CHAPTER 10

Recent Experience in Simulation Modelling for Environmental Management in Different Countries

Some of the problems discussed in Chapter 8 can be illustrated by a survey of existing experience in countries at different stages of development, with different backgrounds in simulation modelling, and with different approaches to decision-making. The following sections summarize experience in seven countries, and demonstrate the influence of institutional and political systems on modelling and on the ways in which it can contribute to environmental management. Appendix 2, which contains an account of a survey of environmental modelling recently completed in Canada, should also be read in this connexion.

10.1 AUSTRALIA

Simulation modelling of environmental problems in Australia is undertaken largely in research institutions, although recently there has been a considerable increase in activities in non-research state and federal government agencies. The main modelling areas include agriculture, hydrodynamics, meteorology, hydrology, water quality, and population dynamics. Although there is considerable modelling of transportation systems, little of this, if any, appears to take environmental issues into account. There is also relatively little environmental modelling of energy, land use and urban systems. The great majority of projects concern relatively small-scale systems of the order of a farm, a catchment, or even smaller. As far as is known, except for meteorological modelling, there are only two projects which are national in scale, and only one of any global significance.

Of the research institutions undertaking simulation modelling, the Commonwealth Scientific and Industrial Research Organization (CSIRO) is by far the most significant. This organization is dedicated to the solution of technical problems in primary and secondary industry and has been involved in environmental problems since its birth in 1926. But – with notable exceptions, such as the TOPAZ model developed for land-use planning and similar purposes (Brotchie, 1969; Brotchie et al., 1971; Sharpe et al., 1974) – most modelling work under CSIRO auspices has served scientific purposes rather than directly facilitating environmental management and decision-making.

University departments have also involved themselves in this field – in fact, approximately half the Australian work on environmental modelling takes place within the universities. Most of this work, however, concerns small-scale systems and little is likely to be applied.

Modelling work undertaken either directly by governmental agencies (state and federal) other than the CSIRO, or else under contract for them, represents only some 20 to 25 percent of all environmental modelling effort. It is significant, however, since it includes most of the modelling work for environmental management and decision-making in Australia. The work done within some of the environmental studies programmes is particularly relevant; one may, for instance, mention those of the Blackwood River Estuary in Western Australia (Agnew et al., 1976) and Westernport Bay in Victoria (Shapiro, 1975; Rennie and Shapiro, 1976). In most cases these studies have been set up with the specific aim of establishing management guidelines for a region. Although the techniques for conducting these studies are still relatively undeveloped, they nevertheless represent a unique opportunity for scientific input to the decision-making process.

10.2 EGYPT

Although in Egypt simulation modelling has not yet received as much attention as it merits, a few projects have started recently, among which the Systems Analysis of Mediterranean Desert Ecosystems of Northern Egypt (SAMDENE) has already been in operation for more than two years. This project is supported by the U.S. Environmental Protection Agency and the Ford Foundation, and sponsored by the University of Alexandria. It aims to identify and select preferred courses of action among several feasible alternatives of land use in the western Mediterranean coastal desert in Egypt (see also Section 9.4).

In the first phase, versions of the U.S. Desert Biome models were programmed on the computer at the American University of Cairo. Difficulties were encountered because this computer was smaller than that in use for developing the U.S. Desert Biome models. However, no conceptual unsuitability as a result of biological differences between the United States and Egypt was found. Attempts have also been made to use the facilities of other larger computer centres in Cairo, since running costs on the computer at the American University proved to be considerably higher than anticipated. However, these attempts are faced with the lack of technical services at these centres. These circumstances are suggestive of problems in transferring models from the developed countries to less developed countries like Egypt, where a large computer is difficult to maintain, especially because of high running cost and/or a shortage of technical staff.

At the start of the SAMDENE activities in 1974, the concept of simulation modelling was new to almost all the biologists participating in these activities. It took some time before these scientists could accustom themselves to the idea of orienting their research towards the requirements of models. In order to develop better understanding of modelling by SAMDENE's investigators and their assistants, a series of seminars was arranged in which accounts were given of the principles and procedures of simulation modelling. It is clear, therefore, that simulation models have also been useful as an educational activity.

