CHAPTER 4

Environmental Management

This chapter is concerned with human response to environmental issues. As Chapter 2 indicated, such responses generally involve successive action at four levels:

- data capture;
- data analysis;
- presentation of conclusions; and
- formation and implementation of social policies.

In the present chapter the same sequence is followed. The first section describes SCOPE's Mid-term Project VI on problem identification and monitoring. This has sought to evaluate the kinds of information about the environment that can most usefully be gathered. It is far too easy to accumulate vast amounts of low-quality data that swamp the analytical process.

Monitoring provides an essential input of knowledge about the environment and its trends, on which human responses can be based. Such information needs logical analysis, and it will not easily be interpreted unless there is understanding of how the environmental systems concerned work. Modelling can both guide data collection and ensure that it is analysed in a logical fashion. One use of mathematical modelling techniques, to describe the processes of ecological succession, is outlined in Section E of Chapter 3. Section B of this chapter describes the broad concepts developed in SCOPE's Mid-term Project V on simulation modelling as a whole. As in UNESCO's Man and Biosphere programme, SCOPE has found the discipline of modelling relevant in all sectors of its work.

Through the rational process of gathering and examining precise environmental data and analysing the behaviour of environmental systems, it is (or should be) possible to make valid statements about the extent to which trends in the environment or man's impact upon it create risks. Section D of Chapter 3, describing the Mid-term Project on Environmental Toxicology, covered some of this ground, especially in its annexed case study of the pathways and effects of methyl mercury. A further general analysis of the processes involved appears as Section C of the present chapter.

Studies of ecotoxicology and the monitoring of pollutants alike depend on the feasibility and reliability of analysis for substances present at low concentrations in environmental media and living organisms. This was recognized early in the development of SCOPE's programme and a Working Party under the Chairmanship of Dr. W. Gallay was set up to study the merits and drawbacks of existing methods of analysis for each of the many pollutants involved. The report of this Working Group has now been published as SCOPE 6 – 'Analytical methods for selected pollutants'.

The capture and analysis of data, modelling of environmental processes, and evaluation of risk are unlikely to be useful unless the outcome is effectively communicated to those who make policy decisions on behalf of the community, a fact that scientists are all too liable to overlook. The format for such communication, as Chapter 2 stressed, needs to be different from that used for scientist-to-scientist exchanges. Section B touches on these questions, which are expanded in Section D, where preliminary results of the SCOPE Project VII on this theme are summarized. Finally, the sequence should end in some kind of social response if the risk makes this necessary and the communication has been adequate. SCOPE Project III on Human Settlements examined the building standards that have been adopted in developing countries. This study revealed that the logical processes of analysis, evaluation, and establishment of a response appropriate to the particular circumstances of a community have not always been followed. Some developing countries still employ standards adopted from wealthier countries in other environmental zones, even though these are clearly irrelevant and at times even wasteful!

A. PROBLEM IDENTIFICATION AND MONITORING

1. Introduction

In environmental management, decisions are most often made in a context in which the outcome is in doubt and the consequences of a given choice cannot be fully predicted. Practically all environmental management involves making decisions under conditions of risk or uncertainty. By 'risk' is meant the likelihood or probability that an event, usually considered as adverse, will occur. By 'uncertainty' it is intended to denote the confidence or lack thereof which can be specified for a given estimate of probability.

There are three main sources of uncertainty in dealing with the environment. These are (1) stochastic variability of the processes involved, particularly the occurrence of rare events such as floods, droughts, and earthquakes; (2) inadequate scientific understanding of how the processes work or of the behaviour of the environment; (3) inadequate data or records for the phenomena or the locality under study.

Methods are available for predicting the probabilities of rare events, given historical time series of sufficient length. Engineers use these methods in the design of flood control systems, tall buildings, and so forth. When an event has been specified in probabilistic terms, however, uncertainty remains as to its time of occurrence.

Uncertainty associated with lack of knowledge and data is difficult to reduce by resort to probabilistic techniques. This is compounded by the fact that uncertainty increases as the prediction or forecast extends further into the future.

2. Problem Detection

From the large array of both natural and man-induced environmental changes that continually occur, it is important to identify those that are, or might become undesirable. The process of discovering and identifying environmental risk has not been well studied. There are three systematic processes which may be used. These are screening with testing, monitoring, and diagnosis.

Screening and testing is commonly applied to new situations, for example where a new product or process is to be introduced and systematic observations and tests are conducted to determine in advance the risk of adverse effects.

Monitoring is also a method of risk detection. Widespread and especially regular measures of environmental variables may reveal changes or anomalies which help in the identification of a risk. For example, the monitoring of carbon dioxide in the atmosphere has indicated the possibility of climatic change. In addition, monitoring can aid in estimating the magnitude of a possible risk.

Diagnosis is a method of risk estimation that is applied where adverse effects or symptoms are evident, leading to a search for causes and often to the identification of some hitherto unsuspected or unverified hazard.

Beyond these three systematic processes lies the broad body of basic scientific enquiry. At any time, logical deduction from existing or new knowledge may lead to the identification of environmental risk. Such a process demands a creative leap of imagination in the mind of usually an individual scientist, who makes a connection or sees a link that has not before been made (Koestler 1964). Such inspiration, intuition, or creative imagination will always be needed and cannot be programmed. However, the conditions in which it can occur need to be created and maintained.

3. Monitoring

a. The Present Interest in Monitoring

The concept of a Global Environmental Monitoring System (GEMS), was endorsed by the United Nations Conference on the Human Environment in June 1972. Many publications (United Nations Environment Programme, UNEP/GC/24 1975, SCEP 1970, SCOPE 1971, SCOPE 1973, NAS 1976) have set out the needs of a global system and the variables to be measured. Some of the proposed schemes are ambitious, idealistic, and very comprehensive.

Despite recent activity, there is disappointment in certain quarters that the idea of a comprehensive monitoring system is not being translated into reality. The delay in implementation may be connected with the fact that deficiencies exist in our basic understanding of how to go about monitoring and hence how to build a comprehensive global monitoring system. The initial generalized planning is much easier than its subsequent practical implementation. A notable exception is atmospheric monitoring. Long experience motivated by the practical need for weather forecasting has led to an advanced understanding of monitoring needs.

The fact remains, however, that in spite of the voluminous amount written about 'monitoring' in general, fundamental semantic, scientific, technical, and procedural difficulties, as well as differences of interpretation, exist. Up to the present these difficulties have hardly been recognized, so that 'monitoring' has been taken up perhaps with more enthusiasm than understanding and has become something of a vogue word. A reappraisal of the scientific and technical basis upon which so many of the ideas and activities planned at present tacitly rest is needed. Such a reassessment might help to identify fundamental differences of approach and existing gaps in our knowledge, leading to a wider endorsement of actions needed to be taken next in order to create a practical global monitoring capability.

b. A Definition of Monitoring

Monitoring is defined here as the collection, for a predetermined purpose, of systematic, inter-comparable measurements or observations in a space-time series, of any environmental variables or attributes which provide a synoptic view or a representative sample of the environment (global, regional, national, or local). Such a sample may be used to assess existing and past states, and to predict likely future trends in environmental features.

Monitoring is thus a systematic method of collecting data needed for environmental problem solving. This is its principal justification. It is a matter of scientific and technical skill to be able to carry out appropriate measurements with enough precision on samples drawn from suitable locations over an adequate period of time to get the necessary information for the lowest cost.

Monitoring observations commonly fall into four categories where different types of variables or characteristics are being observed:

(i) measuring *levels* of potentially harmful or beneficial chemical substances in the media of air, fresh water, seas, soils, sediments, living organisms (including man and his food);

(ii) measuring physical *attributes* of the above media such as solar radiation flux, soil chemistry and texture, turbidity of air or waters;

(iii) measuring the frequency and severity of the beneficial or harmful *effects* on living things caused by such chemical substances or physical attributes under (i) or (ii) above, such as population size, disease incidence, biochemical, physiological, genetic, or behavioural variables; and

(iv) taking inventories which (a) reflect the state of the recent climate such as area of ice caps, mass of glaciers, or sea-water level, (b) quantify human impact such as deforestation-rate, crop-area, urban-area, or energy or resource use.

A great deal of monitoring has already been done all over the world, usually in order to answer pressing local or national problems. Although summaries of the results have been published in scientific journals and reports, many of the data are stored in archives around the world. Broadly similar parameters are monitored from country to country, although each nation has its own specific objectives. Thus, although a great deal of the data are capable of being collated to form a crude picture of states and trends in the global environment as a whole, this largely remains unattempted because the data were not originally collected for this purpose, nobody at present really knows how much measuring has been done and where, and there is no general agreement on methods of sampling and measurement (or observation), so that much of the information collected is not inter-comparable in space or time.

Although these defects make it impossible to use all the current data to their fullest extent in a global context, there is still enough comparability of methods and global coverage to make it worthwhile to attempt to review the existing data and to obtain from them a first approximation of the environmental status of several parameters, particularly chemical variables. The International Referral System for Sources of Environmental Information (IRS) is a first step towards determining how much measuring has been done and where. However it is important to remember that IRS has no assessment or review function. The International Registry for Potentially Toxic Chemicals (IRPTC), another UNEP initiative, is also currently being developed and may well possess more of a review function.

Any critical review or appraisal of existing data is bound to sharpen perception of how to embark on future monitoring. Such critical reviews should be carried out in tandem with the planning of future monitoring schemes, always providing that such collation work on existing data does not try to extract more information than the precision of the data will reasonably bear.

c. Criteria of Approach to Monitoring

A good reason should exist for embarking on any monitoring activity, either a wish to investigate the structure and functioning of some part of the environment in order to understand it better, or a need for more information on some specific problem.

A perturbation in one environmental compartment (such as air, freshwater, oceans, and land) usually has repercussions in others. In other words, side-effects habitually appear in places other than where the environment was first perturbed. It is thus essential to have a good working knowledge of environmental transfer processes in order to predict the scale of the effects which may arise in all environmental compartments from a perturbation in any one of them. Biogeochemical monitoring programmes can provide basic information for making such predictions.

