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DECISION SUPPORT SYSTEMS FOR SUSTAINABLE DEVELOPMENT

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DECISION SUPPORT SYSTEMS

for

SUSTAINABLE DEVELOPMENT

DRAFT

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INTRODUCTION

As an era marked by the highest rates of change in recorded history, the present offers unique opportunities for developing the tools needed for creative management of the inevitable, inexorable transitions which are now taking place on almost every front: resources, technologies, institutions, and development approaches. Most societies have historically dealt with such transitions reactively and adventitiously, making piecemeal adjustments which allowed them to cope, at least temporarily, with the changing conditions they faced. As the findings of the World Commission on Environment and Development show, it is now becoming increasingly necessary for nations and institutions to restructure their affairs and to develop the means to shape the course of change itself so that it can be of benefit for all people, living and yet to be born.

The concept of "sustainable development" as the basic goal of society goes a long way towards reconciling the interests of the development community with those of the environmental movement. Its fundamental value as a basic paradigm for development planning is evident from the broad acceptance it has received at the hands both of development agencies and of conservationists; however, its usefulness as a decision making criterion is still limited by the inadequate understanding we have of its operational requirements.

With the growing reliance on decentralised systems of governance which is becoming possible by rapid advances in technology and becoming imperative because of the complexity and variety of society's needs and aspirations, it is necessary to identify the prerequisites for decision makers to "think globally and act locally". These certainly include clearly articulated and widely accepted societal objectives which are in consonance with the requirements of sustainable development, and the design of institutions, planning instruments and technologies needed to achieve such development.

Over the past two decades, the worldwide effort to incorporate environmental concerns into the development process has led to the evolution of a series of policy and planning concepts which successively improve the ability of society to manage its future. This effort has led from the early attempts to cure the ill-effects of poorly conceived development projects (e.g., through reactive pollution control measures), to the prevention of major environmental damage (through impact assessment), to the fostering of projects specifically aimed at improving environmental values (through administrative measures). If the development aspirations of all are to be met, practical means must now be found not only to minimise environmental damage, but to optimise the manner in which the resources of each state, larger regions and, ultimately, the planet can be used for the greatest possible overall benefit, a concept which has in recent years come to be known by such terms as "environmental management".

The development process is the cumulative result of a large number of decisions made by people at all levels of society, ranging from the individual citizen through the manager of a corporate enterprise to the head of a national government. If development is to be sustainable, these decisions must, in their sum, be based on information and criteria of choice which take full account of their impacts, good and bad, in the same and in other sectors, nearby and far away, now and in the future.

To achieve development that is sustainable, each society must improve the quality of daily choices, and in this way improve its ability to design and manage its future in the light of its own resources and aspirations. The ability for it to make the types of decisions needed will require substantially different paradigms, information, methods of analysis and institutions than have been considered adequate in the past. In particular, decision makers will increasingly find it necessary to address the root causes of mal-development rather than its symptoms, and to overcome the obstacles which presently stand in the way of decisions which promote sustainability.

Decisions are not taken in a vacuum, and cannot be divorced from the political, intellectual or ethical context of a society. The social and political structures set the boundaries and limits within which they must be made. The prevailing system of knowledge, and the perceptions this system engenders bound and define the issues, causes and effects which are taken into account in the making of decisions. The paradigms, hidden assumptions and value systems of the society deeply influence their outcomes.

The institutional infrastructure, including the legislative instruments, planning methods, enforcement mechanisms, monitoring and reporting procedures, also has a deep impact on how sustainable, and therefore "rational", is the design and implementation of the development process. Above all, it is political will and action that are needed to make a rational decision and implement it.

While the social and political structures on the one hand, and the knowledge and value systems on the other, form the societal basis of any decision, it is the support systems which contribute directly to the formulation of a decision - the definition of societal objectives, the information base, the methods of analysis and the institutional infrastructure - with which we shall concern ourselves here. Such Decision Support Systems cannot be substitutes for the deeper, structural changes needed in society to reorient development towards sustainability, but they are necessary and fundamental to the achievement of such development.

The cross-sectoral nature of the management issues which underlie the ability of society to choose paths of development that are sustainable forces us to bring together methodological instrument and conceptual tools from the natural and social sciences, technology, engineering, public administration and other disciplines. To achieve this synthesis, governments and international agencies now have to strengthen their capacity and the capacity of their constituencies - administrators, the scientific community and the public - to monitor, analyze, report on and respond to environmental issues.