Another bottleneck in the Egyptian experience has been poor cooperation between scientists of different disciplines, even in the same research institute. Nevertheless, in spite of these problems, an accumulation of experience by the SAMDENE project will assist in future simulation modelling of environmental problems in Egypt.

Modelling activities outside the SAMDENE project are limited in number and achievements. Of these activities mention may be made of the physical models developed by the Sediment Research Institute of the Ministry of Irrigation to help solve the problems of irrigation, drainage, and degradation along the Nile. Mention may also be made of the modelling efforts which have recently been started by the Nile project supported jointly by the Egyptian Academy of Science and the University of Michigan to investigate the changes following the construction of the High Dam. Schematic diagrams representing the components and processes of the ecosystems of Lake Nasser and the Nile valley and delta have been prepared as a starting point for developing models to predict the physical, biological, agricultural and social changes caused by the High Dam (U.S. Environmental Protection Agency, 1976).

10.3 FEDERAL REPUBLIC OF GERMANY

The Federal Republic of Germany is a highly industrialized country whose prosperity depends on a system of intense material exchange with other countries. Because it lacks many resources, the Federal Republic of Germany has to import much of the primary material and most of the energy it needs for industrial production. Much of this production is exported in part to pay for the imported resources.

Since the early 1950s, there has been a slow but dangerous accumulation of environmental loading that has already caused severe damage to the ecosphere in some parts of the country. In spite of the increasing awareness of the environmental situation, there is some feeling that the decision-makers worry more about upholding German competitiveness in the world market than about the environmental impact of industrial development. Also, through the installation of nuclear power plants, the Federal Republic of Germany plans to decrease its dependence on oil imports. Thus, the economic policy for the future may actually tend to aggravate those factors which have caused ecological damage in the past. Nevertheless, the government of the Federal Republic is concerned with the extent to which economic growth should be sacrificed for environmental protection. A satisfactory balance has, however, not been achieved.

In the past, responsibility for environmental affairs has been widely distributed over the ministries of the federal government. Recently, however, the Federal Office of the Environment has been established, which is responsible for coordinating the environmental activities of the federal government, for interacting with the state and community levels, and for organizing environmental research in preparing new environmental legislation on emission standards, the Polluter Pays Principle (Organization for Economic Cooperation and Development, 1975), and other control strategies. With this decision, the government of the Federal Republic has indicated the need for closer cooperation with the scientific community in solving the grave environmental problems.

German science has a long-standing tradition in the basic disciplines of the physical, biological, and social sciences, and although this is also largely true for many of the subdisciplines of ecology, the interdisciplinary and systematic approaches needed for a science of the environment are yet in their infancy. Curiously enough, the impetus for systems analysis and simulation modelling did not come from the ecologists or biologists, but from the physical and social scientists in

community and state management, and in part from a concerned public sensitized to environmental problems by recent publications (e.g., Meadows et al., 1972; Mesarovic & Pestel, 1975).

Since 1973, interdisciplinary work in environmental research and management has increased, and scientists are turning their attention to applications-oriented research in subjects of public concern. The federal government supports and encourages this development by its research funding policy and, through its financial power, is changing the academic reward system. As a result, a variety of approaches – modelling in particular – are being developed to address environmental problems.

Since the environmental problems addressed and the research needed for their solution are long-term, new forms of continuous research activity are being developed. It is mainly the new role of science in monitoring the environment in its widest sense that has initiated a reform of the institutional interface between the decision-maker and the systems analyst in West Germany.

10.4 JAPAN

Small land areas, poor natural resources, high population, and the economy oriented towards heavy and chemical industries make the environmental problems in Japan quite severe, and activities to develop simulation modelling as a management tool for environmental problems are widespread. According to a survey done by the SCOPE group in Japan, more than 100 models have so far been developed in this field. Development of models for tactical decision-making, especially those involving the prediction and control of air and water pollution and the management of pesticide use, has been especially significant (Shimazu, 1976).