Side-effects may well appear remote in time and space from the perturbation which originally generated them, because these environmental transfer processes take time. Thus side-effects which could be unknowingly triggered may be unstoppable and virtually irreversible by the time they first appear or are perceived. Environmental systems may also be resilient to change and show no detectable side-effect despite repeated perturbation. A detectable side-effect may in such cases occur somewhat suddenly or even catastrophically following a critical threshold quantity of a perturbation, applied in one dose or in successive increments, being exceeded (Holling 1974). Both time-lag and resilience phenomena as well as environmental transfer processes have very important implications when choosing the correct approach to monitoring.

The overall cause-effect concept of a man-induced perturbation (dose) increasing to a level where it generates a significantly inconvenient side-effect (response) is tacitly assumed to apply to all environmental disturbances. In consequence, the building up of a knowledge of the environmental dose-response (level-effect) relationship is basic to the proper assessment of monitoring data. Typical examples are: grazing pressure at specific seasons versus sward productivity (carrying capacity); concentration of lead in human blood versus frequency of lead poisoning symptoms; fishing effort versus fish-stock size; frequency of irrigation ditches versus incidence of malarial mosquito larvae; and global atmospheric carbon dioxide concentration versus global atmospheric energy balance and ambient temperature change. Determining the shape of the environmental dose-response curve aids in the determination of unacceptable levels of perturbation (dose). This implies a decision as to what constitutes an unreasonable amount of side-effect or response. This is a very important point because it is often easier, and nearly always more predictive, to measure the 'dose' than the 'response' routinely for control purposes.

The way to build up a detailed knowledge of the qualitative nature and quantitative severity of any side-effects is to study actual situations where the side-effects are occurring. Such situations can often be devised experimentally under controlled laboratory or field-trial conditions. More often, however, our experience has come from accidental perturbations or special cases of environmental disturbances such as from studies of occupational or accidental exposure to chemicals or radiation, or areas of intensive agriculture or other forms of drastic land disturbance. These have provided essential knowledge of various adverse effects which result from a given level of perturbation. Good examples are our understanding of how badly planned grazing regimes contribute to soil erosion, or our ability to monitor for lead poisoning from human health studies carried out in the work environment. Intensively perturbed environments (hot spots) are extremely valuable for calibration purposes in the early stages of developing a monitoring system. However, some perturbations are not geographically confined to distinct areas in this way. Atmospheric mixing imposes virtually no constraints on the possible effects of such atmospheric contaminants as carbon dioxide and chlorofluoromethanes on weather. In such cases it is not possible to find a special 'hot spot' which might give us information as to what the prevailing situation might be globally, if emissions were to go on completely unchecked.

The existence of time-lags in the appearance of side-effects, as mentioned above, is particularly important with environmentally persistent chemicals such as radionuclides or certain toxic metals and pesticides.

The use of models allows monitoring to identify and concentrate on those environmental compartments coming earlier in the environmental transfer sequence for a given pollutant. Apart from additional valuable warning time given, this strategy usually involves a greater economy of sampling and analytical effort when compared with monitoring strategies which concentrate on collecting data on resultant pollutant levels in the eventual target receptor. Ultimately, the monitoring could go right back to the source itself, giving the greatest economy of sampling and analytical effort and the greatest flexibility in devising appropriate management strategies for dealing with that particular single problem. The difficulty, however, lies in the development of adequate models connecting the pollutant levels in different compartments with their consequential levels and effects in the target population. If this can be successfully achieved, however, the results are so informative and generally useful that it would be prudent to use the approach not only for delayed and persistent effects but in all applicable cases where the nature, time of onset, scale, and duration of side-effects arising from an environmental disturbance are poorly understood. In these latter cases this approach helps in the initial characterization of the problem and in defining more precisely the monitoring system required to obtain the necessary information.

d. The Role of Monitoring in Environmental Protection

In addition to understanding the scientific and technical basis upon which monitoring rests, it is also necessary to place in perspective the role of monitoring in environmental protection. The overall process of environmental protection is akin to a complicated problem-solving process in which monitoring plays an integral part.

One way of describing a problem-solving process is to divide it up into a number of 'functional phases'. If these are consistently related to each other in some way, a conceptual model of the whole process can be formed. It is important to keep a balance between the convenience of a simple model and the greater precision of a more complex scheme. Once one starts to identify 'functional phases', it is easy to escalate the procedure to such an extent that a simple method of interrelating the individual phases is lost. Moreover, as more phases are identified, the terminology necessitated expands accordingly and eventually becomes burdensome. On the other hand too simple a model is not informative enough.

An approach which bears in mind these points can be illustrated by reference to Figures 15 and 16. The former shows in matrix form the phases and activities occurring in environmental problem solving, and the latter depicts a model of how the different phases interact both with themselves and with the external environment.

Phases / Activities	Recognition (R)	Monitoring (M)	Assessment (A)	Policy (P)
Identification (i)	Ri	Mi	Ai	Pi
Appraisal (a)	Ra	Ma	Aa	Pa
Response (r)	Rr	Mr	Ar	Pr

Figure 15 Matrix showing the phases and activities occurring in environmental problem-solving

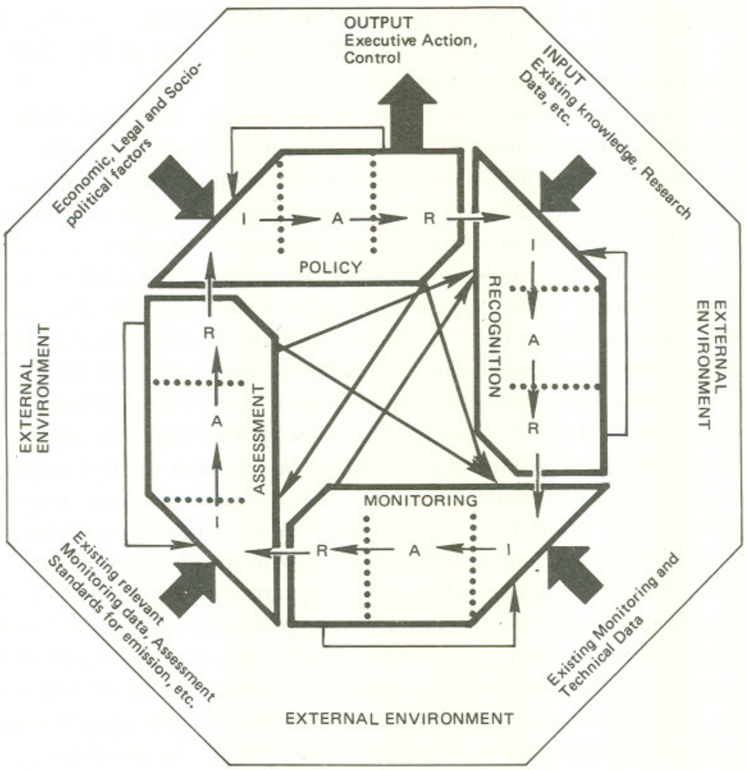

Figure 16 Environmental problem-solving model. Note that I = identification, A = appraisal, and R = response

Before proceeding with elaboration of this model, it is useful to consider how the activities of identification, appraisal, and response relate to any one of the functional phases, for example monitoring.

Consider an individual scientist conducting experiments within a programme intended to monitor the levels of either total or methyl mercury in fish. The activity of identification (i) then involves the selection of appropriate methods for the task at hand. The appraisal step (a) in turn involves the measurement of the actual levels of either total or methyl mercury in the species chosen and an evaluation of the scientific significance of the results. Lastly, based on this appraisal, the scientist in question has to formulate and carry out a response (r), whether this be to repeat his experiment in order to collect further data or pass the information to another body for further consideration.

Similarly, persons operating within the other functional phases perform the same three basic activities of indentification, appraisal, and response, though in their cases the scale and context in which these are carried out are different, as are the informational inputs and outputs. Figure 16 outlines this scheme.

Perhaps the first thing to note from Figure 16 is that the whole process is not, as a rule, a simple linear one in which a problem occurring in the external environment is first recognized and then monitored such that information from this phase is passed on to the assessment phase, used, and then fed to the policy phase where appropriate management action is taken.

Consider first the 'recognition' phase. A problem is often recognized in the absence of any formal or institutional mechanisms explicitly initiated to detect problems The lone researcher or the large research team serendipitously stumbling across a hitherto unknown problem is not uncommon. Such a discovery can then in turn lead to the establishment of monitoring programmes designed to uncover the extent or scale of the new problem. However, attempts can be made to formalize problem identification. Two examples spring to mind. The first involves policy decisions to initiate 'think tanks' to discuss different environmental areas with a view to stimulating the identification of possible problems through the process of information sharing. A decision to inaugurate joint conferences between chemists and meteorologists led directly to the shared recognition that halocarbons in the environment posed an environmental problem. This provides an illustration of the feedback loop from the policy phase to the recognition phase, and further refinements in the 'think tank' mechanism can be envisaged as part of the reiterative, quality control loop peculiar to the recognition phase.

The second example occurs when a large monitoring programme set up to monitor a generic group of problems incorporates procedures which can throw light on a previously unsuspected problem. As an illustration, consider a scheme set up to monitor adverse reactions to drugs. Cross-correlations on an ad hoc basis can sometimes provide evidence of causal relationships between certain drugs and specific effects. In this way a feedback occurs from the monitoring to the recognition phase.

Consider now the monitoring phase, from which information on the particular problem is passed on to be assessed. The quality of this information is determined by the intrinsic 'monitoring' feedback loop, which is a quality control loop, one of whose functions is to formulate and modify the monitoring techniques, the characteristics to be measured, and data handling. The validity of the input is checked in this way, and internal consistency and reliability is sought. In effect, this loop acts to improve the monitoring capability so that its output to the assessment phase is suitable for assimilation and action.

The main aim of the assessment phase is to scrutinize and evaluate the input from the monitoring phase and process it in such a way that an assessment of the situation can be transmitted in a suitable form to the policy phase.

It is also necessary to consider the roles of the direct input from the external environment and the feedback loops terminating at the assessment phase. The input from the external environment provides data to be used in conjunction with that from the monitoring phase. This data could be from other monitoring sources or it could be already existing knowledge related to the problem in hand or to similar problems. Likewise, information about existing standards, criteria, or danger levels would be collated and compared with the monitoring phase data.

The intrinsic assessment feedback loop is another quality control loop, in this case one which implies reassessments of the criteria used in evaluating the output from the monitoring phase and demands for more information from the external environment.

The loop feeding back from the assessment to the monitoring phase has two distinct functions. One is as a quality control loop between the two phases. Its second function is as a research tool in understanding the environment.