Decision making on environmental and development issues requires information which is context-specific regarding both local resources and the needs of particular target groups. The new technologies of remote sensing, information processing and communication open a whole new array of possibilities for rapidly gaining both a large scale and a localized understanding of environment, resource management and related societal issues, and thus to facilitate improved development decisions.

The process of decision making cannot be considered in isolation from its consequences. For development to be sustainable, the decision maker must receive continual feedback from the associated processes of enforcement, monitoring and evaluation and adjust his future decisions accordingly. Furthermore, he must formulate his decisions in the light of operational realities, so that they have a reasonable chance of being implemented.

The purpose of this paper is to develop a conceptual framework at a sufficiently broad level of generality to be applicable to decision making processes in a wide variety of social, economic and political contexts, while being specific enough to offer methodological options on the basis of which concrete action can be taken.

It identifies concepts of design and decision making, based on certain general principles, which appear to have direct application across a great many of the transitions now faced by mankind, and at all levels of development decision making -- from the political leadership of a country to the individual citizen. Within the context of this broader view of the processes of design and decision making, environmental planning becomes one of a large number of design activities amenable to a common set of meta-tools and methods. The same meta-tools and methods broadly apply to the design of objects, products, settlements, spaces, industrial plants, social institutions, and a host of other human concerns, all of which are facets of socio-economic development. While the specific tools and substantive issues will, of course, vary from one sphere of human concern to another, the common principles underlying them are quite similar, if not invariant.

By broadening (and deepening) the concepts of design and decision making, and by incorporating into them criteria which satisfy both private and public objectives, decision makers at various levels or in different sectors can develop the means to work together for development which is sustainable.

Starting with the basic premise that good design is that which leads to sustainable development, it becomes apparent that such design must also, <u>necessarily</u>, contribute to a more just, equitable, economically viable and ecologically resilient development. The analysis further shows that to achieve such a goal, design and decision making must be

- adaptive, self-regulating and evolutionary, and should not close options valued or likely to be valued by society

- based on the convergence of individual and societal interests, and should in turn reinforce these

- in tune with the variety, scale and institutional environment of the problem

- able to synthesise opposing or dichotomous objectives into an integral whole

- collaborative and multidisciplinary to handle the complexity of the societal and technical issues involved

- participative, and should enable people to choose and progressively shape their future rather than have it imposed on them

THE DECISION MAKING PROCESS

Many decisions, whether they relate to acts of commission or of omission, are taken for reasons which appear to be quite valid in the light of the need to fulfil pre-defined societal objectives. Within their own domains of coverage, such decisions may well be justifiable in terms of those specific objectives, without reference to other objectives that society may also have. If, however, such decisions lead to undesirable impacts on environmental values or on the process of development, the cause lies either in a poorly formulated objective based on a misjudgement of the full intra-domain impacts which have not been fully anticipated, or in the extra-domain impacts where other sectoral objectives also important to society have not been adequately taken into account.

The experience with development, planned or otherwise, over the past several decades is replete with examples of undesirable impacts arising from both types of causes. Underlying the decisions which have led to conflicts between environment and development is generally an inadequate understanding on the part of the decision maker of the natural and social processes which provide the foundation for sustainable development.

The Traditional Approach to Decision Making

Over the last few decades, most societies have come to rely heavily on the concept of a project as the basis of development decision making. While the precise definition of a project may vary among different economic systems, and the information on which the appraisal of a project is based may come from different types of sources, many of the broad characteristics of this approach are common to development strategies all over the world.

The project is, in principle, amenable to specialised, highly developed management tools for its planning, implementation and evaluation. By definition, it must be well delimited in space, time and purpose, and have clearly defined direct inputs and outputs. The institutions and professions concerned with development in most societies have evolved the tools and mechanisms needed to manage projects successfully, at least within the limited terms of the objectives normally set for them.

The primary problem with the project concept arises from the necessarily atomistic and therefore restricted view which lies at the heart of any reductionist approach -- whether it is applied to knowledge (broken down by disciplines), to government (sectors), or to development (projects). In comparison with other possible approaches, the individual parts are simpler to understand and work with. This is, of course, the great attraction of the project approach. However, the interstitial gaps between these parts, and the synergistic effects among them, which play a necessary part in the behaviour of the whole, cannot be easily handled. Sometimes the influence of these factors, often ignored because of the limitations of this approach, can be large.

The second problem with projects lies in the limitations of the tools currently used for their management. From the viewpoint of sustainable development, and the wider societal objectives this viewpoint implies, these limitations can adversely affect the management of projects at all phases: appraisal and planning, implementation, evaluation and feedback.

