International Institute for
Applied Systems Analysis

SUMMER 1982
ISSN 0252-9572

OPTIONS

Healing Lake Balaton

László Somlyódy has led the IIASA research seeking to understand — and reverse — the eutrophication of the largest shallow lake in central Europe.

Lakes, like every living thing, slowly age, their ecosystems gradually being modified by changes in the balance between nutrients, oxygen, and the various organisms in the lakes. This process of ageing, called eutrophication, occurs naturally over hundreds of centuries.

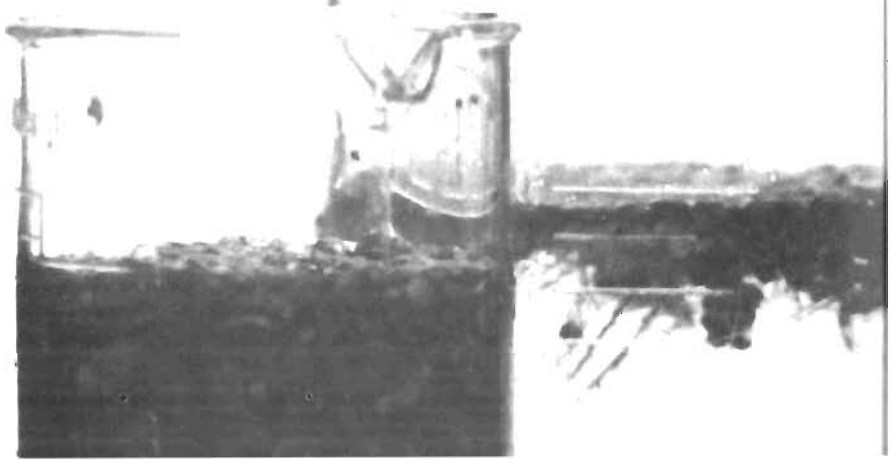
But a more rapid and destructive kind of eutrophication, a penalty of human progress, can destabilize a lake's ecosystem in a short time. Here the natural supply of such nutrients as phosphorus, nitrogen, carbon, and silicon compounds is fatally augmented by human activities, skewing the natural cycle in which tiny plants transform these compounds into the organic compounds at the base of the food chain. The added nutrients encourage excessive blooms of algae, which produce more and more organic compounds. This overabundant organic matter is decomposed by bacterial action, robbing the lake waters of oxygen. The former ecosystem is replaced by a new one, with less diversity and more species undesirable to man. In shallow lakes, where there is no thermal stratification, this eutrophication process can be more rapid than in deep lakes, and it is less thoroughly understood.

The intermediate steps in this destructive process are not easily seen. Instead, we perceive a rather sudden degradation. A lake seems suddenly transformed by concentrations of algal blooms, discoloration, and floating debris. The water tastes foul; it has a bad odor; fish are killed. The internal life of the lake is altered, but so is its wider life, as a source of drinking water, a site for recreation, and an aesthetic object of natural beauty.

But it is just this — the involvement of lakes in the larger human ecosphere — that has accelerated this natural process of ageing into an urgent problem of environmental quality. Inadvertently, over periods of years, we introduce larger and larger amounts of inorganic nutrients into lake ecosystems as we increase our use of fertilizers, discharge wastewater into lakes, and develop tourism and industry along the shores. As we change the regional infrastructure we alter the ecosystem of the lake. While the end result of man-made eutrophication is seen in the lake's water, the reasons and possible remedies for that eutrophication lie in the surrounding region. Thus we have on the one hand an ecological problem driven by the biological, physical, and chemical processes of the lake; and, on the other, a set of socioeconomic factors deeply rooted in human activities around the lake.

Many of the eutrophication studies undertaken thus far have been narrowly focused on certain scientific disciplines — for example, biology — but increasing numbers of researchers have attempted to view the problem more broadly, by incorporating both the processes under way in the lake and those in the surrounding watershed. Some, moreover, have made a systematic attempt to look at both the processes of the lake and the economic and policy dynamics of the wider world.

A systems approach here permits us to consider simultaneously the scientific and the resource management issues, to handle complexity, and to accommodate various kinds of uncertainties. Mathematical modeling is one of the most effective tools in developing a systems approach; however, without field experiments and data, the



model cannot provide a reasonable simulation of the real world.

Hungary's Lake Balaton seemed an ideal "laboratory" for such a case study. The largest lake in central Europe and one of the largest shallow lakes in the world, it exhibited the unfavorable signs of artificial eutrophication. A reasonable amount of data was already available at the beginning of our study in 1978, and intense, mainly experimental, research was under way at various Hungarian institutes. Besides the scientific interest, there was also a strong economic interest in the solution of this real-life problem. Roughly 40 percent of the hard-currency income from tourism in Hungary stems from the superb scenery and agreeable summer climate of the Balaton region. From the standpoint of IIASA, the study offered the prospect of developing systems techniques that could be applied to other shallow lakes with similar problems. Thus a cooperative study was begun between IIASA and the Hungarian Academy of Sciences, the National Water Authority, and their constituent institutes. Scientists from eight other nations at IIASA contributed to this investigation, which was completed this year.

Lake Balaton

The length of Lake Balaton is 78 kilometers, its average width around 8 kilometers, and its average depth 3.1 meters. The major inflow of the lake is from the River Zala, which drains approximately 5800 square kilometers — half the total catchment area. There is a single outflow at the other end of the lake through a control gate. The average residence time of water in the lake is about four years. For a relatively long two-month period the lake is frozen over. In summer the water temperature may exceed 25 C.

The regional economy is dominated by agricultural activity and tourism. The permanent population in the recreational area is around 100,000, but on some summer weekends the transient population may soar to one million. The ten-to-twenty-fold growth in tourism, increasing fertilizer use, and other factors during the past twenty to twenty-five years have had a harmful effect on the biology of the lake: algal biomass increased by a factor of fifteen to twenty. At the most "polluted" western basin, primary productivity peaks of up to 13.6 grams of carbon per square meter per day were observed — a hypertrophic level.

Wind activity strongly influences the resuspension of sediment and the associated nutrient compounds, but it also assures favorable oxygen conditions through vertical mixing. The wind induces intensive water circulation in the lake characterized by spatial "gyres" and a fast back-and-forth movement (seiche) along the length of the lake. The intensity of the latter is like that of a swiftly flowing river such as the Danube, if the Danube flowed from Vienna to Budapest then back to Vienna several hours later.

Phosphorus plays the dominant role in the eutrophication of the lake. The case study indicates that 33 percent of the total phosphorus load of about a thousand kilograms per day is derived from sewage, 27 percent from diffuse sources (mainly of agricultural origin), and 22 percent from runoff processes near the lake. Atmospheric pollution contributes 18 percent. The contribution of sewage discharges in the nutrient load that is readily available for algae (about 50 percent of the total phosphorus load) is higher: sewage released in the recreational area alone accounts for 36 percent. The load distribution along the lake is approximately uniform; but the volume-related value is much higher at Keszthely Bay (about 1.6 milligrams per square meter per day), resulting in a more advanced level of eutrophication and a strong longitudinal gradient in the water quality. The sewage load is largest at the eastern end. At the western end, fluctuations in the load are caused mainly by such nonpoint sources as rainfall runoff processes.

Extensive records are available on hydrology and meteorology. Regular water quality monitoring started in the early 1970s, but irregular data are available back to the early 1960s. Several other *in situ* and laboratory observations were also made, the most recent as a direct consequence of the modeling work.

Our Approach

The major question is: how can the water quality be improved under economic constraints, given the various conflicting socioeconomic interests of the region? The first step toward answering it was to evaluate our understanding of what is going on in the lake and its catchment area. The dilemma was that we had to be both scientific and practical, ending with a "simple" but realistic model that managers and regional planners could understand and use.

We decided to employ the principle of decomposition and aggregation. The essence of this is that the system is first broken down into smaller units accessible to detailed analysis — for example, the region and the lake, or, within the lake, four basins of approxi-

Contents

OPTIONS

is produced quarterly by the Office of Communications, IIASA.

International Institute for Applied Systems Analysis
A-2361 Laxenburg, Austria
telephone 02236 71521; telex 079137

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

Dr. László Somlyódy, pictured above, was the leader of the Lake Balaton case study at IIASA from 1980 to 1982. He is from the Institute for Water Pollution Control of the Research Center for Water Resources Development (VITUKI) in Budapest, Hungary.

mately uniform water quality. The results of these analyses are then aggregated and only the essential features are preserved for the subsequent part of the study – that is, the transition from the "micro" to the "macro" level. Thus a pyramid of models is formed with the water quality management model at the top. The detailed models are not directly coupled to one large model, with the result that the approach is off-line in character.

