelines for risk assessments they propose, makes informed debate possible and can assist in conflict resolution.

**Global International Economic Models**. Bert G. Hickman, Editor. 324 pp. Selected papers from the Eighth IIASA Global Modeling Conference, held in collaboration with the Seminar on Global Modeling of the US National Science Foundation's Conference on Econometrics and Mathematical Economies. Published by North-Holland: Contributions to Economic Analysis Series, Volume 147.

This volume surveys the state of the art of global international economic modeling. All fifteen models included in the survey feature geographic disaggregation of the world economy and interdependencies among the various nations and regions.

Specific applications analyzed include new simulations of the pioneering macroeconometric LINK Project system (Klein, Hickman, and Johnson) using scenarios of oil prices and a fiscal policy stimulus for investment that improves the rate of return on capital; oil price rises are also used to illustrate the general equilibrium Global Development Model from the University of Brussels, Belgium for the World Bank; disarmament scenarios reducing military expenditures feature in the Leontieff, Carter, and Petri input–output World Model, while the newer Nyhus and Almon INFORUM system of linked input–output models simulates the effects of an increase in personal consumption expenditures in one country on the industrially disaggregated exports of partner countries; commodity–price indexation is explored with REMPIS, a hybrid developed by Weinberg, Nadiri, and Choi; and the feasibility of two development patterns – industry oriented and agriculture oriented – for the Asian Pacific countries is investigated with FUGI, a hybrid macroeconometric/input–output/commodity system from Japan designed by Kaya, Onishi, and Suzuki.

## Research Reports

**RR-83-29** Decision Support for Innovation Management: Application to the Lighting Industry. H-D. Haustein and M. Weber.

**RR-83-30** In-house versus Public Videotex Systems. H.A. Maurer and I. Sebestyen. Reprinted from *Computer Networks*.

**RR-83-31** Printing Without Paper? H.A. Maurer, I. Sebestyen, and J. Charles. Reprinted from *Electronic Publishing Review*.

**RR-83-32** A Democratic Use of New Technology. I. Sebestyen and M. Nimetz. Reprinted from *Computerworld*.

**RR-83-33** The Impact of Seabed Nodule Mining: A Qualitative Analysis. J. Tilton.

**RR-83-34** Liquefied Energy Gas Terminal Risk: A Comparison and Evaluation. C. Mandl and J. Lathrop.

*National Member Organizations*

**Austria** – The Austrian Academy of Sciences; **Bulgaria** – The National Committee for Applied Systems Analysis and Management; **Canada** – The Canadian Committee for IIASA; **Czechoslovakia** – The Committee for IIASA of the Czechoslovak Socialist Republic; **Finland** – The Finnish Committee for IIASA; **France** – The French Association for the Development of Systems Analysis; **German Democratic Republic** – The Academy of Sciences of the German Democratic Republic; **Federal Republic of Germany** – The Max Planck Society for the Advancement of Sciences; **Hungary** – The Hungarian Committee for Applied Systems Analysis; **Italy** – The National Research Council; **Japan** – The Japan Committee for IIASA; **Netherlands** – The Foundation IIASA–Netherlands; **Poland** – The Polish Academy of Sciences; **Sweden** – The Swedish Council for Planning and Coordination of Research; **Union of Soviet Socialist Republics** – The Academy of Sciences of the Union of Soviet Socialist Republics; **United States of America** – The American Academy of Arts and Sciences.

# Director's Corner: *Ecological Interdependence*

The post war period has been marked by growing economic interdependence among nations, as a consequence of expansion and development of industry and agriculture. The same forces are beginning to add ecological and resource interdependence to the international agenda.

The extensive economic interdependencies that emerged after World War II led to and were guided by a system of institutional arrangements new to international experience. Those included the Bretton Woods agreement of 1944, the subsequent creation of specialized agencies such as the International Monetary Fund and the World Bank, *ad hoc* groups of international aid agencies, banking consortia, multinational businesses, and supranational authorities like the European Community.