Most methods for the appraisal of a project depend on the valuation of the benefits it will produce and the costs that will be incurred in implementing it. Benefit-Cost Analysis is a specific methodology for making these valuations and most project appraisal procedures in both the public and private sectors depend on one or another variant of it. This methodology uses a systematic approach to reducing the benefits and costs to monetary values using, where possible, the prevailing or expected actual prices for the factors, goods or services which the project will use or produce.

Those goods and service whose value is not adequately represented by market prices are assigned "shadow prices", on the basis of which a more realistic social/economic value can be attached to them. In this manner, the prices of such factors as labour, capital, foreign exchange can be adjusted to correct for various types of inadequacies and distortions in the market.

A second type of price adjustment important in benefit-cost analysis is the value of items over time. The future stream of benefits and costs for the project are calculated using discount rates chosen so as to taper off their values over time into the future in a manner that attempts to represent the degree of "time preference" of society for immediate benefits over deferred gratification.

In both types of calculations, assumptions must be made regarding the specific values assigned to these parameters by society: the shadow price of each item in the benefit-cost equation, and the discount rate for calculating the benefits and costs at a later time. Experience shows that the final calculation of the benefits and costs is often quite sensitive to the specific assumptions made, and that small changes in these can sometimes radically affect the decision to be made.

Benefit-cost analysis has been used widely for development-related decisions, particularly those involving large investments. It is easily understood, and over the years has evolved into a technique with some degree of sophistication. In practice, however, and particularly from the point of view of sustainable development, current benefit-cost methods have the following shortcomings:

* They tend to emphasise those (usually the direct) benefits and costs that can be quantified and monetized and to underestimate those which cannot

* They tend to ignore non-market transactions and phenomena such as human, cultural and environmental values

* They generally give inadequate attention to the values of the poor, partly because the voice of this section of society is less audible, but more importantly because of their inability to participate in the economic transactions which set the prices used in benefit-cost calculations

* They are rarely concerned with redistributive concerns, and generally take care more of who gets the (direct) benefits than of those who pay the (often indirect) costs

  - Over space: e.g., regional disparities
  - Over time: e.g., inter-generational transfers of costs
  - Over social groups: e.g., displacement of people

* They are not able, in their present form, to accommodate the problems of uncertainty and risk arising either from the stochastic nature of relevant processes, or from inadequate knowledge about them -- and in particular they tend to underevaluate low-probability, high impact events.

To summarise, existing practices suffer from the basic limitations of any appraisal at the project level in that they are generally introduced into the planning process:

- at too late a stage to allow genuine alternatives
- as "add-on" procedures to the existing ones
- to justify decisions already made for other reasons

These tools often serve, therefore, simply to fine-tune the design of a project rather than to help integrate into the planning process the more fundamental issues required for meeting broader social objectives.

A Model for Decision Making

In arriving at a decision, the decision maker needs to have some concept of what is the present state of the variables (issues) which are to be acted upon, the possible states to which they should be transformed, and the options available to achieve this transformation.

In a simplified but useful scheme this may be represented in symbolic terms as:

$$A \longrightarrow T \longrightarrow Z$$

where A is the present state
Z is the desired future, and
T is the set of transformation process options (policy interventions and decisions) available to the decision maker.

Needless to say, the realities of decision making are quite complex, and the present model must be understood within their context. Each of the above symbols, and the dynamic links which connect them can, in fact, represent such complexity.

First, the present state, A, comprises a host of variables A(i), many of which may be relevant to the decision at hand. Furthermore, each component A(i) is a dynamic variable, changing with time and circumstances.

Second, the desired future is also itself a set of variables Z(j), themselves evolving over time with changes in perception, aspiration and understanding of the resource base.

Third, the transformation process cannot be a single intervention, but rather a matrix of interventions T(i, j) which together define a reliable path from the A(i) to the Z(j).

Fourth, and perhaps most oortant, development-related decisions can rarely take ociety directly from its existing state to the final one, bu rather through a series of intermediate states, C, D ..... whose sequence may not be obvious, but must be under tood by the decision makers if they are at some point to achi e their goals.

Thus the limitations of th s model for decision making should be recognised. However, en in such a simplified form, this model of decision making helpful in identifying the information and methodolo cal needs of environmental decision-makers.

A Taxonomy of Decision Mal ng

In view of the shortcomin of the traditional project approach described above, and the r d now to evolve approaches which can 'anticipate and preve , institutional decisions on development options must l taken at an increasingly higher level of policy making. ultimate goal of sustainable development can only be a eved if the institutional structures of society are signed to permit decision makers to view their responsibiliti within the wider context of social development, i.e., to 'th globally and act locally'.