Apart from the physical and economic situation of Japan, the impact of the social structure on environmental model development and application should be noted. Traditionally, Japan had a highly homogeneous society in which individuals were presumed to have the same value system. Because complete agreement was supposed to be reached automatically, a decision-making process in an ordinary sense, involving a choice among conflicting options through logical analysis or debate, did not exist. Changing value systems among the people could change this tradition, especially in the resolution of environmental issues.

An additional problem is that the contemporary administration system is highly technocratic. While the authorities have their own excellent planning and modelling staffs, their models and basic data are often withheld from the public. The combination of differing values and lack of information about some of the models makes the resolution of environmental issues even more difficult. Therefore, easier availability of information regarding the structure of models and of the basic data is urgently needed. This will also facilitate the role of modellers, making it possible for them to become translators between the public and the authorities rather than being controllers and managers of the environment.

Admittedly, the Japanese modelling effort is still in the preliminary stages with respect to methodology, training of multidisciplinary managers, and the establishment of data bases. For a multidisciplinary project, it is usual to organize a project team in which the individual members are specialists in individual disciplines. However, Japanese experience has indicated that training a manager with a

multidisciplinary orientation appears to be more effective than organizing a multidisciplinary project team, especially for local small-scale problems which are a significant source of environmental disruption in Japan. The minimum background required for such a manager includes systems analysis, ecology, earth science, economics, and public administration. Exposure in these areas need not be deep, but should be well balanced. A training centre of this type was recently established at Nagoya. Furthermore, a data base is being developed consisting of numerical and descriptive data, documentation, addresses of specialists, and simulation models. These data may be retrieved in a conversational mode using graphic display terminals.

In short, the technocratic nature of decision-making in Japan poses some rather unique problems for modelling. There are indications, however, that these problems are being addressed effectively.

10.5 THE SOVIET UNION

Until the Second World War the Soviet Union had relatively few perceived environmental problems caused by intensive human activity. Since then, however, the situation has changed significantly through expanding industrialization, even into regions that had previously been completely unindustrialized. As a result, the Soviet people now realize that, in spite of the huge biological and natural-resource potential of their country, their environment cannot be exposed to uncontrolled industrial growth without running the danger of irreversible effects on climate, water availability, and other parameters. For example, large projects such as partially diverting Arctic streams back into Central Asia are now being assessed with respect to their environmental impact. This effort to increase the water supply in Central Asia might turn out to be self-defeating: increasing salinity in the Arctic Sea could push the ice barrier farther north, thus shifting the trajectories of rainstorms from Scandinavia farther north and actually leading to a negative net water balance in Central Asia.

Another example involves the 'greenhouse effect', a potentially dangerous effect of industrial activity. Increasing CO_2 concentration in the atmosphere leads to heating of the atmosphere. This effect may be further enhanced by aerosols in two ways: increased heat absorption in the atmosphere, and a decreased reflection of sunlight from snow-covered Arctic regions. The importance of this problem was considered by a special session of the Soviet parliament (Supreme Council) which accepted guidelines for the protection of the environment and for the rational use of natural resources.

In recent years, there have been rapid developments in the application of simulation modelling to environmental problems, in addition to more theoretical studies of the behaviour of complex systems. One may, for instance, cite a model of the Azov Sea (Gorstko & Surkov, 1975), which divides this land-locked body of water into seven cells, and models the distribution of water masses, solutes, and organisms in it, with the changes consequent upon variation in the flow of the Rivers Don and Kuban and the pollution load which they carry. It is hoped that this model will be useful in the management of river flow, industrial and agricultural effluents, and fisheries. Other Soviet applications of modelling to

environmental problems are described in the proceedings of a SCOPE meeting in Moscow in November 1974 (SCOPE, 1975b).

Moiseev and Svirezhev (1975) have described an ambitious system for the storage of generalized sub-models, which can then be assembled as required for the modelling of complex environmental systems; this approaches the system for man-computer interaction envisaged on page 35.