The approach and research incorporated issues such as the watershed and the nutrient loadings, sediment and its interaction with the water, biochemistry, water circulation, the entire eutrophication process of the lake, uncertainties and the influence of controllable (load) and noncontrollable (climatic) factors, and finally the issue of water quality management. One basic feature of the approach is that it looks for the relative importance of various processes, decisions, and policies in the entire problem without making *a priori* assumptions about them, while still remaining on a relatively low level of complexity.

Admittedly, we had many difficulties. The case study presented formidable problems of communication. Because of the interdisciplinary nature of the study, a common language had to be developed – not without pains – among chemists, biologists, mathematicians, hydrologists, engineers, economists, computer specialists, and managers. In general, specialization leads to noncommunication with those outside the field. Each expert was convinced that only one factor had to be considered and that factor was in his own field. Perhaps one of the major achievements of the study was that we were able to work out a common language for the participants – about thirty scientists from Hungary and some twenty scientists from eight other nations. Experimental scientists came to appreciate the work of modelers, managers that of the biologists, and so on. Many fruitful feedbacks were realized between data collection and modeling, and research and management.

The amount, quality, and accessibility of data generated other types of difficulties. Most of the historical data reflected the specific interest of the discipline in question, but seldom addressed the eutrophication problem as such. In many cases only sporadic and uncertain data were available. The elaboration of the Lake Balaton data bank was the precondition of any further research. At a later stage we sometimes had difficulties that were exactly the opposite: how to understand and explain all the irregularities in the systems' behavior reflected by "too frequent" observations. For example, on the River Zala, the major nutrient source of the lake, we showed through an analytical approach and a random simulation technique that, if the sampling were properly planned, the number of samples from the existing monitoring network could be decreased to one-fifth or one-sixth without loss of information about the eutrophication process. Because of the limited resources available, the realization of an "optimal" sampling strategy is a major issue.

Findings

In the Lake Balaton case study, we found that the behavior of the sediment as a possible internal nutrient source is one of the key elements of the problem. In the short term, the wind-induced resuspension of sediments in the water is of major importance. The model developed to simulate this dynamic element of the eutrophication process worked well for Balaton, and is now used for other systems, such as Lake Erie in North America.

Predicting the long-term behavior of the sediment (especially after reducing the external nutrient load) is extremely difficult. Based on the experimental research of five groups working on this subject in Hungary, we found that the internal load (sediment release) is almost equal to the external load. This means that a 100 percent cut in the external load leads to only a 50 percent reduction in the total nutrient load. However, very little is known about the long-term future behavior of lake sediments.

The external load can be controlled, but not the internal one, which is a consequence of pollutants accumulating in the lake during preceding decades. We can offer this warning to managers: act as soon as possible. Otherwise, if the internal load is comparable with the external load, as it currently is in Lake Balaton, a one-year delay in corrective action causes two to three years' delay in achieving the same improved water quality level.

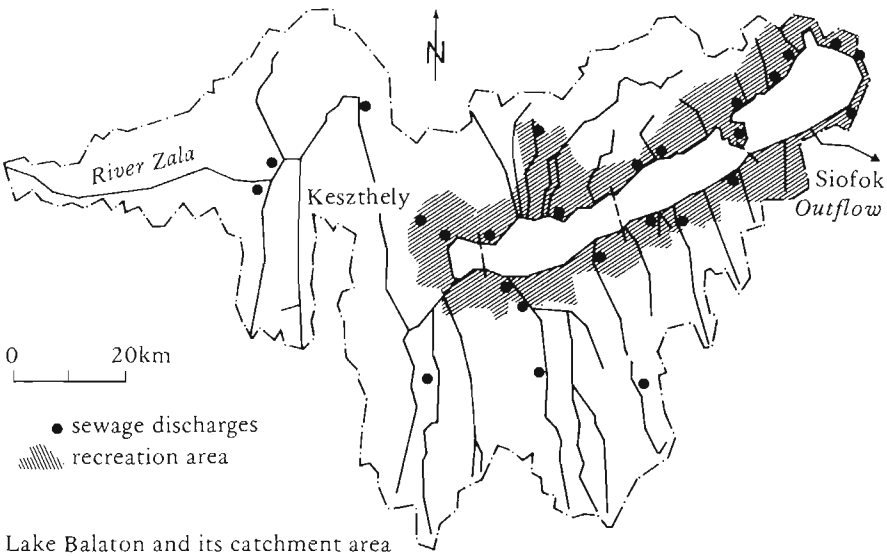
On the basis of the analysis of historical data, we developed models for generating meteorological and nutrient load scenarios in a random fashion. This is a precondition to studying the future behavior of the lake under changed conditions. Through the use of the lake model (supplied with a stochastic input) we found that Balaton, especially the shallowest, western end, is heavily influenced by climatic factors. Unfavorable conditions of temperature, solar radiation, and the like can compensate a large reduction in the nutrient load (similar conclusions were gained in a different way for Lake Erie).

For the "macro problem" the detailed properties of the system are less important. Decisions are made on the basis of the behavior of some aggregated parameters. We selected the yearly peak chlorophyll-a concentration as a measure of the recreational use of the lake. Through model experiments it turned out that this variable is approximately a linear function of the nutrient load for all four basins. Thus we succeeded in replacing the detailed, dynamic lake model with a "static" model for the

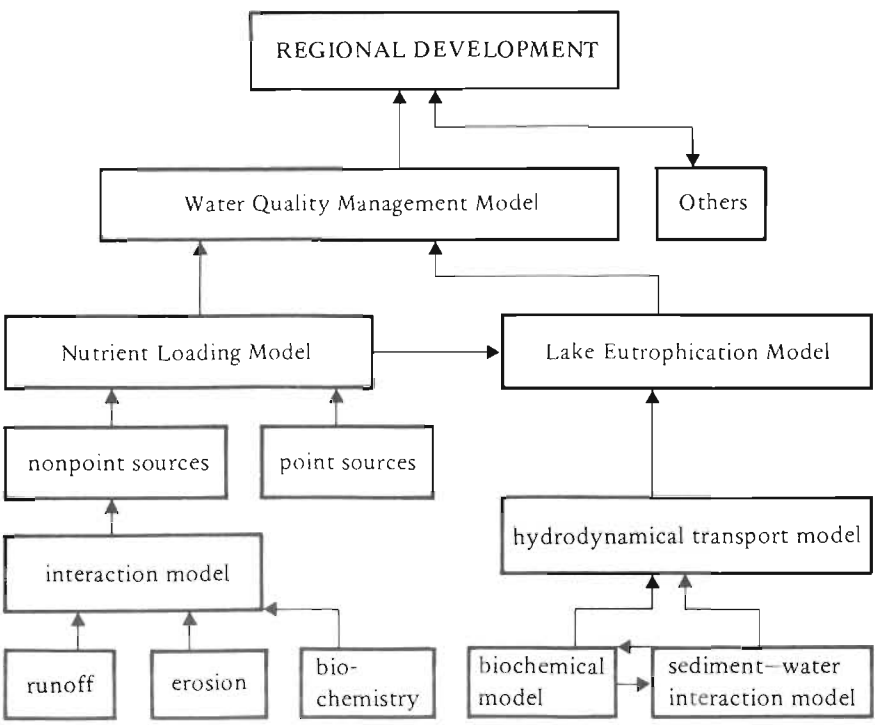
most critical parameter to be used for decision making. The stochastic version of this model, accounting for the dominating uncertainties in climatic and load factors, was also worked out and calculates the "immediate response" of the lake after the load reduction. On the average, a 100 percent reduction of the phosphorus load at the most eutrophic end of the lake would cause a decrease in chlorophyll-a peak concentration from about 75 micrograms per liter to 30 micrograms per liter, a notable improvement. Further decreases would depend on weather conditions and the behavior of sediments, both uncontrollable processes.

We consider a lake to be eutrophic when the peak chlorophyll-a load is in the range of 30 to 70 micrograms per liter, and hypertrophic above 70 micrograms per liter. Our predictions show that without control measures the chlorophyll-a peak concentrations in Balaton can range between 30 and 150 micrograms per liter. This view of a broad range of values, rather than a single mean value, was not readily accepted outside the scientific community. But this year, "surprisingly" high values close to the upper extreme were observed, convincing decision makers that stochastic effects are indeed important in planning control actions.

The study resulted in several essential methodological achievements. These are associated with the research approach and model development, parameter estimation, model structure identification, sensitivity and uncertainty analysis, and coupled hydrophysical and biochemical modeling. Emphasis should be given to the management model which also accounts for uncertainties; as far as we know, no similar approach to the problem of eutrophication control has been developed before.