Figure 1 represents a simp fied but useful view of the hierarchy of decisions in society of organisation. It attempts to demonstrate h decisions which are embedded within a larger decision making text must be formulated in a manner that allows higher level siderations to be incorporated in them. At each stage, alte atives based on the fullest possible analysis of soci l goals and natural resources must be evaluated for their ec mic, social and environmental impacts.

SEQUENCE OF ENVIRONMENTAL
PLANNING

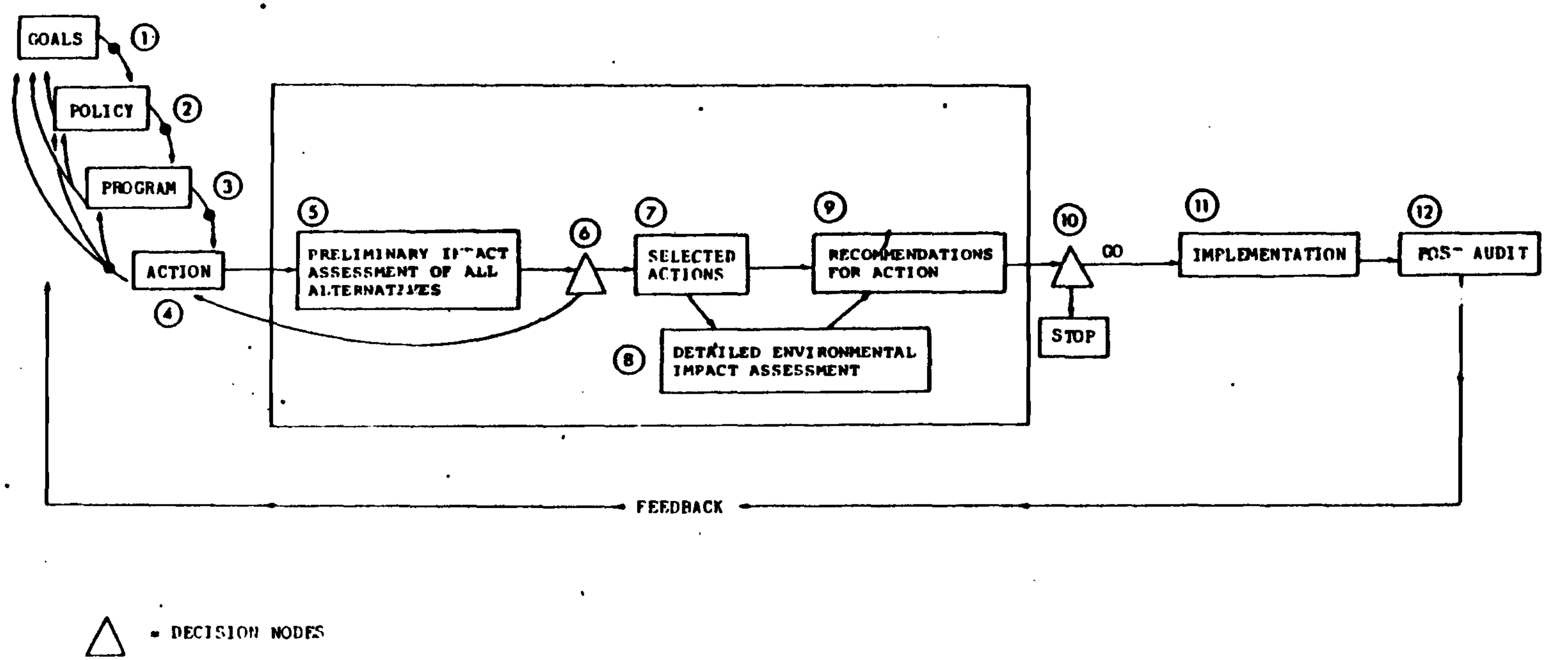


Fig.1. The Decision Making Process
(Ref: SCOPE 5 - "Environmental Impact Assessment")

The process of decision making at each level has to be designed so that the 'thoughts' formulated globally can become a set of coordinated 'actions' which can be implemented locally. For such a decision making scheme to work, the policy made at any specific level must be translated into concrete decisions (and finally action) at successively lower levels. In the opposite direction, the evaluative information from each level must be fed back to its immediately higher levels to permit mid-course correction in the tactics or the project under consideration, and reformulation of broader strategies for future decisions.