Finally, at the policy phase, objectives and options are formulated and matched and any resulting plan of action implemented. The inputs to this phase include not only the direct assessment of the basic data transmitted along the monitoring-assessment chain, but also an injection of social, political, economic, and legal determinations and values.

Feedback loops to the other phases act as quality control loops. For example, the loop from the policy to the assessment stage might act to modify any standards previously used in the assessment phase to evaluate the relevance of the output from the monitoring phase. The loop back to the monitoring phase will specifically affect this phase in its role as part of the enforcement and quality control mechanisms, or shift its focus of attention to a modified problem area which may have emerged as a cause of public concern. The existence of these feedback loops ensures that each phase is sensitive to all the inputs.

The preceding Environmental Problem-solving Model can be used to appreciate the role particular monitoring strategies play in environmental protection schemes. The two examples which follow are drawn from the fields of resource management and pollution control respectively.

An important reason why the management of natural resources is a problem of much greater complexity than the management of many pollution problems is that natural resources tend to form interacting components of dynamic ecosystems in which change is an integral part. Long-term changes can occur through trends in climate and in soil structure and chemistry, and through natural successional processes. For example, the occurrence in parts of Africa of tropical rain forests on fossil sand dunes indicates the potential magnitude of this type of change. However, the time scale of these changes makes them of relatively minor importance to present-day management systems. Short-term responses in the environment to high and medium frequency perturbations such as rainfall and temperature can be of considerable importance. Fluctuations in the grain harvests of the USA and USSR and the Sahelian drought illustrate the very real importance of these perturbations. These changes are induced by management practices and especially by land-use control strategies. Sustained high levels of productivity resulting from intensive farming practices, and the creation of sterile, saline soils from badly planned irrigation schemes are both examples of this type of change.

Any environmental management system must be responsive to these types of change if it is not to become out of phase with them and cause possibly disastrous results through positive feedback. In order to achieve this responsiveness, a continuous and iterative monitoring programme must be maintained. In fact, the major role of monitoring in resource management is to provide a constant and efficient feedback of information specifically to maintain flexibility and responsiveness in the policy stage of the management process. In the case of such complex systems, both the assessment and the policy stages in particular must, therefore, be based on some form of working model of the environment. The model must, firstly, include the baseline characteristics of the area, and must take into account the dynamic interrelationships between the various levels of the local environment as well as its inherent variability. It must then be able to predict the response of the environment to a whole range of management options. There is no doubt that a continuously iterative system of monitoring and model building forms one of the most powerful tools in natural resource management.

Working examples of this approach to environmental management and resource utilization are uncommon. However, one example from Africa can be briefly considered, both as an illustration of the environmental management model proposed in Section (d) and as a promising approach to resource management.

In Tanzania, East Africa, the National Parks are faced with the task of managing their conservation areas as renewable natural resources. In the Serengeti National Park, a multidisciplinary team of scientists has designed a management system based upon a long-term, large-scale monitoring programme. Supporting short-term research projects have produced a number of predictive models for different aspects of the Park's ecology and these are utilized with continuous development of a generalized model which predicts the response of the whole ecosystem to alternative management strategies, outside influences, and climatic variations. The monitoring programme is based upon, and feeds information into, this generalized systems model.

This has maintained a dynamic flexibility in the management of the Serengeti. For example, concern was expressed about the possible over-grazing of the pasture following the eruption of two ungulate populations. Five detailed research projects were initiated into the primary production of the grasslands and into the dynamics and movements of the populations concerned. These projects indicated that the populations would stabilize through density-dependent feedback processes before the rangelands became over-grazed, and models were formulated which predicted the population level at which this would occur. On the basis of these findings, the active management of these populations through culling was considered unnecessary. These population models were subsequently absorbed into the monitoring programme, and data were continuously collected in order to check the validity of the models and to ensure that the predictions were proved to be correct. Up to now the populations have behaved as predicted, and active management is still considered unnecessary. However, monitoring will still continue in case the situation changes.

The fact that the emissions of fluoro- and chlorocarbons (e.g., CCl_3F, CCl_2F_2) constitute an environmental problem was suspected only a few years ago. The chronology which follows (Table 3) is intended to illustrate the terminology used in

TABLE 3 Chronology of Recognition and Response to the Problems Posed by Halocarbons

Management Phase		Date	Event
External Environment		Before 1970	Introduction of the use of CCl_3F and CCl_2F_2 and their subsequent release to the atmosphere.
Recognition	(I)[a]	1970	Invention and development of a device capable of detecting CCl_3F in ambient atmosphere at concentrations of about 50 parts per 10^{12}.
Assessment	(A)	1970–1971	Association of CCl_3F transport by atmosphere with emissions from anthropogenic sources
Monitoring	(I)		Use of halocarbons to observe atmospheric motions.
Assessment	(I) (A)	1972	Identification of substance as potential long-range atmospheric tracer.
Recognition	(R)	1972–1973	Improvements in halocarbon detection methodology. Expansion of measurement programmes.
Monitoring	(I)	1972–1973	Detection of increasing atmospheric concentrations of halocarbons.
Assessment	(I)	1973	Identification of photolytical decomposition of substances. Identification of interactions between Cl^- and O_3.
Assessment Monitoring	(R) (I)	1974	Study programmes designed and commenced in order to elaborate stratospheric chemistry including that of halocarbons, water vapour, NO_x, etc.

TABLE 3 *(continued)*

Management Phase		Date	Event
Assessment Recognition	(R) (I)	1974	Further improvements in instrumentation for measurement of CCl_3F concentrations; detection of CCl_2F_2.
Monitoring	(I)	1974	Stratospheric flights to obtain concentration profiles of CCl_3F, CCl_2F_2.
Monitoring	(I)	1974–1975	Development of methods to detect ClO, HCl at minute concentrations ($\leqslant 1$ in 10^9).
Assessment	(I)	1975	Data on halocarbon atmospheric concentrations. Models and associated environmental effects assembled.
Assessment	(A)	1975	Organization of comprehensive, inter-disciplinary, inter-agency groups to assemble and consider all available relevant information.
Assessment Policy	(A) (A)	1975	Comprehensive reports qualitatively assessing current knowledge and applying economic-physical models to assess future situations. Reports: 'Fluorocarbons and the Environment' – Report of the Federal Task Force on Inadvertent Modification of the Stratosphere; 'Possible Impact of Fluorocarbons and Halocarbons on Ozone' – (May 1975) Interdepartmental Committee for Atmospheric Sciences.
Monitoring	(A)	1975	Increased measurement effort in space and time and equipment development.
External Input to Assessment	(A)	1975	Further theoretical studies of chlorine chemistry and radiative transfer effects. Analysis of increasing CCl_3F, CCl_2F_2.
Recognition	(I) (A)	1975	Detection of additional chlorine compounds in the atmosphere (e.g., CH_3Cl).
Policy	(A) (R)	1975	Recommendations for initiating legislation controlling fluorocarbon emissions.
Policy	(A) (R)	1975 and beyond	Chemical industry studies of alternatives.
Monitoring	(I) (A) (R)	1975 and beyond	Improved and expanded monitoring programmes.
Assessment	(R)	1975 and beyond	Improved evaluations.

[a]The letters (I), (A), (R) are abbreviations respectively for the activities Identification, Appraisal, Response.

the conceptual model above and the interactive and iterative nature of the environmental management process. This section also describes an important example of a process in which the initiation of management actions was based upon models predicting the consequences of specific levels of emission, rather than waiting until such consequences were detected. The models, which included actual monitoring data, indicated that the release of chlorofluorocarbons would have cumulative and persistent effect on atmospheric ozone, causing ozone levels to decrease for decades.

It seems highly likely that similar situations will arise in the future in which 'early warning' will be best provided by an appropriate combination of theoretical models and physical measurements.

This example demonstrates the interactive responses between the four stages of the process model which can act to improve and optimize the information available for management decisions. The recognition, monitoring, and assessment phases were and are often acting simultaneously and constructively to resolve uncertainties. At this time the results are being fed into an ongoing policy phase. The roles played by individuals and institutions led to the establishment of both governmental and private organizations directed to this specific environmental issue.

It is interesting to point out here that this ability to respond arose from an existing, long series of environmental studies into the atmospheric transport of radioactivity, carbon dioxide, and particulates, and into the effects of supersonic aircraft on the stratosphere. Although none of these studies was directly concerned with the halocarbons, a considerable body of professional and administrative expertise could be rapidly mobilized once the new problem was defined.

e. Conclusion

Monitoring of biogeochemical cycles can draw attention to significant alterations in the amount of substances in circulation and appreciable changes in the patterns of the cycles which have been caused by man's activities or by a significant shift in natural events. This gives a yardstick by which to gauge major impacts on the biosphere in relation to both human and natural interferences and helps in predicting whether protective measures, such as changes in release rates of a substance may be necessary. (See Chapter 3B on Biogeochemical Cycles.)

Gradual building up of knowledge about the dose-response relationship from studying 'hot spots' and other cases of special exposure, whether in pollution situations or from other kinds of human impact, helps us to identify levels of exposure which give rise to unacceptable side-effects. Subsequent monitoring schemes can use this knowledge to help decide where perturbations are beginning to approach critical levels and to predict at what rate. (See Chapter 3D on Environmental Toxicology.)

Where side-effects, from the ongoing action of a human perturbation, are delayed, environmentally persistent, or poorly understood, the calculation of the level to which the environment is irrevocably committed helps in predicting limits and hence guidelines for controlling human practices which generate the perturbation. The most prudent course to adopt for global monitoring is the implementation of carefully planned but modest pilot monitoring projects designed to gain experience as well as information about the environment.

B. MODELLING

1. Introduction

For centuries, man has been seeking to understand the environment, and to predict its future behaviour. He has had some outstanding successes in such fields as meteorology, hydrology, and plant physiology. In recent years, he has also developed a modest capability to understand large mixed biogeophysical and socio-economic systems. These scientific methods are all based on conceptual models, however crude, of the behaviour of the universe. Some of the 'laws' of nature are elegant in their simplicity, but environmental systems are often very large, contain random components, and include many interactive couplings. A perturbation introduced at some point in space and time may cause reverberations throughout the entire system. Usually, the reverberations damp out, but there is always the possibility that they may briefly amplify at some other place or time, or that they may even change the state of the system.