Lake Balaton and its catchment area



Water Quality Management

The establishment of this linear stochastic model allowed its direct inclusion in an optimization framework: a solution we looked for on the level of water quality management. The objective was to discover which control strategies would maximize the improvement of water quality at a given level of funding. (Water quality is expressed here as a combination of the mean and standard deviations of peak chlorophyll-a concentrations in all four basins.) Several other constraints exist in the system. Major control alternatives are tertiary sewage treatment and the establishment of prereservoirs. Both the spatial distribution of the investments (the lake is fed by many sewage discharges and tributaries) and the scheduling are important questions to be answered. Several parameters expressing the subjective judgment of decision makers are incorporated into the model, which can be used in an interactive fashion in the policy making procedure. Analysis suggests that the long-term solution of the problem is to divert the sewage from the region, an expensive undertaking that could not be completed before the 1990s. But Lake Balaton cannot wait. Provisional measures are urgently required. Thus, while the management model developed in the study can be used for making decisions over the next fifteen to twenty years, it should also be applied, with special emphasis on the needs of decision makers, to decisions

Lake Erie is the shallowest of the five connected Great Lakes reaching nearly halfway across the North American continent and forming part of the border between Canada and the United States. It was classified in the 1960s as the most polluted of the Great Lakes. Population and industrial growth on the US shore (including Detroit, Michigan and Cleveland, Ohio) generated the phosphorus and other compounds responsible for the advanced eutrophication.

Dr. David Lam of the National Water Research Institute of Canada, involved in the intensive research program undertaken on the Great Lakes, notes that "there are many points of similarity between Erie and Balaton, leading to North American interest in the IIASA study of Lake Balaton. The IIASA application of systems analysis is very efficient."

James L. Amos, NGM

One of the problems shared by the two lakes, because of their shallowness, is the sediment constantly being stirred up by the wind and weather. Dr. Lam reports there are no difficulties in using in Canada the IIASA sediment resuspension model developed for Lake Balaton. Dr. Lam's wave-interaction formula was the germ of the IIASA model.

"Now that the IIASA study of Lake Balaton has been completed, we are discussing ways to continue this cooperation with Hungarian scientists," says Dr. Lam. "The more we understand the eutrophication process in shallow lakes, the better equipped we are to control – and reverse – the process."

Successful efforts to "clean up" the Great Lakes began in the 1970s, with a ban on phosphorus detergents and improved sewage treatment. Now there is swimming again in Lake Erie.

needed during the next few years.

When we began to study Lake Balaton, the assumption was that the majority of nutrients had an agricultural origin. Based on thorough data collection and experiments, a load estimate incorporating temporal and spatial changes was established. Because sewage appears to contribute roughly 50 percent of the available phosphorus load, we see tertiary sewage treatment as one of the most effective tools in this case for controlling eutrophication. From the analysis of the stochastic features of the load – the climatic and hydrological effects – it became clear, however, that the fluctuations in the load are related to rainfall runoff processes. The reduction of these fluctuations requires other control alternatives, such as prereservoirs consisting of two parts: a sedimentation basin and a reed lake.

Our results clearly showed that investments should start at the western end of the lake. If uncertainties are neglected or the budget is limited (around 300 million forints, or about 10 million US dollars) tertiary treatment is found to be "optimal." If uncertainties are taken into account, a combination of tertiary sewage treatment and reservoir projects is the preferred result (requiring a budget roughly ten times larger), clearly indicating that sewage treatment is a more effective technique for reducing the mean load, but has little effect on fluctuations in the tributary load and the concentrations already in the lake. Introduction of tertiary treatment in the western subwatersheds would decrease the mean chlorophyll-a concentration at Keszthely from about 75 to 40 micrograms per liter (short-term response), with possible extreme values of the order of 100 micrograms per liter. But the reservoir project would decrease chlorophyll-a mean values to about 30 micrograms per liter, with extreme values of about 50 micrograms per liter, showing quantitatively that natural factors are much more successfully controlled this way. All this shows that it is extremely important to include stochastic load factors in formulating water quality management options.

Epilogue

In May, top-level Hungarian politicians and scientists visited IIASA and discussed the results of the Balaton case study. One of their conclusions was that the study gave the first comprehensive picture of the Balaton problem and that it should serve as a "unified" basis for further Hungarian research and management. The results and models will be implemented in Hungary with special emphasis on the management model and the problem of monitoring.

Certain decisions have already been made. The first stage of the largest reservoir project, called Small Balaton, at the mouth of the Zala River is now under construction, and will provide a sedimentation basin with a surface area of some 20 square kilometers. Our results clearly showed, however, that the scheduling of this large investment should be reconsidered, a point recognized by our decision maker partners. Most urgently needed, according to our study, is the introduction of tertiary treatment at Zalaegerszeg, a city of some 60,000 people, and the largest along the Zala River

We deeply feel that our efforts contribute to the preservation of this unique Hungarian "sea" and to similar shallow lake systems around the world.

Staircase to Profitability

A Swedish economist sends Skåne an economic bulletin, using a novel technique. **Carl Posey** describes the message and the medium.

Ulf Stromqvist speaks persuasively to the people gathered in the low, smoky room in Malmo. They are an unusual mixture of regional and urban planners, politicians, public-spirited citizens, environmentalists, all drawn to this renovated sixteenth century meeting room at the Saint Gertrud complex to hear an unwelcome message: their economy is in trouble.

The message is a byproduct of the Swedish economist's involvement in a regional case study carried out jointly by the Malmo-based Intermunicipal Association for Southwestern Skåne (Sydvästra Skånes Kommunalförbund, or SSK) and scientists at IIASA. His audience is skeptical, possibly uncomfortable, on hearing the results of that work. Traditional planners are wary of computer models in the analysis of regional systems. The scenarios are unpalatable, for they seem to say that the good life as lived in this southern corner of Sweden has something wrong with it. But it is the Stromqvist view of their economy that is most disconcerting, for he sees industrial cracks in Skåne that can be repaired only by solutions from outside the region — even outside Sweden — and by taking undesirably high risks in the international marketplace.

At the same time, they are aware that the one portion of southwestern Skåne's industry that has been exposed to international competition, the region's two large shipyards, will release some 4000 people in 1982. Hurt by the energy crises of the 1970s, and by the lower prices of far-eastern shipbuilders, a Malmo yard that has flourished for a century now holds a halfbuilt supertanker for which there is no buyer. So, in the shadow of the immense, idle cranes of the Kockum shipyard, this evening's audience is less than cordial, listening to the unwelcome news that this could be the first of a string of failures.

But they may also be put off by the Stromqvist delivery, which has developed a faintly evangelical note. This derives from his having reached his conclusions by applying unconventional — and controversial — techniques in gauging the economic situation in Skåne. As a consultant economist, Mr. Stromqvist was first drawn into the regional case study to develop a data base — a precondition of using computer models to examine alternative futures for the region. Then, as his data unfolded, his perception of the regional economy began to darken. "I had no preconceptions on going into the study," he says; but neither did he expect to come to his present conclusions. These, while not fully shared by his colleagues on the project, depict a stagnating regional economy sheltered from international competition, with some institutions in some industrial sectors — heavy equipment particularly — actually operating below their payrolls.

Nowhere is this protective isolation more pronounced, in his view, than in the food industry of the region, which constitutes about 40 percent of the nation's. However, the very richness of its farmlands, and the wealth of recreational lands dispersed among them, has stimulated protective governmental reflexes. And these policies, intended by the government to shield the food industry from much external competition, are not entirely beneficial, according to Mr. Stromqvist.

"Skåne has a well-developed food industry that is expanding relative to the rest of Sweden. But 80 percent of the Swedish food industry is not open

to international competition. It is sheltered, along with agriculture. You can't expect a further increase in the industrialization of Skåne from the food industry because its growth is actually a function of household income in Sweden and because of the degree of political protection given to the food and agriculture sector."

Enter Stagnation

By the late 1970s a roughly stable Swedish population and economy and the absence of any national or international forces for dynamic change had begun to produce signs of stagnation in Skåne's food industry — stagnation, Mr. Stromqvist notes, for which there is no simple cure.

"An obvious solution might seem to be to increase what we already have in Skåne, but that only seems to shift the entire Swedish food industry here. With all the food production in one area, you have long distribution lines to the north, and higher prices for domestically produced food. On the other hand, if you cut down the land used for agriculture in Skåne so that other parts of Sweden can compete more favorably, you will also increase the cost of agricultural production."