To make this more concrete, the environmental tragedy at Bhopal can be analysed in terms of such a decision making process, as shown in Figure 2. Whatever the immediate proximate causes, published analyses of which can already fill a small library, the primary lesson resulting from this event is the clear demonstration that a specific set of societal goals implies a given set of agricultural policies, which in turn necessarily entail the manufacture and use of certain highly toxic chemicals. It then becomes a matter of only time, place and chance before an 'environmental' tragedy strikes.

Under the best of circumstances, a decision support system designed to anticipate and prevent must therefore be structured in such a manner as to permit early introduction of environmental considerations into the policy making process, and very strong flows of information between the different levels of this process. It is only through a dynamic interaction between the makers of higher level policy and decisions and the lower level implementers and enforcers of these decisions that the needs of society and the resources of the environment can, in the longer term, continue to be matched.

DECISION PROCESS WHICH LED TO UNION CARBIDE ACCIDENT AT BHOPAL		ALTERNATIVES AT SAME LEVEL OF DECISION MAKI
SUPERGOAL	SUSTAINABLE DEVELOPMENT	
GOAL	FOOD SECURITY FOR ALL	
OBJECTIVE	INCREASED AGRICULTURAL PRODUCTIVITY	REDUCE POPULATION EXPAND CROP AREA IMPORT FOOD
POLICY	MORE PEST CONTROL	CROPPING PATTERNS GENETIC VARIETY
PROGRAMME	PRODUCTION OF CHEMICAL CHEMICAL PESTICIDES	BIOLOGICAL PEST CONTRO
SUB PROGRAMME	PRODUCTION OF CARBARYL	DIELDRIN, ENDRIN LOW TOXICITY PESTICIDE
(SUB PROGRAMME)	MIC-BASED TECHNOLOGY FOR CARBARYL	OTHER TECHNOLOGIES
PROJECT	PLANT AT BHOPAL	OTHER LOCATIONS
ACTION	DISASTER MITIGATION	ENVIRONMENTAL MANAGEME ACCIDENT PREVENTION DISASTER MANAGEMENT

Fig. 2

Real-life situations are often even more complicated. While it is always, in principle, desirable to formulate decisions in the light of societal goals and the resource context, the actual, objective realities include such factors as short political time horizons, bureaucratic delays, and a variety of frictional losses in the social and economic system. The context within which most development decisions are made is characterised therefore by rapid change, great uncertainty and many operational constraints. Unless decision making processes are evolved that take these factors fully into account, the decisions made will at best be academic and unimplementable, but more likely, counter-productive and wasteful.

Broadly, the planning methods now needed to achieve sustainable development must be able to identify, forecast and pre-emptively act upon an ever wider set of developmental interventions and impacts. The full information required for a rational decision is often not available. Within the time frames of an impending decision, the information at hand may be either too extensive to analyse meaningfully, or insufficient for the drawing of definitive conclusions. In these cases, the concept of "Adaptive Management" as a method to manage resources under conditions of poor information, rapid change or high uncertainty offers a powerful alternative to the decision making methods currently in use.

The adaptive management approach encourages the decision maker to take account of operational realities and to build the implications of these integrally into the assessment and design of the decision. It takes the process of decision making to include the design of appropriate enforcement and performance monitoring mechanisms, to ensure that the conditions of the decisions are implemented, that corrective action can be taken as needed, and that the lessons learnt can be fed back into higher levels of policy making.

The adaptive management approach relies on incremental decision making, and seeks to keep open as many important options as possible for future choice. It employs sophisticated modelling techniques to study the likely impact of alternative decisions, and to assess the sensitivity of the resulting environment to the assumptions made regarding those variables for which the information available is unreliable. Perhaps the most important aspect of adaptive management methods is the use of highly interactive techniques to encourage continuing, iterative exchanges of information among the decision makers, the technical experts and the concerned public.

THE DECISION MAKERS

To place the role of decision making in a more concrete context, the following examples attempt to show how decisions at various levels can impact development.

The choice by the individual citizen of a life-style has, in its accumulation on over large numbers, a profound impact on the use of resources, the creation of waste and the long-term quality of life in the immediate neighbourhood. The individual, as a professional, can have an even greater and more widespread impact through the decisions he makes at his work as a scientist, an engineer, a judge, a businessman, a policy-maker. The individual, as a voter or a member of a citizens' action group can further leverage his capacity to influence social action, both to the advantage or detriment of environmental values.