The Soviet Union's most important challenge in modelling for environmental management is to improve communication betweeen decision-makers and environmental scientists. A State Committee for Environmental Management will be installed on a governmental level between the Council of Ministers and the State Ministers. It will act as a 'translator' between scientists and the highest Soviet decision-makers.

10.6 THE UNITED KINGDOM

The United Kingdom has a well-developed decision-making structure at the national and local levels of government. Both levels are supported by government research institutes, by research council institutes, or by university research, some of which is financed by grants from the research councils. Partly because of war-time experience, the need to obtain scientific advice is generally recognized. Furthermore, the success of operations research, under conditions of official secrecy, demonstrated the value of seeking advice from a wide range of well-organized sources of expertise. These two conditions have ensured the availability of scientific advice on problems likely to have an impact on the environment.

Much of the advice given to central or local government, to industry and to public and private organizations has increasingly depended on mathematical models of various kinds. Particularly since the development of the electronic computer, these models have included simulations of environmental systems from which the environmental impacts of decisions can be assessed. Experience with simulation models in the United Kingdom has included urban planning (Batty, 1974), strategic planning for agriculture and forestry, development of water resources (see Section 9.2 above), and the economies of alternative forms of energy sources. Environmental impact assessment has not yet been made a statutory requirement, but the impacts of various kinds of industrial developments have been assessed by means of simulation, and the effects of pollutants in air and water are also being simulated by such models.

Currently, the renewed emphasis on structural planning by the reorganized local authorities has stimulated a major modelling effort involving the likely changes in the ecology of the areas in response to the planning proposals. This modelling has stressed the need for an increased level of ecological survey information to provide a firmer base for the ecological models; consequently, a national ecological survey has been instituted. Finally, plans are currently being prepared for the modelling of the utilization of natural resources in response to the need to replace non-renewable resources with renewable ones.

In contrast to some other countries, the British institutional structure permits effective communication between different levels of government, and with scientists including modellers. Thus, modelling is far more likely to be used effectively in environmental management.

10.7 THE UNITED STATES

A detailed survey of environmental modelling in the United States has recently been compiled by the National Committee for SCOPE (Holcomb Research Institute, 1976). This survey documents a rich array of activities in every important area of environmental science, some which were failures or were only partly successful, others largely attaining the goals set. These efforts can be broadly classified into seven types: atmospheric, water resource, ecological, agricultural, urban, regional environmental management, and world systems. The past decade has seen a marked evolution in the approach or style of these modelling efforts.

While early efforts were often quite ambitious, their success was limited by four factors: problems with data, both qualitative and quantitative; inadequate theoretical structure; limitations of computational and processing output; and inexperience with simulation modelling for practical policy purposes. In recent years these difficulties have led to emphasis on less ambitious, more precisely defined, and more successful models. Nonetheless, this is very much an emergent field, and continued rapid change in style must be expected.

One particular characteristic of the United States experience should be noted. The technical modelling work has, by and large, been done by academics in a university context; but the presumed audiences have been decision-makers responsible for policy-making in the real world. These are two distinctly different milieux, and major problems have developed at this interface. In pragmatic terms, this means that good quality scientific work has in some instances been of little applied value. On the other hand, some poor modelling work has been applied to decision making – in some cases, with disastrous results.

A variety of solutions are being pursued to improve the interaction between modellers and decision-makers. These include: increased efforts to bring modellers and users together during the design, construction, and testing phases of model development; the emergence of a new type of person, the 'policy analyst', who serves as intermediary during development and use of the models; and the formulation of a series of man-machine linking devices such as gaming-simulation which, when used with precision, shows considerable promise. The problems associated with the interface between modelling and the decision process constitute the most significant remaining hurdle to successful use of modelling for policy purposes in the United States.

The interface difficulties also indicate that the models have not addressed problems which are significant to decision-makers, or have done so in a way that does not inspire confidence. Solution of this problem should clearly be of highest priority wherever modelling of new, complex environmental problems is envisaged. Failures of this sort in the United States, where there has been so much simulation activity, should be taken into account very seriously in other countries with less relevant experience.