Alternative industries that are not energy intensive, such as electronics, are poorly developed in southwestern Sweden, he says. "The problem in the chemical industry, for example, is that it didn't develop in an international context, but in a Nordic one. It isn't the sort of chemical industry you find farther south. Among the twenty most highly developed nations in the world, Sweden is at the bottom in terms of the proportion of chemical production in total industry."

These problems of stagnation in the various industrial sectors of southwestern Skåne are probably endemic in the regional economy, he believes, as long as it is sheltered from the challenge of international economic forces.

"If you take Skåne and look at it outside the public sector," he explains, "half or more of employment and capital and land allocations are used by sheltered industries. In the northern part of Sweden, 90 percent of this same allocation goes to sectors engaged in international competition. Of course, this gives Skåne a robust structure, but at the cost of certain dynamic features. For example, rising unemployment there, because of this sheltered aspect, will be quite persistent. This is curious, because Skåne is so well situated for international competition in comparison with other parts of Sweden. I find it counterintuitive."

The "counterintuitive" message he delivers to the gathering at Saint Gertrud's arises from his unconventional approach to analyzing the economic structure of southwestern Skåne. This analysis assesses the profitability of each institution in any given industrial sector — each element of the regional food industry sector, for example. Mr. Stromqvist is quick to point out that his methods, while unconventional, are in fact found in traditional production theory. The difference is that he has combined those elements of theory with the calculating capabilities of computers and the dense data base developed to support case-study models. The result is a diagram that shows at a glance the relative profitability of each part of any given industrial sector.

Ulf Stromqvist

Since 1979, the rich, rolling fields of southwestern Sweden have been the laboratory for an experiment to test the potential of systems analysis to illuminate the complex, often competing processes involved in a region's economic development. While this analytical computer-based approach to problems has become routine in such high technology areas as space research, it has only recently begun to be applied to solving problems at the municipal and regional levels. The southwest Skåne regional case study is one of four conducted by IIASA. The other three studies focus on the Silistra region of Bulgaria, the Noteč region of Poland, and, in a study just beginning, the Tuscany region of Italy.

According to Dr. Folke Snickars, the Swedish economist who led the project at the International Institute for Applied Systems Analysis (IIASA), systems analysis works best in countries with a strong regional planning tradition — Scandinavia, for example, and eastern nations with centrally planned economies. He notes a rising North American interest in multiregional economic modeling, however, as regional planners there are increasingly forced by environmental and other considerations to intervene in the "market solution."

The study, carried out by IIASA scientists and planners with SSK, the Intermunicipal Association for Southwestern Skåne, derives from the concept that the conflicting forces and demands that shape the development of regions are also interdependent, and must be examined jointly.

At the same time, Swedish planners have been increasingly concerned over the region's economic future, which has been jarred by the declining prospects of the region's two major shipyards and signs of stagnation in the regional economy. But compensating industrial development is constrained by protective national policies toward the agricultural lands that cover much of southwestern Sweden. The need to resolve such conflicts in a relatively short time forged the present partnership between an international research institution and a small team of regional planners.

Profitability "Stairs"

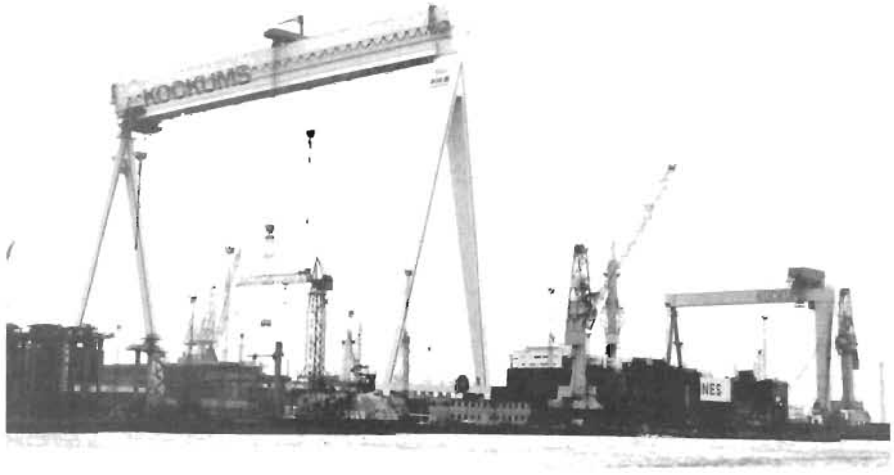
The method of displaying these data results in a productivity structure diagram for the industrial sector, in which the vertical axis is "value added per employee" (an amalgam of labor and operating costs and gross profits) and the horizontal axis is the cumulative percentage of that sector's labor force. To the resulting "staircase" diagram he adds a calculated "wage level" derived from value-added-per-employee totals. The industrial institutions – the steps – above that horizontal line are operating at a profit. But in those which fall below the wage-level line, the companies are not even meeting their payroll.

"We call this part 'worst practice'," says Mr. Stromqvist. "In these cases either people have to be sacked and facilities shut down or the industry has to be subsidized, like the steel and automobile industries everywhere."

The value of this kind of diagram, he explains, is that it permits managers to see where failure is occurring – and presents, in a way that is easily seen, alternatives to such decay.

Those alternatives, according to Mr. Stromqvist, require that the sector be inoculated with what he calls "national best practice," a term describing efforts to increase productivity and capital by exercising the best available investment options and by realizing the resulting "capital-disembodied growth" – productivity increases achieved through reorganization, training, and the like. The application of this kind of dynamic change, in the context of his diagram, "lifts" some failing companies above the critical wage-level line, raises the wage level, but also encourages an economic climate in which companies operating at a loss can be shut down without human catastrophes. This is the kind of dynamic element that, in Mr. Stromqvist's view, southwestern Skåne lacks. "Remove the shelter," he says, "and you add this necessary dynamic feature."

But his insight into regional economics is still largely theoretical. Some critics of the process contend that it oversimplifies, and mixes "apples and oranges" in lumping together all organizations in one sector – for example, by combining productivity values for highly mechanized and relatively unmechanized units in the industrial sector being studied.



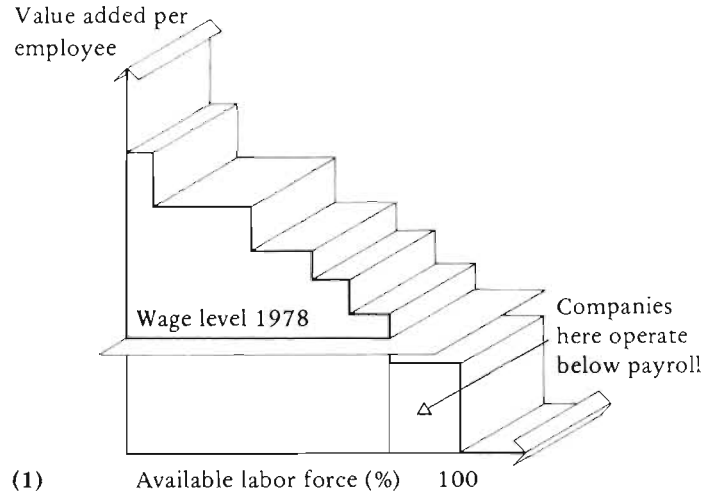
Another criticism leveled at the technique is that it does not accommodate the region's most difficult problem, that of land use. Land use policies in southwestern Skåne deny the region the obvious economic solution to its problems – to expand industrial development in other, less energy-consuming fields – because of the high priority given to protecting agriculture. Employment-intensive industries have a problem finding physical space there, let alone room for growth in the international marketplace. Mr. Stromqvist wants to incorporate land use data into his diagrams.

Bridges

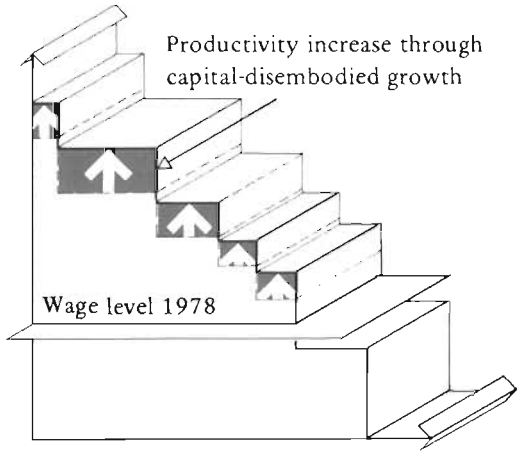
This land use question also points up the physical aspect of southwestern Skåne's economic isolation. While geographically well situated to involve itself with the high technology industries of Denmark and the rest of Europe, the south of Sweden is physically linked to the continent only by air and sea routes. There is no bridge between Jutland and Sjaelland, and no bridge to Sweden; any bridge construction will involve the question of land use in southwestern Skåne.