The computer provided man with the capability of studying 'big' systems. In 1923, L. F. Richardson could dream of predicting the weather with the help of an army of mathematicians, all solving differential equations on individual desk calculators. This dream became a reality sooner than Richardson might have expected. Today, the phrase 'simulation model' is often synonymous with the phrase 'a numerical representation of a complex system', and the potential applications are enormous, ranging from the behaviour of an individual cell under stress, to models of various world systems.

Simulation modelling of physical, biological, or socio-economic sciences includes a variety of methods, from graphical mapping and empirically fitted algebraic relations representing static or dynamic phenomena, to the use of highly sophisticated high-speed computing (analogue or digital) methods for solving complex systems of nonlinear partial differential equations or stochastic relations representing such phenomena. In order to represent a physical or biological process by equations, in most cases it is necessary to make some simplifying assumptions in describing the process in abstract mathematical language. Such assumptions may be particularly difficult to make if the process in question is not clearly understood and may eliminate from the mathematical equations some essential features of the process. The final results may have serious errors which could be aggravated by the high speed with which the computer may multiply such errors. The power of simulation models lies in the complexity of the systems they can examine; their weakness lies in the simplistic assumptions that are used in some or all of the component parts.

The modeller should realize that his objective is to simulate the behaviour of real physical systems, rather than to communicate more effectively with his computer. On the other hand, the investigator of complex environmental problems should recognize that he may not be familiar enough with the potentialities of simulation modelling developed by the specialists. The difficulties to be encountered in building and validating a big numerical model of a mixed biogeophysical-socio-economic system are immense.

The depth of knowledge of modelling within the ICSU Unions is great, but to a certain extent is compartmentalized. Thus, with the emphasis placed on simulation models at the present time and even more so in the years to come, the need for greater interdisciplinary exchange of knowledge and experience is urgent. In the following sections, the present state-of-the-art is summarized and the likely modelling problems of the next decade are discussed.

2. Purposes of Environmental Modelling

Models of environmental systems have been used for three main purposes: advancement of knowledge, education, and application of knowledge to decision-making.

Simulation modelling can be used in the management of research. In building a model, gaps in knowledge that might otherwise have been ignored can become evident. Where a number of research projects serve a common set of objectives, a model of the system may provide an objective basis for decisions regarding priorities and allocation of resources. The process of sensitivity analysis, which examines the response of variables of interest to changes in different parts of the model, enables research to be concentrated where the benefit is likely to be great.

In schools and universities, models are a way of displaying the chain of cause and effect in a complex environmental system. Building models of systems requires students to recognize the types of interaction involved, and to try to express them unambiguously and quantitatively. Models may also have important educational functions outside the formal educational system. An example is the enormous public impact of modelling work on the global scale by the Club of Rome and others, in drawing attention to the possible consequences of growing population pressures and depletion of resources. Education of the public on the likely future consequences of current trends and activities is a continuing need: the Club of Rome study just referred to also demonstrated that such education must encompass some instruction on the limitations of modelling and the dangers of uncritical acceptance of the results of extrapolation from imperfect data.

For the environmental manager who needs to reach decisions with environmental consequences, as in the case of a terrestrial ecosystem, modelling can constitute a special and sophisticated prediction based on the data at his disposal. These predictions then can be used with his evaluative judgment to arrive at a social policy. A simulation model incorporating existing knowledge of the structure of the system, and of its present state, can be used as a predictive tool. Its utility is influenced by how dependent the system is on unknown future inputs. The predictions may be arrayed as a series of several management strategies. It is as a tool for management and as a contribution to decision-making that simulation modelling of environmental problems plays its most important role.

3. Decision-maker's Outlook

There is no valid stereotype for decision-makers. However, many decision-makers see themselves as operating under a large number of conflicting pressures, and subject to difficult constraints. It is clear that models which will be accepted as useful by decision-makers must take account of political and other constraints, must address those specific problems the individual decision-maker views as important, and must be accessible without requiring an excessive learning period. A final requirement is understandability: a decision-maker may be more likely to accept the conclusions of a straightforward, logical analysis that he understands than those of a complex simulation which he does not. A conclusion supported by many observations is that recommendations arising from simulation studies are most readily accepted by those decision-makers who are closest to operational and technical problems, as with the operator of a water distribution system. This may be due to the fact that these managers are already familiar with such aids as complicated management information systems and optimizing programmes.

The use of models in decision-making is likely to be more effective if decision-makers can themselves be involved in the specification and development of models which they are to use. Otherwise, their values and perspectives cannot be successfully anticipated by modellers. Direct involvement of decision-makers in modelling depends on their willingness to participate as well as on the nature and scope of the problem, and may be impractical at present in many areas or where the highest political and administrative echelons are involved.

4. The Model Builder's Outlook

There appear to be four major issues that an environmental modelling effort directed to decision-making must resolve if it is to be productive:

(a) Model purpose – The development of models for decision-making purposes has been the least successful of the three purposes. Often models have not been designed for policy use or, when they have been, are unsuccessful in fulfilling this objective. Modellers, in general, are primarily scientists, and often seem more concerned with the design and development of models than with implementation. The actual model-building process involves their scientific talents, while the transfer of the model from the research arena to the operational arena may involve quite different skills.

(b) System definition – In forming a framework for analysis, the usual strategy is to divide the problem progressively into subsystems and components, until each component is recognized by the model builder as a segment for which there is adequate understanding. The primary issue may not be addressed, since 'adequate understanding' is never achieved. Another difficulty is failure to define the state of knowledge for each component of the system. Lacking this definition, a commitment is often made to a level of resolution where information on many components is inadequate and models based on existing experimental data are more likely to be completed than models that require new data from experimental observations.

(c) Interdisciplinary integration – Interaction between modellers in different disciplines, in practice, is difficult. Given a sector of a model to construct, individual scientists often prefer to explore the frontiers of this topic in more and more detail rather than develop simple representation adequate to support the total model. In addition, those components of the model that are strongly supported by theory and data are emphasized while those areas weak in theory tend to be underdeveloped. This, combined with the difficulty of establishing interdisciplinary linkages, may result in models that do not successfully address the whole system.

(d) Documentation and transfer – Understanding of an existing model requires knowledge of the nomenclature and philosophy of the disciplines involved as well as of the modelling language. Model documentation is difficult, and, even with minimum acceptable documentation, many features of a model remain in the mind of the modeller. When the modeller leaves, the model also leaves. Most model builders have little interest in model use. Models that process data or focus on resource allocation problems are currently easier to transfer into the policy arena than are actual simulation models because they perform functions similar to those already in use. Models that require practising analysts to develop new skills will not, on the other hand, be as readily accepted. The insight obtained through model construction may be easier to transfer to a key group of personnel than an entire, fully developed model itself. The concept of constructing basic modules that can be combined into many models has been advocated, but seldom successfully developed.

5. The Gaps

Major gaps exist in those common areas where the facets of environmental modelling interact.

A central theme running through many of the interface issues is one of communication, between human beings, between disciplines, between computers, and within disciplines. If the decision-maker and modeller fail to understand the common problem, whether it be one of predicting the consequences of a decision on control of a contaminant or finding an optimum solution to a resource allocation situation, no progress may be made, and future interactions may be harmed. Even if both sides understand the common problem and a solution is produced, there may still be difficulties because the decision-maker may feel that his power is being threatened by the results of the model.

The decision-maker and the modeller are often heavily constrained by working within limits of time, money, knowledge, personnel, and equipment. The restrictions that limited resources bring to the effectiveness of environmental modelling, particularly in the developing countries, should be specifically defined at the beginning of any work.

It is only recently that some effort has been made to study the transferability of models. Compatibility between programming languages, between computer systems, and between documentation is a major concern. Another question is whether the problem being addressed has already been solved and, if it has, if the solution can be used in the local or particular situation under study.

Another concern is interfacing between different types of models, although separate disciplines tend to favour a limited range of models within their own domains. The scale (both temporal and spatial) of aggregation, and of precision, can often be very different when studying separate submodels of the environment. Some difficult decisions have to be made when trying to incorporate these factors into a main environmental model. The decisions should be made explicit and their effects assessed by the environmental manager.

6. Environmental Simulation Models

It has already been observed that most modellers restrict themselves to only one or a few of the many logical, structural, and philosophical approaches to the subject of simulation, and that this sometimes results in a communication problem within the modelling community itself. This can be counteracted by a classification or taxonomic scheme, which need not be particularly detailed and need not involve careful definitions of terms, but can rather be constructed using only a few key descriptors. Suggested below is a fivefold classification, including:

(a) Purpose: Is the primary purpose of the model to provide (i) information for policy decisions of some duration, (ii) assistance in day-by-day operations, (iii) educational or training purposes, or (iv) information used to gain understanding of the system itself?

(b) Distance Scale: Is the area encompassed by the model best described as (i) local, (ii) regional, (iii) national, or (iv) global?

(c) Time Scale: Does a simulation run provide information on the scale of (i) day-to-day operations, (ii) periods up to one year, (iii) from one to several years, (iv) more than ten years, or (v) is it a static model providing steady-state information only?

(d) Type of System Modelled: From a list of descriptors provided, the most appropriate words or phrases should be chosen to describe the system being modelled. Examples would be: regional air pollution, coastal fisheries management, heavy metals transport in rivers.

(e) Model Type: Descriptors should be chosen from a list such as: stochastic, deterministic, linear-programming, dynamic, normative, descriptive.

In addition, note should be made of any constraints impeding further development or successful implementation of the model such as data shortage, user credibility, or validation expense.

Many examples of modelling studies could be given within such a classification. Two instances are the applications of population-dynamics models such as those of the spruce budworm (Holling 1974) or certain commercial fish populations. These can be thought of as quite successful applications, concerning which it is worthwhile to make three observations: first, that decision-makers were involved in the studies from the outset; second, that the decision-makers involved had technical backgrounds; and third, that an extensive and reliable data base was immediately available.

Another promising application involves numerical studies of atmospheric phenomena spanning short-range pollution studies and global-scale weather forecasting. These studies are generally very complex but the results are easily accessible to non-specialists and have been under discussion for many years. Both of these points have contributed strongly to the credibility of the models.