The manager of a corporation daily makes decisions which can have deep and widespread impact on resource management issues. Primary among these are the investment choices a corporation makes, the product-mix it chooses to offer, the manufacturing processes it uses and, not least, the pollution controls it employs. Corporate investment and operational decisions profoundly determine the quality of the working environment for its workers and the living environment of its neighbours and employees.

Decisions, usually taken by governments but also by others, on the deployment of services and utilities such as transportation, electricity, water and sanitation, directly affect a host of environmental variables, including the availability of clean water or energy, and more intangible though no less important amenities such as mobility, public health and recreation. Through their ability to facilitate or hinder other economic activities, decisions taken by those responsible for the design and management of infrastructural systems can cause considerable misallocation of resources and the creation of unnecessary pollution. On the other hand, through the application of modern efficiency techniques, such as operations research and network analysis they can greatly reduce unnecessary use of resources and generation of waste and pollution.

Each ministry of government daily makes decisions which have great impact on the way agriculture, industry, transportation and every other sector contributes to and deals with development issues. Experience shows that many such decisions do not adequately take account of the side-effects (particularly extra-domain) of these decisions. Other jurisdictional issues which can impact decision making at the national level include constitutional responsibilities between federal and state governments, the division of responsibilities between local governments in adjacent urban and rural areas, etc.

Taking a particular example from the agricultural sector, the decision to deploy a particular chemical pesticides rarely takes adequate account of the impact on other sectors (e.g.,. health), over time (e.g.,. genetic or teratogenic effects), across space (e.g.,. downstream populations), on species (e.g.,. migratory birds), on the rate which the target or other species acquire immunity, or in their re-distributive impacts (e.g.,. who gets the benefits and who pays the costs).

The value systems of society, which are often determined by social consensus rather than specific government decisions, are in themselves in the nature of a group decision. The formulation of such values, which evolve and change over time, rest in the longer term on similar supports to those needed for any other type of decision. The life-style and choice of development pattern at the level of a society can have a far greater impact on resource management practices than perhaps at any other level. Unfortunately, it is at this level that the decision supports, particularly the information base and the explicit goals, are at their weakest. It is this factor which more than any other underlines the need for a widespread public participation in setting goals and defining strategies to achieve them, and for education which emphasises the close inter-relationships between people, development and the environment.

Because of sovereignty issues, resource management decision across national boundaries are perhaps the most difficult to arrive at, let alone enforce. However, many of the emerging threats to the sustainability of development are precisely of this type. Major transfers of technology, financing and other agents of change are made through the agency of transnational enterprises, bilateral and multilateral aid agencies, and international trade. In terms of environmental and resource management concerns, these transfers can have significant impact on global and national development.

Such transfers are often the results of choices and decisions made by external actors whose interests do not necessarily coincide with those of national development within the host country. To this extent, the decisions at the national level on matters of considerable importance to sustainability issues can become constrained by factors which sometimes lie outside the control of the national decision maker. Many of the recent problems of the debt crisis are the result of factors of this type. The inadequacy of international decision-making machineries is compounded by weakness at the national level in terms of access to the information base, technical knowledge, analytical capabilities -- all of which can be improved by strengthened national institutions -- as well as in terms of political power and the ability to undertake negotiations from a position of equality.

THE DECISIONS

In addition to the importance of the process by which it is arrived at, and who makes it, the decision itself can have characteristics which are relevant to the question of sustainability. Decisions made to anticipate and prevent are inherently of a longer term nature and at a higher level of policy making than ones made to react and cure.

This requirement need not conflict with the desire of many societies to involve broad-based public participation in the making of decisions. The overall lifestyles chosen by the members of a society reflect their broad consensus on the desirable goals for development. It is through the mechanisms established for decision making, however, that these goals can be reflected in specific action.

Introduction of the environmental dimension into development planning has brought with it a whole new level of complexity into the very nature and composition of societal decisions. This complexity manifests itself in the far larger number of levels, sectors and disciplines that the decision must now cut across and embody.

As will be demonstrated below, if the decision is to address a problem successfully, it must have the "requisite variety" (i.e., mix of interventions) to meet the needs of the problem, and it must be formulated at the relevant scale.

Since the root causes of environmental problems often lie in decisions made at higher levels in the policy making process, or in other sectoral or geographic areas, any viable solution must incorporate the means to incorporate, counteract or in some way deal with these causes. Thus decisions aimed at achieving sustainable development require dimensions and coverage whose disciplinary, methodological, institutional or spatial range is often far greater than those experienced in traditional political systems. Table 1 outlines some of the characteristics of environmentally sound decisions.