Whether messages like the one Mr. Stromqvist delivers on this chilly April evening in Malmo will help build the necessary real and metaphorical bridges is moot. But it is entirely possible that the industrial sector "staircases" he presents provide a rough starting point in the long journey toward the hard economic decisions ahead of southern Sweden.

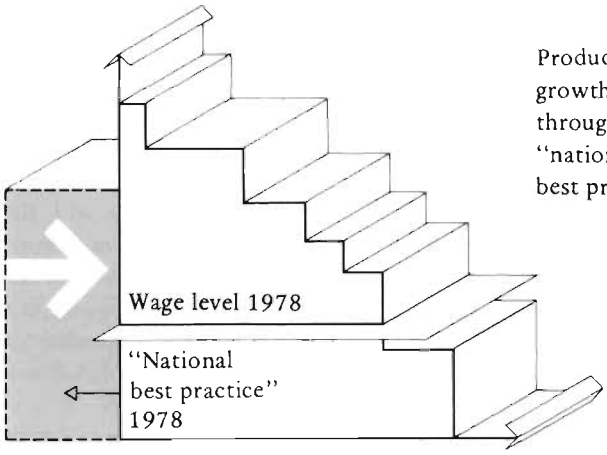
Steps to Greater Productivity. Averaging productivity in a given industrial sector generalizes distributions within the sector. The display used in the IIASA-SSK Skåne study breaks down each industrial sector into its elements, which appear (1) as individual steps linking a vertical axis (value added per employee) and a horizontal one (the cumulative percentage of that sector's labor force). A horizontal line denotes the sector's wage level. Organizations whose "steps" fall below that line are not meeting their payrolls; either they operate at a loss and are finally shut down, or they are buoyed up by subsidies. The productivity steps can be raised (2) by "capital disembodied growth" obtained through training, reorganization, streamlining, and the like. In a competitive, dynamic economic setting, this kind of growth can be both effective and real. (BUT in heavily subsidized sectors such as Sweden's food industry, the subsidies create only the *illusion* of such growth. Such illusory productivity increases are as attractive to capital as the real thing; but they endure only as long as the subsidy stays in place.) Applying "national best practice," an optimum mix of investment options (3), capital and productivity also rise (4), which increases productivity by introducing new industry, but also raises wage levels (5). The difference in wage level (6) is an indicator of long-term productivity.


Value added per employee
Wage level 1978
Companies here operate below payroll
Available labor force (%)
100

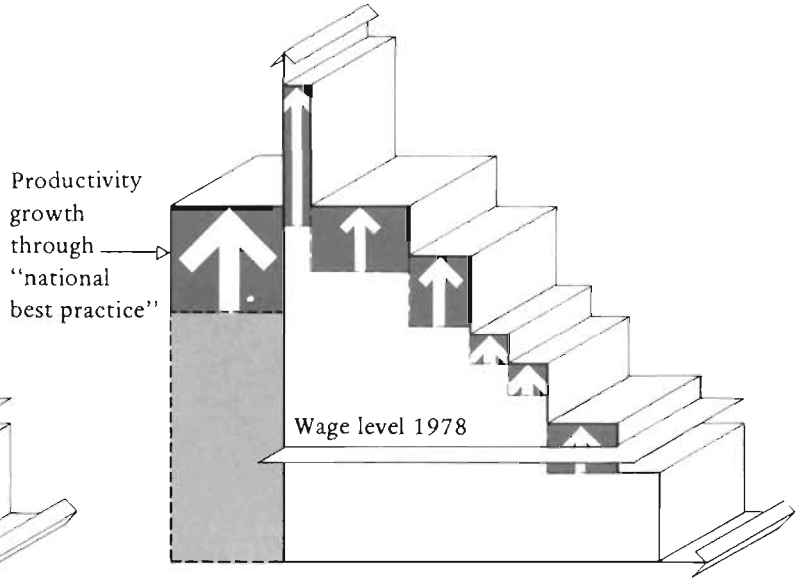
(1)


Productivity increase through capital-disembodied growth
Wage level 1978

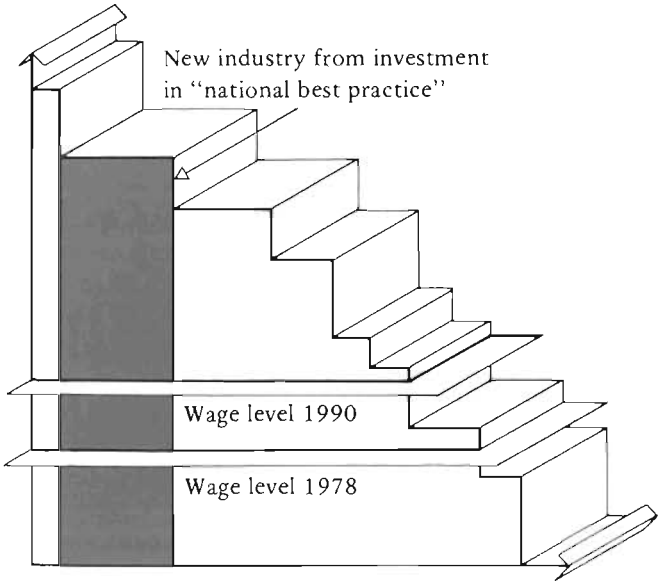
(2)


Wage level 1978
"National best practice" 1978

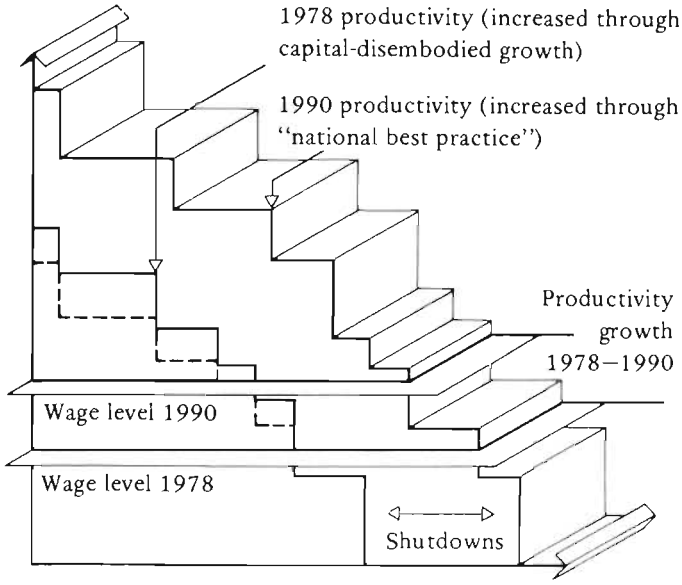
(3)


Productivity growth through "national best practice"
Wage level 1978

(4)


New industry from investment in "national best practice"
Wage level 1990
Wage level 1978

(5)


1978 productivity (increased through capital-disembodied growth)
1990 productivity (increased through "national best practice")
Productivity growth 1978–1990
Wage level 1990
Wage level 1978
Shutdowns

(6)

How to Get from Here to There

Viable solutions to traffic problems are offered by Horst Strobel, author of *Computer Controlled Urban Transportation: A Survey of Concepts, Methods, and International Experiences*, Volume 10 in the Wiley IIASA International Series on Applied Systems Analysis (John Wiley and Sons Ltd., Chichester, UK, 1982).

The human toll paid the automobile is one of those well-known, appalling statistics for which there seems no cure. Year after year about 150,000 people worldwide – the population of a medium-sized city – are killed in automobile accidents. This risk is far higher than the risk of being killed in accidents involving fire and explosions or by natural catastrophes.

But there is another less obvious kind of destruction arising from the automobile, in its nonlethal way as hazardous as the accidents. The congestion caused by automobiles destroys the quality of urban life, drains the vitality of cities, and forces people to flee the combined effects of concentrated air pollution, noise, building vibration, and the visual intrusion of more and bigger freeways and arterial streets.

Annual losses due to traffic congestion in cities such as London, Paris, and Tokyo run into hundreds of millions of dollars. And congested traffic conditions greatly increase the automobile's considerable appetite for dwindling supplies of fossil fuels.

Traffic problems have developed in most countries along similar lines: there is a sharp increase in the number of automobiles over a five-to-ten-year period, in which time it is not possible to create the new space needed by the vehicles, so that congestion occurs more frequently and to a larger spatial extent. These phenomena were observed first in the USA at the end of the 1950s, in western Europe in the mid-1960s, and in Japan in the early 1970s; most eastern European countries are presently faced with the beginning of this kind of development. The usual reaction is to build more and bigger traffic areas. For example, 28 percent of the area of most US cities is devoted to highway vehicles; in some cities this rises to over 50 percent.