At the larger end of the modelling spectrum the early presentations of world socio-economic models experienced considerable criticism, and may be described as strongly aggregated models, the technical details of which were not readily available. Furthermore, many subtleties and special interests were not adequately represented in these models. More recent studies have specifically addressed several of these points and have been rewarded with greater credibility. In general, however, models with a considerable socio-economic content are less likely to be accepted by decision-makers than those based on purely physical-biological systems, partly because of the less secure data base, but also because of the difficulty of defining values inherent in social policy judgment.

At the intermediate level are studies such as detailed watershed or catchment models. These studies deal with aquatic, hydrological, and atmospheric transport, are of intermediate size, and involve detailed input from decision-makers. From the standpoint of technical suitability and of credibility, these are successful environmental management simulations.

7. The Potential for Environmental Systems Analysis and Model Building

Unfortunately, many of the models of the past decade have fallen far short of expectations. Those typically accepted or understood by decision-makers and the public belong to the monodisciplinary or technical-operational level, such as diffusion models in pollution control and pest management models. Models of an intrinsically complex and interdisciplinary structure have usually not been applied beyond either academic interests or normative perspectives. This situation is not due to lack of potential in systems analysis and model building. Rather, the understandable excitement of at last being able to grapple with complex problems led to grandiose dreams. Nevertheless, useful and usable techniques have emerged from small groups of scientists, who have had an interdisciplinary background and have made great efforts to link the modelling effort with policy questions and vigorous data validation from the start. Disregarding the early 'over-selling' of the simulation modelling technique, some useful progress has been made.

With the aim of improving the potential of environmental systems analysis and model building, the following factors need to be taken into consideration:

(a) Training of the modelling project co-ordinator in interdisciplinary approaches. It appears to be more effective to organize an interdisciplinary team in which individual members include exposure to, at a minimum, the necessary backgrounds of systems analysis, ecology, geophysics, social science (economics at least), and behavioural science. This exposure need not necessarily be deep, but should be balanced over the required areas. Special training centres should be prepared to fulfil this need, in and for the Third World. Venezuela and Japan are currently being prepared to house such centres.

(b) Creating clearing houses for data and models. It may be helpful to new modelling activities if special arrangements are made to provide ready access to relevant knowledge and experience. This might, for instance, take the form of a clearing house for each continent where a data bank of environmental information is maintained, and existing models are stored. Computer networks for ready transfer of this information would also help.

(c) Using semi-quantitative or purely qualitative methods. This approach should be cheaper in terms of data and resource requirements than most current rigorous answers to the basic questions posed. It may also be expected to help developing countries and further public education.

(d) Rendering modelling methods compatible with incremental decision-making. Basically, there are two different types of models for decision-making: technocratic and incremental. In the technocratic approach, one starts from the recognition and analysis of the problem, and then, through review of all feasible alternatives, the optimal solution is eventually chosen. The second, or incremental approach, is rather common and assumes that there is no decision or solution on a long-term basis, but a continuous stream of minor decisions on a subject whenever this subject confronts the decision-maker.

8. Bridging the Gaps

a. Scientist to Decision-maker

Decision-makers will rely on management procedures, as long as they are successful. Even when success deserts them, they will attribute this to circumstances, unless something or someone makes them feel that new insights are necessary and that the policy itself requires innovation. The steps and rules for building credibility of the environmental scientist, systems analyst, and simulation modeller are:

(i) to make the decision-maker aware of the problem, for instance, by furnishing objective analyses of critical and/or dangerous events;

(ii) to be constructive in criticism of past policy, to say how things can be improved without neglecting the constraints that the decision-maker must observe (political acceptance, etc.);

(iii) to point out that indeed the assessment of environmental impact cannot yet be based on an integrated science of ecology, technology, economy, and sociology, but that the relative evaluation of alternative measures is now possible;

(iv) to help make the decision-maker's task easier by participating in public educational activities remembering that politicians have to be elected and that the scientist also needs the support of an enlightened public;

(v) to make environmental sciences and the application of systems analysis and simulation modelling more acceptable to the scientific community by basing it, to the degree possible, on solid scientific work, and giving other disciplines the credit they deserve; and

(vi) to listen to the problems as seen by the decision-maker and take the initiative in devising effective channels of communication (SCOPE 1975a).

Environmental impact analysis often requires a long-term and global or universal approach, but decisions have to be made locally and cannot always be delayed. Thus, the simulation modelling of some environmental management problems on the world scale may be very logical from the scientific viewpoint, but be entirely unrealistic from the political viewpoint. Policy suggestions made by simulation modellers must face this dilemma. A few initial successes will improve the chances of decision-maker and systems analyst becoming a team whereas initial failures will impede progress for years; therefore, generation of unduly high expectations by the politicians and the public must be avoided. The costs of developing a satisfactorily validated model are often grossly underestimated. In communicating with the decision-maker it is a part of the responsibility of the scientist to make sure that these costs and the prospective benefits are taken into account in initiating the modelling effort.

b. Scientist to Scientist

To environmental scientists it is clear that a truly problem-oriented approach is required and that this will in turn require co-operation among the disciplines.

Development of simulation models that span the disciplines might prove to be effective in tackling complex problems that a single discipline cannot master, as well as in bringing scientists from different disciplines together.

It is widely appreciated how difficult it is to become a specialist in each discipline; however, because there is little appreciation of the necessity to look at problems that require co-operation, those scientists who point out the holistic nature of the human predicament are often regarded as would-be generalists who know 'nothing about everything'. This is in part a dilemma which can be overcome by teamwork. It is possible that universalists of the past will be replaced by teams of experts whose knowledge and experience will be accumulated and integrated through simulation, gaming, and other techniques for improving communication between groups.

c. Gaming

Gaming provides an extension of simulation modelling by allowing the user of simulation techniques to introduce the decision-maker's behaviour into the simulation process. Decisions are made between the time steps as the simulation proceeds. The user becomes more aware of the complex of factors that should be observed before allocation of resources. He performs these allocations and then lets the in-built dynamics of the underlying simulation model carry him to the next time step. The adjustments and compromises with other users who simultaneously represent other interests allow him to see political, social, economic, technological, ecological, and psychological constraints that might otherwise escape attention.

d. Handling Uncertainty

Simulation models are always subject to uncertainty; in their structure, in the data incorporated, and in any future inputs that are assumed. The only hope for successfully dealing with these combined uncertainties, given a certain level and structure of knowledge, is to make these sources as explicit as possible, and to distinguish clearly established facts and relationships from assumed or less established data and relationships. As research continues, knowledge increases, the simulation (or gaming) process is organized in such a way that newly acquired relevant knowledge can be absorbed in a continuous updating process. Only a highly flexible and modular simulation technique can achieve this end. Remaining uncertainty can be dealt with by analysing the effects of varying assumptions; this is essentially a sensitivity analysis. Identification of areas which urgently need further research can emerge from these studies. Also, decision-makers learn more about the sensitivity of the system to the set of alternative policies or measures they are considering.

e. Validation and Credibility

A simulation model cannot be validated solely by reproducing past phenomena and past time series, particularly if it is to be used for assessing present or future alternative policies. Perhaps the gravest validation problem the modeller faces comes from structural change in the real system. Often, the parameters of a simulation model with fixed structure are fitted to generate past time series for a period of time in which the structure of the real system has changed, and the same model is then used to simulate a future in which the structure might change again. The only chance to develop models which can be structurally validated is to leave those parts of the model structure variable which do not represent invariant relationships during the time period under analysis. Clearly, even dynamic models are not adequate unless structural variation is introduced. Because opinions differ widely on which structures can be affected and which cannot, only such models as allow the user to vary structural assumptions may be acceptable to decision-makers who expect or want structural change. Again, the extension of simulation modelling by gaming seems to offer procedures for generating the credibility required.

9. Steps toward Improvement

Environmental models cannot usually be tested in a laboratory under controlled conditions. However, simulation models often provide some clues concerning the causes and the effects, and a sensitivity analysis may suggest experiments in areas of science where fundamental research might be most productive. The use of both mathematical and physical models to represent a complex environmental situation will, in many cases, be effective particularly if the method of using some simple laboratory models is first compared with a mathematical simulation of such models and a direct verification is made of the conditions under which such a use is justified. Based on such a validation the more complex environmental situation could be modelled with a greater degree of confidence. A further validation will, of course, be necessary by comparing the simulation results with the real environmental conditions.

In order that the full contribution of simulation modelling be realized, it will be necessary to address several main groups of problems.

(a) The sophistication of modelling in those fields where it has been less developed should be pressed forward in co-operation with such bodies as the International Institute for Applied Systems Analysis (IIASA).

(b) Every effort should be made to disseminate knowledge and interest in modelling among practitioners in these fields.

(c) All those concerned with modelling as a tool in environmental management should recognize the desirability of involving the decision-maker in the model-building process from the earliest possible stage.

(d) Special attention should be given to the difficulties of interfacing models from different disciplines and at different scales of space and time. In particular, this will be the case with physical, biological, and socio-economical models, when some inputs are measurable while others are in terms of value judgments.

(e) A major effort should be made to call the attention of those ICSU Unions and Scientific Committees whose expertise is within the physical, mathematical, and biological sciences, to the need for basic or applied research on those scientific problems which are not fully understood and which presently require, for their simulation, the use of empirical relations, unjustified assumptions, or guesses.

(f) Co-operative studies with the Committee on Space Research (COSPAR) on the possible application of simulation modelling in the study of atmospheric pollution and interfacing of data derived from satellite observations with those obtained near the ground or sea should be planned.

(g) Co-operative studies with the Scientific Committee on Oceanic Research (SCOR) on those problems of simulation modelling of oceanographic processes which are of common interest are desirable.

(h) Existing techniques for optimization of space and time distribution of monitoring stations should be examined on an interdisciplinary basis. Each discipline has solved or ignored this problem in its own particular way, but no attempt has yet been made to synthesize across disciplines or environmental media.

C. RISK ESTIMATION

1. Concepts

The word 'risk' can be used in two senses. In everyday speech it can imply a value judgment about the severity of consequences of a possible event. Under such circumstances the appreciation of risk can be very different from community to community according to the base line from which it is judged. In scientific terms, however, the word is used more strictly to denote the probability of an event and its estimated consequences, usually an event whose consequences have been identified by a value judgment system as being 'undesirable.' In this section of the report the word is used in the latter context.