By comparison with this richness of international economic relations, the environmental component of the international system is still in an embryonic state. It will not be easy to develop another expansion of the international regime of collaboration and regulation. It will require an ability to comprehend the currents of industrial and agricultural change, and the directions they might take. It will require an adequate understanding of the biological, chemical, and physical systems that determine the behavior and the limits of global ecological systems. It will require a capacity to learn from past experience in developing international accords so as to design broader international regimes of governance that integrate the security and economic experience of the past with the resource and ecological pressures of the present.

The first generation of environmental pollution problems were localized, and at the most contained within defined air or water basins. The pollution episodes affecting Lake Baikal in the USSR and Lake Erie in North America influenced tens of thousands of square kilometers of water surface. These problems were largely controlled, despite their size and despite the uncertainty expressed at the time concerning the most critical causes. They represent problems of a scale that is essentially reversible. Costs are low enough to be absorbed. Alternative technologies exist. And there is a source for renewal of the air, water, and even species that have been affected.

Now, however, industrialized countries are facing a second generation of pollution that increases the spatial scale of the affected area by up to two orders of magnitude. Air pollutants in North America and Europe now are known to travel hundreds or even thousands of kilometers from their origin in power plants and industrial boilers.

Because of the jump in scale, the *qualitative* character of the problems are changing. Now the costs to reverse the trends are enormous. It has been conservatively estimated that it would require 2 billion US dollars for each of 20 years to reduce sulfur emissions generated east of the Mississippi River in the USA by 50%. Traditional policies seem infeasible because the source of emission and the major impacts are separated by hundreds to thousands of kilometers. Otherwise reasonable policies, such as that of "polluter pays", hence seem economically destructive, politically impractical, and lacking in equity. They are problems that cross so many political jurisdictions that the authority and credibility needed for action are often lacking. Finally, the difficulty of the solutions places an inordinate demand upon certainty of knowledge of the causes and effects, in order to provide a basis for confident action.

But still a third generation of problems – and opportunities – are now emerging. An example is the accumulation of carbon dioxide in the atmosphere. Geological and biological evolution has led to a balance of the chemical constituents of the atmosphere. Man has shifted some of those balancing forces. Carbon is released through the burning of fossil fuels. Removal of forests for agricultural or settlement purposes has released more carbon previously locked away from the atmosphere. Industrial and agricultural expansion has therefore set in motion a new generation of problems whose scale is essentially hemispheric to global.

Two qualitatively new dimensions appear. First, the costs of remedial action, and the absence of a source for renewal suggests, for the first time, that the trends may not be reversible. Adaptation to the inevitable might be the only achievable goal. Secondly, the label of "pollution" or "environmental" is no longer appropriate. These are problems not understood simply in terms of industrial or agricultural outputs burdening the air or water. They are fundamentally ecological because they affect processes that link elements of our biological world to global atmospheric and hydrospheric processes. Forests, swamps, and termites become more than resources or curiosities of nature. They are part of a system of sustainability.

Over the last decade, however, there has been a remarkable accumulation of knowledge that does make it possible to define what can be done. Four activities can achieve results. First, it is now possible to develop consistent scenarios for energy and agricultural expansion and development. IIASA itself has had a lead role through its first major project – Energy in a Finite World – and its Food and Agriculture Program. Second, recent advances in the natural sciences are leading to a deeper understanding of the biosphere and its links with the atmosphere and oceans. That understanding has also been shaped by international scientific institutions: the World Meteorological Organization, the International Council of Scientific Unions and its Scientific Committee on Problems of the Environment. The third would focus on experience in developing international accords, and upon international policies of adaptation and cooperation in relation to the emergence of ecological interdependence among nations. And finally, IIASA itself has had a decade of collaborative experience that can now be directed to the expansion and evaluation of alternative methods of synthesis.

It is for those reasons that IIASA has established a one year feasibility study to design a long-term project on Sustainable Development of the Biosphere. The problems are clear. The base of experience for a synthesis seems on hand. And the global character of the issues relates closely to national needs among IIASA's sponsoring national groups.

C.S. Holling