Urban Transportation author Professor Horst Strobel is from the Institute for Transportation and Communication in Dresden, German Democratic Republic.

In addition to this increase in the city areas used for driving and parking, the automobile has also changed land use patterns in many countries, in particular the locations of residential and industrial zones. Conventional public transport systems – fixed-route bus, trolley and streetcar lines, or urban railway systems – were designed to serve city structures typical of fifty years ago, when more than two-thirds of the urban population lived in the high density center. These systems are becoming more and more incompatible with the changing spatial distribution of populations and activities in cities. With the increased use of the private car, this causes a decrease in the number of people using public transportation systems, resulting in less frequent services. This then convinces more public transit riders to use private cars for their daily trip to work. It is generally true that most public buses and streetcars occupy the same traffic areas as automobiles and thus experience similar delays.

Overall Strategy

In Professor Strobel's view, the complexity of urban traffic problems requires the application of a set of approaches as a general *combined transport and urban development strategy*.

This entails clearly defining the conflicting objectives of the three groups of interested parties: the public transit travelers and private car drivers; the inhabitants of the city and the city as a whole; and public transit companies. For example, the users of public transportation would like independence with regard to departure time and des-

tination, convenience, and speed — the qualities inherent in a private car. The city inhabitants, however, would like to preserve the social function of the city as a political, social, cultural, and economic center, and to protect the urban environment and use resources effectively. Public transit companies require traffic safety and operational reliability, a reduction of operational expenses, and the ability to integrate any new systems into existing ones.

With these three groups in mind, Professor Strobel explains the complex policies required to balance supply and demand for transportation over the short, medium, and long term. The long-term strategies involve urban redevelopment, construction of new towns, relocation of factories and markets and other urban facilities, and the provision of entirely new — automated, demand-oriented — public transportation systems.

The medium-term strategies take the existing configurations and apply controls to reduce the use and ownership of automobiles while encouraging the use of public transportation. Simultaneously, measures such as road widening and increasing parking facilities would be taken to alter the capacity of road networks.

The short-term policies to be implemented immediately are aimed at controlling the time distribution of transport demands in the city by such measures as staggering work and school hours. The system operation should also be optimized by automation and computer control. The constraints on implementing these strategies obviously vary from country to country and from one socioeconomic system to another.

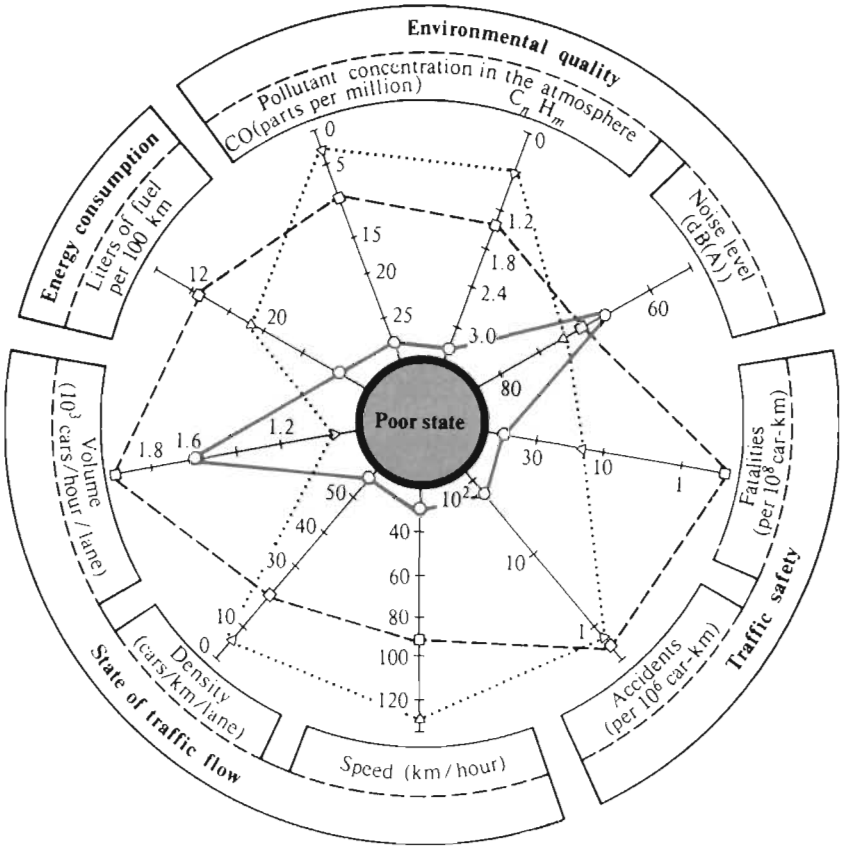
There is a further strategy that traffic planners in several countries are proposing — the "no-action philosophy" — in which any enlargement of the street network is believed to attract more traffic, creating congestion again after a certain period of improvement. The idea is that no enlargements should be made, and that the existing traffic congestion will persuade many drivers not to use their cars to go to the city center. Whether the resulting equilibrium based on traffic congestion — with such associated evils as danger to the environment and increasing energy consumption — is acceptable is an open question. It is very uncertain, however, whether the medium- and long-term measures for increasing the capacity of existing public transportation systems will provide a feasible alternative to this no-action philosophy.

Instead, qualitative changes are needed with regard to both the operation of the existing transport systems and the structure of the urban transport system. Professor Strobel points out that one important way to make these changes is the extensive use of advanced systems technology.

Improving the Status Quo

Existing urban highway systems should be developed to a level where the capacity of the road network is automatically adapted to the automobile transportation demand as it changes over time and space. This requires three tasks to be carried out for a large area within seconds — in a real-time operation mode. Automatic detectors must measure the state of traffic flow in the various parts of the network. This information has to be sent to a control center and analyzed to produce an optimum control strategy that allows the most effective use of available traffic areas. These instructions for traffic flow must then, of course, be communicated to drivers, by traffic lights and speed signals for example. The only way this can be achieved is with high speed control computers.

The book reports on the state of the art in automobile traffic control with a brief survey of basic systems concepts and methods of control with respect to route guidance, urban street and freeway traffic flow control, and vehicle control. More than a hundred cities all over the world have successfully installed computerized area traffic control systems. To illustrate the application of the various techniques poss-



This "star diagram" shows the interdependence of traffic flow conditions and traffic safety, environmental quality, and energy consumption. The larger the area enclosed by a particular line the better is the operation of the traffic system. Thus the blue line represents a congested state, the dotted line represents free traffic flow, and the broken line the optimum point for heavy but smooth-flowing traffic.

ible, the teething troubles, and the operational experience gained so far. Professor Strobel presents nine specially commissioned case studies: San Jose and Washington in the USA; Glasgow and London in the UK; Tokyo and Osaka in Japan; Moscow and Alma-Ata in the USSR; and Nairobi in Kenya.

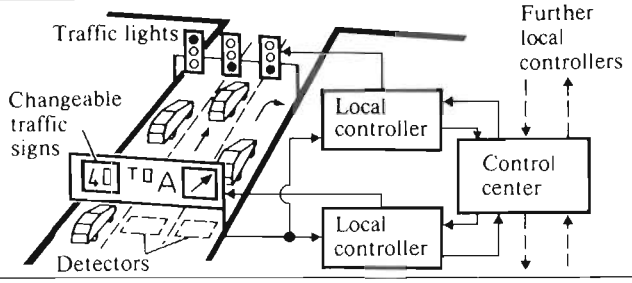
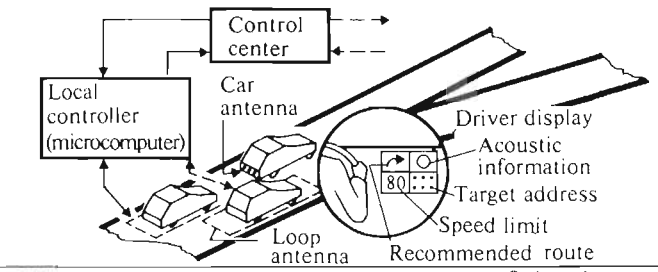
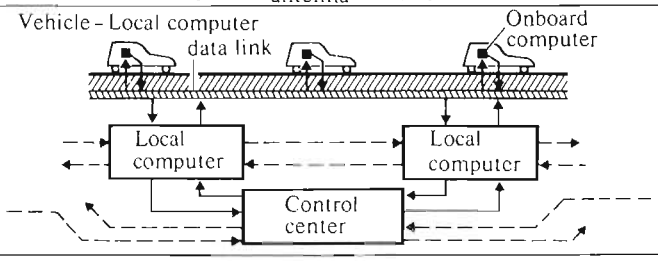
Similarly, he analyzes the experience gained with freeway traffic control systems through specially prepared case descriptions of the Dallas North Central Expressway in the USA, the Hanshin Expressway in Japan, the freeways centered on Paris, and Opération Atlantique in France.