When a risk has been identified and when models of environmental processes suggest adverse effects, there is need to specify the degree of risk in precise terms. Increasingly, scientists are called upon to calculate estimates of the risk of certain conceivable events occurring and to state the consequences in probabilistic terms if such events were to occur.

Decisions always involve risk estimates, and the methods of estimation have been steadily improved. It is now possible to state with considerable accuracy for some countries the general risk of death or severe injury for private car drivers or passengers, for passengers on commercial aircraft, or from crossing the road. These technological risks are somewhat easier to estimate than environmental risks where the connection between an event and a consequence is often not so direct or immediate.

Where scientific estimates are not available, and in some cases where they are, reliance is placed by some on acts of revelation, especially as performed by individuals claiming superior authority or ability in such matters. While scientifically doubted or discredited, such methods are still widely in use and widely believed. Many environmental management decisions involve assumptions as to what risk estimates people will make for themselves or accept upon authority, however dubious.

One method of revelation is the practice called water dowsing, water divining, or water witching. Many farmers call in a water dowser who with the use of a forked stick, preferably hazel in many places, claims to detect or reveal the best place in which to locate a well. While this process is scientifically doubted, and no process or causal mechanism can be described in scientific terms, it is widely used.

Another non-scientific method of risk estimation that is widely used is intuition. Laymen, as well as scientists, use intuition in their daily lives to reach decisions and make choices. Intuition can be defined as 'reaching a conclusion on the basis of less explicit information than is ordinarily required'.

When the choices to be made are numerous and trivial (i.e., the consequences of a wrong choice are not serious) intuition may be a satisfactory way to proceed. It saves time and effort in making more scientific estimates. Where major consequences are at stake, intuition alone is not recommended.

There are three main scientific approaches to risk estimation: extrapolation, reverse extrapolation, and analogue methods.

The most systematically employed methods of estimation involve the use of extrapolation from experience. Most common is the projecting of past events into the future in order to estimate likelihood of events or rates of continuance of observed trends. Estimates of changes in atmospheric composition serve as an example.

Reverse extrapolation is a method of tracing backwards from imagined events and consequences, reducing the risks to a series of component events for which experience does exist. Such methodology underlies fault tree analysis of the risk of failure of complex engineering structures. Core meltdown and subsequent release of fission products, for example, is a conceivable event at a nuclear generating station. Such an event has never occurred, but the structures and processes of the generating station can be reduced to component links for which there are experienced rates of failure. Risk estimates in this case involve a series of contingent probabilities.

A third approach to extrapolation is the analogue method in which experience is transferred from a different but not dissimilar situation. For example, estimates of the maximum probable flood in a small river basin with poor records may be achieved by transferring known weather patterns of the region into that basin.

2. Example of Risk Estimates

There is an extensive literature on the risks of late effects from the irradiation of the human body and its organs and tissues with ionizing radiations. There are many recommendations, in effect or being proposed, for dose limits for ionizing radiations. Thus the risks for any dose limit can be estimated and compared with other risks of ordinary life for populations or with other risks in industry for occupational workers.

A recently proposed standard for the protection of populations is an annual dose equivalent to the whole body of 25 millirems (US EPA 1975) for the whole fuel cycle. The risks of late effects from this dose rate are (Rothschild 1973):

(a) Fatal cancers, 3 to 13 cases per year per million people (C/Y/M) irradiated. The total cancers would be about twice this number (NAS 1972). These numbers may be compared with the rate of cancer deaths per year in the USA, 1,700 C/Y/M. Thus 25 mrem per year would given an increase of about one-third of 1 percent.

(b) Genetic injury to the first generation, 5 to 80 C/Y/M. The higher rate established at equilibrium, after the irradiation of several generations, would be about ten times higher (NAS 1972). This may be compared with a natural incidence rate of 60,000 C/Y/M. Again 25 mrem per year gives an increase of about one-third of 1 percent.

These rates of incidence may be compared with other risks of ordinary life estimated as follows (Pochin 1974, 1975):

Event or practice	Estimated resulting death rate C/Y/M
Traffic and transport accidents	150
Accidents in the home	130
Smoking 20 cigarettes per day	5,000
Drinking 1 bottle wine per day	750
Pregnancy	230
Oral contraceptives	35
Abortion at less than 12 weeks	20
longer than 14 weeks	170

In addition to these methods of risk assessment, attempts have been made to develop systematic approaches that combine the intuitive judgments of experienced persons with quantitative estimates of probability and trends. These include scenario methods and the technique to analyse judgment. Judiciously used, these might play a role in the process of risk assessment especially where broad concepts of future development are concerned. They are less likely to be useful in the assessment of specific risks.

3. The Future of Risk Estimation

The state of the art of risk assessment was reviewed by a SCOPE Working Group (see Appendix C) (SCOPE 8 1976). Various suggestions are made for improving risk assessment. These include the development of hazard taxonomy, and the examination in a systematic fashion of the role of three types of social risk assessment: (1) in the market-place by buyers and sellers; (2) in the sounding of social concerns, including public polls, surveys, and exercises in public participation; and (3) in adversary or judicial situations.

On the estimation of health risks it seems clear that much might be gained by an application of the thinking developed in the assessment of ionizing radiation and radioactive materials to other forms of environmental contamination. The concepts of dose commitment and harm commitment, reference man, and the linear non-threshold dose-effect relation as developed in the International Commission on Radiological Protection (ICRP 1965) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR 1972) merit wider application. Section D of Chapter 3, on Pollutants in the Environment, and its annex on methyl mercury, illustrate how this may be done.

Epidemiological studies are critical. For a number of reasons estimates may vary by one or two orders of magnitude. This wide range of estimates of hazard to human health is one of the chief causes of confusion in the public mind and of debate with government administration in setting standards.

D. EVALUATION AND COMMUNICATION

Risk evaluation is the conversion of estimates of risks into social meaning. The meanings may be expressed in symbolic terms, in value (economic and otherwise) and in effect (feelings). There are many dimensions to risk evaluation, and it is a process in which all engage. To bring order out of this diversity it is helpful to think of three approaches to risk evaluation: aversive, balanced, and benefit-risk.

Aversive approaches to risk evaluation are those which seek total avoidance or minimization with little or no attention to other considerations. Examples of aversive risk are the food and other taboos deeply embedded in traditional cultures, some of the standards and regulations set in modern society, and the avoidance behaviour of people everywhere. Risk aversion seeks to achieve zero probability of damage.

By contrast the notion of balanced risk recognizes the continuance of some risks greater than zero tolerance, and seeks to achieve a measure of balance among them by making comparisons. It is well known that people accept much higher risks in some directions than in others although the reasons for this are imperfectly understood. Comparisons may be made in terms of risk of death in standard units of exposure or in other terms. Systematic comparisons of many environmental risks are largely lacking. Such attempts as have been made (Starr 1969) show a difference between voluntary and involuntary risk-taking or exposure and between public and private sector risk levels. A comprehensive examination of environmental risks, if undertaken, would be able to point to areas of relatively high but neglected risk and to risks of much lower probability which receive much more attention.

Related to comparative risk are the techniques of cost-effectiveness analysis. An evaluation of costs allocated to preventing injury and death in three British industries (agriculture, steel handling, and pharmaceuticals) shows wide divergences and an implied differential evaluation of a life varying from thousands to millions of pounds (Table 4) (Sinclair et al. 1972).

It seems safe to assume, given the present state-of-the-art, that were similar analyses to be made of a broad set of environmental risks similarly wide discrepancies would be found in the amounts expended to achieve a degree of protection.

Attempts to compare risks not only with other risks but also with associated benefits are developed theoretically, but deficient in practice. Benefit-risk analysis is a newly developing form of benefit-cost analysis in which the focus is upon a comparison of risks with associated benefits. The assumption here is that higher risks are acceptable where associated or anticipated benefits are higher. The most comprehensive attempt to make such comparisons in the technology assessment field is that by Starr (Starr 1969). No attempts have so far been made to develop similar relationships for specifically environmental risks. It would be worthwhile to try to do so, not because the end result would be convincing (there are many caveats to be entered about Starr's analysis) but because the process of attempting to compare benefits with environmental risks would itself be highly illuminating.

TABLE 4 Comparative Risks, Outlays, and Implicit Life Valuations

	Annual Risk per 1,000 Workers of:				
Sector	Injury	Serious Injury	Death	Average Outlay (£/Worker)	Valuation (£), Death
Agriculture	25.7[a]	4.44[a]	0.197[a]	3 (1966–68)	15,000
Steel handling	72.7[b] 62.54[c]	9.92[c]	0.216[b]	50 (1969)	230,000
Pharmaceuticals	25.0[b] 36.80[d]	2.42[d]	0.020[b]	210 (1968)	10,500,000

SOURCE: Sinclair et al. (1972), p. 50.
[a]Ministry of Agriculture, Fisheries and Food, 1966–68 average.
[b]Annual Report of the Chief Inspector of Factories, 1969.
[c]Department of Health and Social Security Digest of Statistics Analysing Certificates of Incapacity, 1967.
[d]Annual Report of the Chief Inspector of Factories, 1967, and Department of Health and Social Security Digest, 1967.

TABLE 5 A Structure for Risk Assessment

	Identification	Estimation	Evaluation
Methods	Screening and testing	Revelation	Aversive
	Basic research	Intuition	Balanced
	Monitoring	Monitoring	Benefit-risk
	Diagnosis	Extrapolation	–
	Creative imagination	Analogue and transfer	Delphi
		Modelling and simulation	Scenario
			Reverse scenario
Theory	Scientific method	Statistical inference	
		Theory of return periods	

The attempts at synthesis of methods and techniques from many fields into a framework for risk assessment are continuing. A preliminary structure is shown in Table 5. They give promise, if pursued, of being able to reduce the number of occasions in which opportunities are foregone because of excessive or unnecessary fears, the number of hazards that remain unidentified, and the risks recognized but underassessed. The importance of the task is not yet matched by performance, however.

Three themes requiring further detailed research and development that have emerged from SCOPE workshop discussions are: (1) the development of typologies of hazards, events, and consequences; (2) the refinement of methods of risk estimation and evaluation; and (3) the communication and use of risk assessments (Burton et al. 1977, Whyte 1976).