Given the need for development, particularly in the less economically developed parts of the world, and the imperatives of sustainability, development decisions have also increasingly to incorporate a much greater variety of technical and resource considerations and are therefore generally far more conditional than was the case in the past. Even in the assessment of projects, it is rarely possible any longer to treat the decision to proceed as a direct yes/no choice, and even simple projects need increasingly to be constrained in matters of design, technology choice, resource utilization and waste disposal, and operating conditions.

TABLE 1

TYPES OF DECISIONS FOR ENVIRONMENTAL POLICY AND ACTION

APPROACH: CHARACTERISTIC	ENVIRONMENTAL ASSESSMENT	ENVIRONMENTAL MANAGEMENT
SCOPE OF CONCERN	ENVIRONMENT AS A SECTOR	ALL SECTORS
ROLE OF ENVIRONMENT	EXTERNAL	INTERNALISED
FOCUS ON	SYMPTOMS	CAUSES
EMPHASIS ON	ENVIRONMENTAL PROBLEMS	INSTITUTIONAL BASIS OF PROBLEMS
PROBLEM HANDLING	CONTROLS & REGULATIONS	CYBERNETIC & EVOLUTIONARY
SOLUTIONS	INTRA-SECTORAL	INTER-SECTORAL
EVALUATION	OCCASIONAL MONITORING	CONTINUAL FEEDBACK
CORRECTIVE MEASURES	ADD-ON & AD HOC	INTEGRAL & SYSTEMIC
BASIS FOR PLANNING	PROJECT	PROGRAMME/ POLICY
TIMING OF DECISION	TOO LATE	EARLY STAGE OF PLANNING
TYPES OF DECISION	YES/NO OR YET BUT	CHOICE AMONG ALTERNATIVES
NATURE OF INTERVENTION	DIRECT	INDIRECT
PHILOSOPHY	REACT & CURE	ANTICIPATE & PREVENT

At whatever level a decision is made, the act of making that decision generally excludes the possibility of alternatives which might have been considered by certain sections of those affected to be more appropriate responses to the development problem at hand. In this event, the requirements of sustainability make it especially necessary not only to enlist the cooperation of those who feel that their environmental interests have not been adequately served but also to incorporate to the extent possible measures to safeguard these interests.

For this reason, while it is only the political process which can legitimately make the tradeoffs and choices among alternatives, it is becoming more imperative than ever before that development decisions be based on objective information and widely agreed criteria of choice. The decision making approaches outlined below attempt to incorporate these considerations into their design.

DECISION SUPPORTS FOR SUSTAINABLE DEVELOPMENT

The imperatives of environmentally sound development greatly reinforce the need for society to devise the means to make development decisions at the micro-level, while taking full account of the macro-level implications. The possibility of maintaining a chosen course of development depends on how well-defined and clear is the agreement on common goals, and a high level of communication and feedback to permit the necessary course corrections.

An effective decision making system must be able to address the root causes of the problems in its sphere of concern. The fundamental impediments to achieving sustainable development lie partly in the limits of nature and imperatives of technology, and partly in the behaviour of social institutions and the structures of knowledge. Table 2 attempts to identify the primary roots of the environment and development problem.

In the light of these underlying threats to sustainability, and the simple decision making model described earlier, the decision support systems needed can broadly be classified into four categories:

- Societal goals
- Information
- Techniques and tools
- Institutional structures

Societal Goals

At the most fundamental level, the decision maker is influenced by the paradigms and values of his society. These are usually implicit in the assumptions he makes, and he is not always even aware of them or of their implications. Since they can sometimes run counter to the needs of sustainable development, they must, to the extent possible, be made explicit.

TABLE 2

ROOT CAUSES OF ENVIRONMENTAL PROBLEMS

LIMITS OF NATURE

IMPERATIVES OF TECHNOLOGY

CONSTRAINTS OF SOCIETY

- ENVIRONMENTAL ETHIC AND VALUE SYSTEMS
- DEFINITION OF SOCIETAL OBJECTIVES
- SOCIAL INERTIA
  - SHORT TIME HORIZONS
    - HIGH DISCOUNT RATES
- VESTED INTERESTS
- BEHAVIOUR
  - WORLD VIEWS AND LIFESTYLES
  - LEVEL OF MATERIALISM
  - PATTERNS OF RESOURCE USE
- LOW PRIORITY ON ENVIRONMENTAL VALUES
  - ALLOCATION OF FINANCIAL RESOURCES
  - ENFORCEMENT SYSTEMS
  - CHOICE AMONG ALTERNATIVES.