As the urban highway systems are improved, there must be a corresponding increase in the efficiency and attractiveness of public transport. Improvements must be made that could lead to a reduction in operational costs, including personnel levels and energy consumption. There should also be increases in line and station capacities and in service frequency.

Another way to make public transport more attractive is to introduce a service that can adapt to randomly changing demands – trip origins, destinations, and starting times. These demand-responsive bus systems require a dispatching center able to do three tasks in a short time: collect trip requests sent to the dispatching center by telephone calls or other means; prepare optimal routes and schedules for the available fleet of vehicles (buses, taxis); and transmit these routes and schedules to the vehicles.

Time losses and deviations from timetables caused by automobile traffic must also be reduced for buses and trams. This can be achieved by giving priority to public transport at intersections controlled by traffic lights and by supervising the operation of the whole rail, bus, or streetcar system by a dispatching center. The center should have the capacity to identify the positions of all means of transport, detect irregularities, and take measures to reduce such irregularities.

All of these improvements require powerful computer-based surveillance and control systems to handle the large amount of data and determine the control actions in real time. The practical application of the concepts and methods is demonstrated in the book with case studies in three categories of public transport. The experience gained in two advanced dial-a-ride demonstration projects in Haddonfield, New Jersey and Rochester, New York in the USA is described together with a survey of other dial-a-ride projects in operation. The potential and limitations of computerized monitoring and control systems to improve bus services are considered in case studies of Dublin in the Republic of Ireland, and Hamburg in

Concepts	Basic structures	Basic systems features	
		Observability	Controllability
(1) **Traffic signal control**		**Partial** Traffic state can be identified regarding • aggregated variables (volumes, speeds, densities) • at discrete points	**Partial** Control information display by roadside devices • to groups of drivers (not selectively) • at discrete points in time and space
(2) **Comprehensive automobile control**		**Nearly complete** Traffic state can moreover be identified regarding • routes and trip destinations of individual drivers	**Nearly complete** Control information display inside the cars • to individual drivers (selectively) • at discrete points and partly continuously (wireless communication)
(3) **The automated highway concept**		**Complete** Traffic states and movement states of individual vehicles can be identified • selectively • continuously	**Complete** Control information transmission to onboard computers • selectively • continuously

Three approaches to controlling automobile traffic. (1) represents the traditional computerized traffic signal control, which has been in use worldwide for the past fifteen to twenty years. (2) shows a relatively new design to supplement traffic signal control systems that is already at the stage of large-scale demonstration projects in Japan. Routes of individual drivers can be identified and control information conveyed to them. In (3), not only are the information processing and exchange processes automated, but also the operation and guidance of the individual vehicles. This is still the subject of fundamental research.

the Federal Republic of Germany. The third set of case studies shows the experience gained so far from introducing computer control and surveillance systems into urban and suburban railways: the Moscow Metro, the San Francisco Bay area rapid transit system, and the Munich S-Bahn system.

What about the Future?

Potentially the most important contribution of advanced computer and automation technology is in the creation of completely automated, computer-controlled public transport systems. These new systems are intended to encourage drivers not to use their cars, especially for their daily journeys to and from work, through the creation of a demand-responsive, nonpolluting, resource-conserving, and safe public transport operation. The desired objectives of independence, convenience, and travel speed for the public user would result in:

- small, comfortable vehicles, comparable in size with today's automobile, that can be operated individually;
- a guideway separated from the established street network;
- a dense traffic network with short walking times to the stations;
- a demand-responsive operation with nonstop 24-hour service, short waiting times at stations, and no changing necessary.

For the city to preserve its social function, to protect the environment, and to conserve resources, it is necessary to have:

- pollution-free, quiet, energy-efficient vehicles;
- narrow guideways;
- a network that can be adapted to an existing city structure;
- energy-saving operation.

These two sets of objectives can only be met by a system that does not violate certain basic criteria for a public transport company: the number of employees, the operational costs, safety, reliability, and integrability into existing transport systems. All these requirements together determine the following dominant features for the essential components of any new system. Because of the large number of vehicles required, they must be driverless. Similarly, the dense network with a large number of stations requires automated passenger information and guiding systems to reduce the number of employees needed. Finally, this type of public transportation requires the coordinated control of all vehicles and stations — in fact, of the whole system. This complicated control task cannot be undertaken by human operators alone. The solution lies in the implementation of large-scale computerized traffic and transportation control systems.

The experimental Cabinentaxi system in Hagen, Federal Republic of Germany. The capacity of the several sizes of cabin varies from three to twelve passengers.

The fairly well developed methodology for designing totally computerized systems has had practical applications and produced new types of driverless urban transport. Among these are the Morgantown group rapid transit system and Airtrans at Dallas-Fort Worth airport in the USA; VAL in Lille, France; the Kobe rapid transit system and the computer-controlled personal vehicle system used at the Okinawa Ocean Expo '75 in Japan; and the experimental Cabinentaxi system in Hagen, Federal Republic of Germany, pictured here.

Professor Strobel agrees it is hard to say whether the automated transport now being developed will really bring about the breakthrough to better urban transportation that we need. It is even more difficult when one considers the differences in the economic and social structures of different countries. Any fundamental change in transportation will need a certain period of time for experimentation; this was certainly the case for railway systems, whose development began with the invention of the steam engine. It will doubtless be true for the period of development from the invention of the new systems technology — the large-scale integrated digital computers and related automation techniques — to totally new urban transportation systems.

Nevertheless, the possibilities of saving lives, reducing pollution, conserving valuable resources, and protecting our cities provide very strong motivations for continuing the search for these systems.

Paul Makin

News from the Institute

Meeting: Innovation Management in Electrotechnology

While certain key industries are declining, in some countries electrical engineering has a steady rate of growth and shows more innovative trends than other mature machine-building industries. One reason for its great potential is the stimulus of rising demands for energy production. Experts believe that even bigger innovations could be on the way because of the potential applications of such phenomena as piezoelectricity and superconductivity, and through new materials and new techniques such as computer-aided design. There is now wide industrial interest in the ways that managers handle innovation in different enterprises. Despite different socioeconomic climates, there are some basic aspects of the innovation process that are common to all enterprises, whether they be US corporations or Soviet production amalgamations.

To combine practical and theoretical aspects, directors of seven important electrical engineering firms and representatives of state organizations and research institutes from east and west met in Leningrad, 24–29 May 1982, to discuss innovation policies and management problems. They were the guests in the city of Dr. Boris Fomin, General Director of Electrosila, the largest electrical engineering concern in the USSR. The meeting was called by IIASA's Innovation Management unit, led by Professor Tibor Vasko.

Dr. Thomas Moss, Staff Director of the Subcommittee on Science, Research and Technology of the US House of Representatives, attended and found the exchange of experience encouraging: "Collaborative international ventures have definite advantages over isolated efforts. Problems in innovation management need an interdisciplinary approach where systems analysis can represent scientific and methodological guidelines. We will all be able to adapt most rapidly to new problems and opportunities if we exchange and utilize the lessons of our varied experiments."

These "experiments" were described in the many papers presented at the meeting, and there was ample time for discussion. There were questions of organizational structure: "How do you establish connections and overcome problems of competition between the profit centers and R&D units?"; of relations with other enterprises: "How do you encourage the allied industries and organizations to be innovative too?"; and of people: "How do you involve people at all levels in innovation activities?"

This meeting was one of a series to develop an IIASA case study of the electrotechnology industry, coordinated by Dr. Vadim Goncharov. A comparative analysis of firms in both planned and market economies will form the backbone of the study.

Valery Lazovsky/Novosti

From left to right: Mr. Wolf, Director, Siemens Austria; Dr. Fomin, General Director, Electrosila; Dr. Goncharov and Professor Vasko of IIASA in Leningrad for the May meeting to explore the role of innovation management in electrotechnology.