It would also be useful if a series of detailed studies could be carried out of human experience in dealing with environmental risks in order to provide a comparative assessment between risks, among countries, and among methods of identification, estimation, evaluation, and communication (White 1974). National and cross-sectional studies would be required with appropriate guidance from international groups of experts and 'users'. In addition to the insights gained by such an exercise, it would be possible to produce a guidebook or handbook of risk assessment methods and approaches which would be widely used.

The complexity of the research processes involved in risk assessment – identification, estimation, and evaluation – partly accounts for the difficulties that have been experienced in communicating the information content of research results to policy-makers and the general public. There is a widespread feeling in the community of environmental scientists that the manner and process of communication is crucial to the nature of societal response. This is paralleled by a sense of powerlessness to affect the process consistently in desired directions. Behind this feeling lies a lack of understanding of the ways in which scientific communications are used and their effects on public and policy-makers.

It is now only possible to describe some of the symptoms of the underlying difficulty and to outline the main dimensions or variables in question.

In the typology of environmental issues described in Chapters 1 and 2 it was noted that issues frequently are allocated to the wrong category, contrary to the intentions or judgments of the informed scientific specialists. Scientific papers or reports often point to the possible existence of an environmental issue deserving more research and some precautionary actions. There are many such papers and many of them do have the desired effect. That is to say, those responsible do facilitate continuance or redirection of the research and take precautionary or preventive action where appropriate. The process goes on quietly, the responsible policy-maker taking calculated action without major publicity. Often, however, the scientific warning is ignored or passed over. This may be because it fails to come to the attention of the appropriate person or group. It may be because the recipient of the report considers the questions raised embarrassing or awkward to deal with and prefers to let the matter rest. Another possibility is that the judgment of scientist and policy-maker differ as to the significance of the issue.

When this happens an individual scientist or a scientific group may feel a responsibility to inform the public of the suspected danger. This may be difficult to do. The channels of communication to carry the message to the public may not be open or if open the message may strike no response. On the other hand, the message may be modified or exaggerated in transmission and a great deal of public concern or alarm may be generated.

When the spotlight of public interest focuses upon an environmental issue the actions of policy-makers are changed. The policy options may be enlarged in one direction and curtailed in others. The scientific evidence carries less weight and is mingled with the emotional reactions of the public, especially those exposed or likely to be affected. What was a suspected issue may be swept by the power of partially formed public opinion into the category of the real and the urgent, irrespective of reality.

Steps towards the improvement of the processes of scientific communication lie in several directions. It would be helpful to have a more considered and deliberate approach to communication by scientists. For environmental scientists, it is important to be able to communicate accurately and precisely, in terms that can be understood by laymen and policy-makers without distortion of the essence of the message. Such aims are unlikely to be achieved without better understanding than now exists of the factors that affect the 'communicability' of a message and response to it.

Some of the variables that now seem of key importance are the nature of the source of information, the form of the message, and the situation of the recipient.

The communication and response process is affected strongly by its point of initiation. In particular the authority or perceived authority of both the originator and transmitter are important. Usually scientists enjoy a high reputation in the eyes of both policy-makers and the general public. Their pronouncements are likely to be taken seriously and accorded weight. To what extent this authority is eroded by the considerable public disagreement among scientists which often emerges on environmental issues is not known. Two observations from recent studies merit consideration in this context. Scientists remain in the public view among the most reliable and responsible sources of information. Scientists are commonly rated more highly in this regard than members of legislative bodies, government officials, and the men and women of the media.

At the same time surveys show that many people feel that they have insufficient access to authoritative scientific information or to the scientists themselves. It seems important that the authority of scientific statements be protected and enhanced and this requires careful attention by scientists to the statements they make and may benefit from use of specialists in communication. Continuing efforts are needed to carry such statements to a wider audience. The public has never been so receptive to scientific information as it is now, and has never been so hungry for accuracy and authority in such information.

The requirements of authority and accuracy have hitherto been best satisfied by the use of established scientific grounds rather than the mass media. The latter have an unenviable reputation for distortion and exaggeration. The way to improvement lies open, however, and scientists using the mass media to inform the public are in a position to exert much more influence than has been customary.

Scientists could be helped in this regard if more was known about the effect of message content, presentation, and timing upon response. It is not sufficiently understood how message format, its urgency, the magnitude of possible consequences, or the nature of the group exposed affects the character of societal response. More detailed and systematic examination of the record with a variety of formats in different countries and for different environmental risks would prove instructive and the understandings thereby gained would provide an opportunity for the process of communication of scientific information to improve.

Response to scientific information clearly varies greatly with the situation of the recipient. Under present practice such information frequently reaches recipients who are in no position to act or to protect themselves from possible environmental threats. Hence the information may generate anxiety without providing any means for its alleviation. There is research to show that extremely dramatic and threatening information is less effective in encouraging response that when more soberly and cautiously expressed. Extremely scary stories tend to evoke in the recipient a psychological response of denial or impotence to act.

Thus both the target audience of the message and its mode of expression can powerfully affect the likelihood and character of response. The whole process of scientific information and communication in the context of decision-making and government policy, and in relation to public awareness and behaviour, needs systematic study.

E. STANDARD SETTING

1. Introduction

Standards are theoretically promulgated by governments or other regulatory bodies in order to protect or enhance the public health, well-being, and quality of life. Environmental standards are commonly of two sorts, prescribing:

(a) maximum permissible levels of environmental contaminants, or

(b) minimum permissible quality of construction, such as for human habitation or dams.

Ideally these standards are based on scientific criteria which have been defined as a collection of data giving quantitative relations between the cause of an undesirable effect and the probability of occurrence of that effect. In practice these data are considered by the standard setters and taken into consideration with economic and social factors. Levels are chosen which correspond to an acceptable degree of risk for a given situation. As new scientific evidence becomes available, and as social and economic conditions change, standards should be subject to periodic review and amendment.

The procedure for arriving at a standard of type (a) above is illustrated in the summary of the ecotoxicology of methyl mercury (Appendix D). This shows that the most important route of intake of methyl mercury for man is eating fish taken from waters contaminated by mercury compounds. The calculations presented show how the body content of methyl mercury in a fish eaten could be calculated from the daily intake. An example of a body content giving an acceptably low risk of neurological symptoms was also given. In this way maximum permissible levels of methyl mercury in fish could be calculated. To set a standard for a given population would require a knowledge of the amount of fish eaten per day or week and the length of the period of consumption.

The acceptable level in a receptor such as man was defined at the Stockholm conference as a primary standard. The corresponding level in an intermediary stage on the pathway, such as the fish, was defined as a secondary standard. Other secondary standards would be the corresponding concentration of methyl mercury in the water where the fish lived. This is called an Environmental Quality Standard. With adequate knowledge of the quantitative transport from the point of release into the body of water to the final human receptor, acceptable release rates and total releases can be calculated; these are called emission standards.

The other kind of standard [type (b) above] is best exemplified from the field of building and construction. It is illustrated by the work of SCOPE Mid-term Project III on Environmental Aspects of Human Settlements, a summary of which follows.

2. Standards and Criteria for Human Habitations

a. Background

The United Nations Conference on the Human Environment held in Stockholm in 1972 gave prominence to the problems of planning and managing human settlements for environmental quality. The rapid rate of population increase and especially of unplanned urban growth in some developing countries, and the need to improve living standards in at least portions of almost all countries adds importance to these issues.

A primary need in this field is an interdisciplinary appraisal of the existing state of knowledge. One topic regarded as of the highest priority is the evaluation of the scientific rationale behind standards and criteria that influence the relation between the provision of human shelter and the environment, especially in the developing regions of Latin America, Asia, and Africa. Such an evaluation compels a review of current construction methods and density of building with special emphasis on the use of renewable and non-renewable resources, climate, cultural values, building and administration costs, water supply, air quality, occupational noise levels, geophysical hazards, and sanitary and education services. This should lead to a fresh appraisal of what are, for instance, minimum standards for housing density or water supply and should considerably enhance the overall understanding of the essential human needs in a wide range of settlements.

The following objectives were adopted by the SCOPE Mid-term Programme:

(1) to collate existing information on the various standards and criteria that define the environmental context of human settlement and, in particular, determine the supply of housing and other services and amenities;

(2) to carry out an interdisciplinary evaluation of the scientific rationale behind these standards and criteria;

(3) to develop proposals for planning and promoting comparative research into the development of new standards and criteria which may ameliorate the current environmental crisis in human settlement.

Three institutions were designated, one each in Latin America, Asia, and Africa, to be responsible for the collating of existing information on standards and criteria within their regions. The Centre for Urban and Regional Studies of the Instituto Torcuator di Tella, Buenos Aires, Argentina was in charge of the Latin America region; the Institute of Development Studies of the University of Mysore in India took responsibility for the Asian region, and the Planning Studies Programme, University of Ibadan, Nigeria undertook the task for Africa.

Two types of standards were agreed upon: official and cultural. Official standards are those set by legislation, bylaws, rules, and regulations. Cultural standards relate to what is tolerable and acceptable to a large number of people. Criteria, on the other hand, are guides to standards arising from social values or recommendations as to levels of tolerance offered by professional or scientific bodies and based on published reports, case studies, and professional judgments.

In many developing countries and frontier areas, the conflict between official and cultural standards and the difficulties in enacting standards at social levels are influences which cause a relatively inefficient system of shelter provision. As a result, it was decided that the project should investigate both official and cultural standards. Official standards were to be investigated for each of the continental regions. Questionnaires were sent to appropriate agencies and individuals in various countries and followed up by direct visits. Cultural standards were to be investigated by surveys conducted in the countries in which each of the collaborating institutions is located.

However, for Latin America, it was possible to collate the necessary information for official standards only for four out of the thirteen countries: Argentina, Bolivia, Brazil, and Paraguay. Surveys for evaluating cultural standards were undertaken for two agglomerations in Argentina – Greater Resistencia and Greater Tucuman. In Asia, the investigation of official standards covered, apart from India, four other countries – Malaysia, Philippines, Singapore, and Thailand. Within India ten case studies covering six urban and four rural settlements in different parts of the country were undertaken. In Africa, information concerning official standards was collected in the following countries – Botswana, Egypt, Ethiopia, Ghana, Kenya, Nigeria, Sudan, Tanzania, Uganda, and Zambia. The investigation of cultural standards was limited to four settlements that have recently developed within the metropolitan area of Lagos.