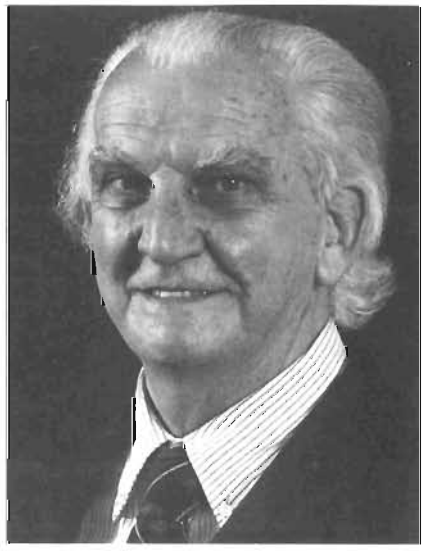
Young Scientists Summer Program

For the sixth consecutive year, IIASA arranged a summer study for young scientists. Twenty-one scholars from thirteen of the National Member Organization countries are participating in the Institute's research activities between June and September. Young scientists were chosen whose training and interests complement IIASA's current program of work.

There is also a series of lectures for the young scientists on the major themes of IIASA's research program: national food and agriculture policies, environmental risks and conflicts, forestry, population and settlements, integrated regional development, international negotiations and interactive methodology, energy policy analysis, and patterns of economic structural change and industrial adjustment.

The Dean of the Summer Program, Professor Tibor Vasko, believes that it is "a unique opportunity for IIASA and for the participants to explore new possibilities for research and to share with others the work of the Institute. It is also a rare opportunity for the participants to work in an exciting international environment."

Visitors



Professor Kenneth Boulding, Distinguished Professor of Economics Emeritus of the University of Colorado and

past president of the American Association for the Advancement of Science, visited to continue consultations on IIASA's future research. He presented two lectures, discussing how individuals form their own images of the world and use them to make evaluations of problems. He then considered the question of how to test such evaluations, particularly those made by individuals in important positions.

Visiting IIASA in August were several delegations to UNISPACE, the UN Conference on the Exploration and Peaceful Uses of Outer Space. Pictured above are Soviet cosmonauts Vladimir Dzhanibekov (right) and Alexander Ivanchenkov. The President of the Czechoslovak Academy of Sciences, Bohumil Kvasil (below, center), and Czech cosmonaut Vladimir Remek (left) are with Professor Tibor Vasko.

New Titles

International Series on Applied Systems Analysis

Volume 10 **Computer Controlled Urban Transportation: A Survey of Concepts, Methods and International Experiences.** H. Strobel, Editor. 500 pp.

Available from John Wiley and Sons Ltd., Baffins Lane, Chichester, West Sussex PO19 1UD, UK, or John Wiley and Sons Inc., 605 Third Avenue, New York, NY 10016, USA.

IIASA Proceedings Series

Volume 16 **Managing Technological Accidents: Two Blowouts in the North Sea.** D.W. Fischer, Editor. 234 pp.

Available from Pergamon Press Ltd., Headington Hill Hall, Oxford OX3 0BW, UK, or Pergamon Press Inc., Fairview Park, Elmsford, NY 10523, USA.

IIASA Collaborative Proceedings Series

CP-82-S3 The Operation of Multiple Reservoir Systems. Z. Kaczmarek and J. Kindler, Editors.

CP-82-S4 Nonpoint Nitrate Pollution of Municipal Water Supply Sources: Issues of Analysis and Control. K.-H. Zwirnmann, Editor.

IIASA Reports

Volume 5 Number 1 January–March 1982

Volume 5 Number 2 April–June 1982

Research Reports

RR-82-10 Videotex Message Service Systems. H.A. Maurer, W. Rauch, and I. Sebestyen. Reprinted from *Electronic Publishing Review.*

RR-82-11 Alphabetic Searching in Videotex Systems. H.A. Maurer, W. Rauch, and I. Sebestyen. Reprinted from *Electronic Publishing Review.*

RR-82-12 Computerized Message Sending and Teleconferencing in an International Environment: Present and Future. I. Sebestyen. Reprinted from *Electronic Publishing Review.*

RR-82-13 A Long-Term Macroeconomic Equilibrium Model for the European Community. H.-H. Rogner.

RR-82-14 Evolution of Future Energy Demands till 2030 in Different World Regions: An Assessment Made for the Two IIASA Scenarios. A.M. Khan and A. Hölzl.

RR-82-15 Migration and Settlement: 14. United States. L.H. Long and W.H. Frey.

RR-82-16 Water Demand for Generating Electricity: A Mathematical Programming Approach with Application in Poland. J.C. Stone, F.D. Singleton Jr., M. Gadkowski, A. Salewicz, and W. Sikorski.

RR-82-17 Models for Analyzing Agricultural Nonpoint-Source Pollution. D.A. Haith.

RR-82-18 The Growth of Energy Consumption and Prices in the USA, FRG, France, and the UK, 1950–1980. C. Doblin.

RR-82-19 Kenyan Agriculture: Toward 2000. F.D. McCarthy and W.M. Mwangi.

RR-82-20 Energy for Agriculture in Pakistan. Muhammad Jameel.

Single copies of journal reprints are available free of charge. All other publications can be ordered from the Publications Department, IIASA.

Guest's Corner

Dr. Kaftanov is a Deputy Director of IIASA.

Castles and Big Machines

More than twenty-five years ago, two institutions were created – the European Organization for Nuclear Research, CERN, in Geneva, Switzerland, and the Joint Institute for Nuclear Research in Dubna, USSR. Both were created to join efforts in nuclear research for the western and eastern communities of physicists. The two facilities were founded separately, but more or less in the same moment, for the idea behind them was the same – no nation could stay outside this rapidly growing field of science. But for countries smaller than the United States and the Soviet Union, it was clear that if you wanted to do anything in this field, you would have to combine resources. Just the construction of the big machines necessary, such as the quarter-billion-dollar synchrotron, is too expensive for just one or two countries, even big countries. That was the thinking behind the establishment of these places.

IIASA and CERN

Having come to IIASA a few months ago after working at CERN, I am often asked about the similarities and differences between CERN and IIASA. Very often the same question is put in an even simpler way: What in IIASA is equivalent to the big machine at CERN? To answer this question let us look again at CERN. Of course, to build an expensive big machine is very difficult for one country, so many countries combined their efforts and budgets to build it. But why did they do it? Because every nation understood that the problems of nuclear physics, which a few decades ago were purely academic questions, were no longer simply academic. Even the words "nuclear" or "atomic" were too serious, too heavy, too close to everyday life. It meant that this field of study should be regarded as a most important science that no nation could ignore. This was the basic reason for the decision by each country – even small ones – to pay the high price of admission into this field of research. It was a good step. Today we know the experiences of both CERN and Dubna have been successful.

Now let us come to the creation of IIASA. There was at that time also the growing realization that there are problems in the world besides nuclear energy which are terribly important to all nations – problems no nation could study and solve alone, without the collaborative efforts of other countries. The birth of IIASA in 1972 was a sign that society had reached a higher stage of consciousness regarding such issues. Thus, to have on the list of problems studied at IIASA some of the most important ones facing mankind is a first, necessary condition for the successful life of this Institute. It is one of the most important conditions; but it is not the only one.

Communities of Colleagues

Let us look again at CERN. There the large commitment of resources and the inherent difficulty of research in high-energy physics led participating countries to send the best people they had. The result of this has not been the purely arithmetical sum of their efforts; it is a much more complicated reaction because people working together teach each other, help each other – they coalesce into a scientific community of shared interests. In this community, with this everyday interaction, even the best people become better. Such an environment is extremely important in getting the best scientific results.

But there has been more. First, a strong connection has been sustained with national institutions; and second, the ageing of the institution has been slowed by a very strict rule that even very good people can work at CERN no more than six years. This rule ensures two important effects: it allows an infusion of CERN experience back into the scientists' institutions in their home countries; and this, in turn, encourages constant close interaction between researchers and CERN. There is an example in my own life. After a few years at CERN, I returned to Moscow as an individual physicist and formed a group of younger people to begin research in neutrino physics, at first around the Serpukhov machine. Then, when we became stronger, we went back to CERN, to join efforts in neutrino physics as a strong group with a very good reputation. This happens with many other people and institutions around CERN.

So, what is IIASA's "big machine" after all? The castle is relevant, for it provides an environment conducive to scientific accomplishment. But here, as at facilities like CERN, it is the people, the community of colleagues, the rich exchange of ideas, the close ties with participating nations that produce the best results. We are more and more conscious at IIASA that such productive combinations are a precondition of success.

I have spent much of my professional life seeking new knowledge among the communities of good people and new ideas drawn to the big machines of nuclear research. Now I hope to apply this experience in IIASA's castle, among its international community of researchers. I hope this is just one of many such links, bridges between the scholars of IIASA and other communities in other settings, whether of castles or of big machines.

Vitali Kaftanov