The full result of this study appeared in a report by SCOPE to HABITAT, the United Nations Conference held in Vancouver in August 1976.

b. Existing Standards and Criteria

One of the interesting aspects of the study is the recognition of the varying degrees of governmental interest in matters concerning human settlement. In Latin America and Africa, governments have established official standards for shelter provision only in respect to urban settlements. In Latin America, the suggestion is that this is due to the fact that a high proportion of the population live in urban centres. In Africa, the situation is the reverse and the absence of any interest in non-urban shelter must be put down to inadvertence. Asia provides a wide spectrum of human settlement types and in a number of the countries official standards exist for both urban and rural types.

With respect to standards specifications, it was possible to identify three broad groups in the area of shelter provision. These are: accommodation, threshold, and technological (performance) standards. Accommodation standards define the level of intensity with which a particular activity such as housing construction may be conducted. The unit of expression varies. It embraces such units as building space, number of persons or buildings per unit area as well as space standards for community services and similar activities since these can be viewed as standards limiting the intensity to which a particular piece of land is put to a particular use. Of the different accommodation standards, those for occupancy, density, and minimum accommodation are of considerable environmental importance.

Threshold or range standards define lower and upper limits of populations, area or distance serviced by a particular amentity or a community service. These may range from standards regarding the per capita supply of water, the desirable number of students to support a school, the number of shops, to the size of a recreation area required for a specific size of population. Range standards define the maximum distance to as well as the maximum area serviced by a facility while threshold standards define the respective minima.

Technological or performance standards define the quality of environment such as the quality of construction, use of materials, quality of services, or tolerable levels of toxicity. Building bylaws, codes of construction, regulations on wastes, industrial effluents, fire, and noise, all tend to devote considerable amount of space to these types of standards.

c. *Evaluation and Rationale*

In most of the countries investigated, the accommodation and performance types of standards were found in considerable detail in legislation. Only in a few countries, such as India and Zambia, were there many standards of the threshold type. However, because of the legal style in which most of these standards have to be specified, their scientific rationale was seldom stated beyond broad claims of health, safety, privacy, and easy accessibility. Attempts to investigate the scientific rationale behind a few of these standards revealed that either these were non-existent or, where they did exist, they had little or no basis in local experience. A good example are the standards on day-lighting in tropical countries of East Africa, where given the latitudinal location, there is little likelihood of an insufficiency of light penetration into buildings. It appears that the common effort by the local population is to limit the degree of penetration. Yet, in Kenya and Uganda, the standards specify that for day-lighting, the area of windows in a house must be at least 10 percent of floor area and the windows must open to open spaces. Such a standard, which is more appropriate to high latitude, temperate countries, comes to affect the density of buildings allowed per unit area.

A few other factors do affect the nature and rationale of standards which were encountered in the three regions in the field of shelter provision. One such factor is the absence of any definitive and clear governmental policies on the issue of shelter provision for the masses. It is typical to find statements in the development plans of many of these countries which indicate governmental determination to build a certain amount of low-cost housing at a given amount of money. When the agencies saddled with this responsibility realize the difficulty of matching the number of units to be built with the actual funds available, one of the variables that they manipulate is the standards, particularly the accommodation standards. In such situations, the enforcement agency itself may already be party to this manipulation or may find itself incapable of enforcing compliance with the official standards against another governmental agency. In short, a common feature of official standards setting and enforcement in most developing countries is the multiplicity of agencies involved in the operation.

This situation becomes more complex when foreign or international agencies are also involved in financing the provision of shelter. Especially in Latin American countries, their definition of criteria for approving building loans to individuals or governments invariably implies the establishment of standards which in many cases have no relevance to environmental conditions in the countries or to actual needs of the people.

Most of the standards tend to be characterized as minimum. For most of the countries, given the average level of income, the minimum standards are often unattainable for the masses. This is particularly true with respect to technological standards. In most countries, technological standards for walls are defined in terms of stones, bricks, or concrete blocks. In the Ghana regulations, for instance, it is stated that bricks or blocks used in any wall shall be composed of sand-cement, soil-cement, concrete, burnt clay, or sand line and have a resistance to crushing at 28 days of not less than 400 pounds per square inch of gross horizontal area where the wall is for a small house, 1,500 pounds per square inch if bricks and blocks are solid, or 750 pounds per square inch if bricks and blocks are hollow. Yet, Ghana only began to produce cement locally in 1967 and even now imports a high proportion of its consumption. An unrealistic set of standards in the provision of shelter can adversely affect a country's balance of foreign payments. Naturally, since people must satisfy their shelter needs somehow, the tendency is to ignore any governmental guidelines in this matter and thereby challenge government to react. Not unexpectedly, governmental response has in many instances been one of indifference at the numerous but less conspicuous instances of non-compliance.

The operation of relatively high minimum standards implies the acceptance of a process of social stratification in the thrust of governmental policy with respect to shelter provision. As long as these standards and criteria continue to be enforced in their present form, it is unlikely that shelter can be provided for other than the middle and upper income groups in most developing countries. The vast majority of the population would therefore be constrained to seek solutions to their shelter needs outside official guidance, using technology and material whose appropriateness and adequacy can be made flexible and adaptable to their changing needs and resources.

Already, a few countries are trying new methods of setting standards. One such method, based on housing-user surveys, has been used in Egypt and the Sudan. Descriptions of different types of house construction using various material and design specifications are given to occupants whose levels of satisfaction with different aspects of the building are investigated. In other places, research on the functional efficiency of various materials provide an initial basis for the hope that realistic changes may occur in the setting of standards and criteria for shelter provision in developing countries.

d. The Emergence of Policy

In attempting to evaluate the present situation with respect to standards and criteria for shelter provision in developing countries, certain basic issues must be emphasized. The first is that developing countries are experiencing an unprecedented rate of urbanization. The millions of people who are moving from their normal rural abode to seek new residences in cities give the question of shelter provision a poignant urgency. It is evident that there is considerable diversity within this urbanizing situation which makes the shelter-environment issue assume different dimensions in different countries.

A second issue is that, almost without exception, developing countries have not seriously considered the implications of development. Everywhere there is a lack of explicit urban and housing policies. Low priority is given to the problems of shelter provision. In the absence of such policies, standards and criteria tend to be enforced in a vacuum since there is no overriding basis for validating their effectiveness as implements of desired national objectives.

The SCOPE project underlines certain aspects of shelter provision which need to be given high priority in the development of urban and housing policies, especially if the shelter needs of the total population are to be considered. The starting point for this consideration is the assertion that in the foreseeable future most of the shelter in developing countries will be self-built. This realization must direct attention to the formulation of policies which would assist rather than hinder the ability of the majority of the population to minister to their own needs directly. It should also underline the need to develop standards and criteria which are simple to implement and whose rationale and relevance are easily appreciated.

A second point of crucial importance is the consideration of shelter more as a process than an object. For the majority of the population in developing countries, shelter is an incremental product reflecting stages in the socio-economic mobility of its owner. This consideration immediately points out the conflict inherent in an existing situation where static standards are being applied to a dynamic process. It is often clear that when the masses of the people are engaged in providing their own shelter, the end position of their effort is not easily identified. The problem of how to develop a set of rolling standards which can reflect current capabilities confronts the scientific community with some challenging tasks in the shelter-environment field.

Given these two facts concerning the future prospects of shelter provision, a primary area of policy development for governments in developing countries is the provision for the masses of building plots for which the right of occupation is guaranteed. In many studies that have been conducted to date, it has been shown that the positive environmental effect of a sense of secured tenure has been considerable. The confidence deriving from the knowledge of undisturbable occupation has led many migrants in cities to devote tremendous resources to improving their shelter while striving to maintain an appreciably high quality of the environment.

One other important consideration that needs to be emphasized in policy concerns the relationship between available natural resources and current standards for shelter provision. Unless there are tremendous new mineral discoveries or a dramatic technological break-through, it can be stated unequivocally that it is impossible for developing countries to provide shelter for the masses of their population on the basis of existing standards. To attempt to do so would lead to a rate of depletion of natural resources that is hardly imaginable. If India, for instance, is to build all its shelter with cement, it is estimated that it will need more than current world production of this commodity. The economies of most developing countries are unlikely to be able to bear the level of expenditure that will be required for such a purpose.

Given this fact, a novel way of looking at the issue of standards is to redefine it within the framework of an equitable distribution of national resources among citizens. Such a reconsideration brings to the forefront the concept of maximum as opposed to minimum standards. This concept requires that a maximum limit be set to the amount of land and material that any individual can consume in the process of shelter provision while assuming that with a minimum of guidance the vast majority of the population can exercise good sense in the provision of shelter for themselves.

The concept of maximum standards may appear revolutionary until some of its rationale is appreciated. For instance, setting maximum standards to space or material use in the provision of shelter will ensure that more resources are available to the majority. It also raises the probability that many more of the masses can attain current so-called minimum standards in their shelter provision. Moreover, the implementation of maximum standards is sure to cut down on wasteful uses of resources while at the same time considerably improving the efficiency of human settlements.

Furthermore, the operation of a maximum standard may provide new and vast opportunities for the construction industries to build many more housing units rather than concentrating on producing expensive and relatively luxurious dwellings for the few. Such opportunities can, however, only be seized if the problems of appropriate technology and suitable material are first resolved.

e. Conclusion

The present SCOPE project on standards and criteria has underlined a significant fact about shelter provision in developing countries. This is the incompatibility of present policies or lack of policies with the maintenance of a desirable level of environmental quality. Current standards in many developing countries are foreign in origin, often lack a base in science, and continue to depend on technology and organization structure which make them unable to provide the shelter needs of the majority of the populace.

Yet, in terms of shelter needs, it is important to ensure considerable flexibility in the setting and enforcement of standards. Flexibility in this context should be interpreted as entailing much experimentation. Human settlement is the result of the culture and the resources of a country. As such, in order to be meaningful, standards and criteria must relate to current, or established modes of production. Flexibility therefore also involves providing broad guidelines whereby standards and criteria can be modified in the light of changing modes of production.

Very little is known about the considerations which should aid in developing such guidelines. There is almost no information as to what type of cities can be built by different economies using different technologies. Even less information is available on the bio-psychic limits of human endurance within the shell of a shelter. Any theoretical approach to human settlement must be policy-oriented if it is to catch the significance of the current crisis in the provision of shelter. All these and many more problems compete for the attention of the international scientific community in its consideration of the environmental aspects of human settlement.