INSUFFICIENCY OF KNOWLEDGE

- NATURAL SYSTEMS
- TECHNOLOGICAL SYSTEMS
- SOCIAL SYSTEMS

- DISCIPLINARY BOUNDARIES
- LACK OF EXPERT MANPOWER

INADEQUACY OF CONCEPTS AND METHODS

- FIRST, SECOND AND HIGHER ORDER EFFECTS
- SYSTEMS MANAGEMENT

RIGIDITY OF INSTITUTIONS

- SOCIO-POLITICAL SYSTEMS
- ADMINISTRATIVE FRAMEWORK
  - TRANSPARENCY OF DECISION MAKING PROCESS
  - INEFFECTIVE INTERLINKAGES
    - SECTORS (MINISTRIES, INDUSTRIES, ETC.)
    - DIFFERENT LEVELS OF GOVERNMENT
    - SPECIAL INTEREST GROUPS
- PRODUCTION SYSTEMS
- MANAGEMENT SYSTEMS

The goals of society are set at various levels of generality. At the most general, they now have to include:

- "the quality of life must be raised, particularly for the poor"

- "development must be sustainable"

However, this does not provide an operational goal in the light of which action can be designed or taken. Nor does the only slightly more concrete and equally correct concept that a development decision should not foreclose the options of future generations.

To make the concepts of sustainable development operational, society at each level must first formulate well-defined goals and translate them into sectoral objectives. These must lead to guidelines and criteria for the design of programmes of action and finally to specific operational standards, rules and codes on the basis of which projects can be designed.

The global goal of sustainable development has to be converted into clearly and explicitly defined social and economic objectives against which the consequences of a decision can be measured and its implementation evaluated. At this more specific level, sectoral objectives can be set, such as:

- "to maintain genetic diversity"
- "to make possible adequate shelter for all"
- "to achieve food security for all"
- "to minimize industrial pollution"

These sectoral objectives must then be translated into quantifiable, time-bound targets at levels of detail corresponding to the requirements of planners and decision makers entrusted with the responsibility of implementing these objectives. It is at this level that the cross-sectoral implications become important, and the section below on institutional structures discusses the modalities by which these can be built into the decision making process.

At the working level, field personnel cannot always be expected to have the expertise to be able to calculate the precise operational parameters from first principles. Thus in a parallel exercise, the sectoral objectives must also be translated into standards, rules, by-laws, codes and other operational guides. Sustainability considerations introduce new factors into the setting of such operational guides, and they must now be based not on criteria which might historically once have had validity, but on a continuing evaluation of performance, safety, opportunity cost and replicability.

At each level of society, and at each step in this chain of increasingly concrete and operational criteria, it becomes important to ensure adequate consistency--first within the decision making hierarchy and second between it and the capabilities of natural and man-made systems on the one hand, and society on the other. Moreover, these objectives, criteria and goals must incorporate the constraints and opportunities offered by the resource base available, and the developmental needs and aspirations of a society. They will therefore have to bet set by each society in the light of both its own specific developmental context and such goals and objectives as can be agreed at the regional or global level.

The requirements of sustainable development place new demands on the process of goal setting. For the reasons elaborated above, this process must be able, much more directly than ever before, to incorporate inputs both from the technical experts and the public and to reconcile a far greater range of development concerns. The design and decision making approaches described later in this paper attempt to possible develop methods for this purpose.

Information

The second type of decision support needed is a base of reliable technical, resource and social information.

Throughout the world, there now exist extensive programmes of research and environmental monitoring which produce vast quantities of technical and resource data of potential value to the development planner. The social and political sciences have also progressed in recent years to a stage where the interest of the public and the constraints and possibilities offered by societal processes can be understood in some detail.

The emerging technologies for data processing and communication, based on rapid advances in micro-electronics and software design are beginning to open new possibilities for access and use of a far higher quality of information than possible ever before. Advances in the science of informatics and the creation of data banks in many fields now make it possible for the decision maker to access a wide range of information at varying levels of detail.

At the same time, there is a growing awareness of the function and importance of information in decision making. During the past decade, this awareness has been further intensified because of the accelerating rate at which the process of change is occurring, partly because of increasing human intervention, and partly because of the inability of natural systems to adapt to this change without losing their productivity. Many of the changes -- such as continuing desertification and deforestation -- imply loss of environmental values in an irreversible manner. Technical, resource and other information is now, more than ever before, essential to permit society to detect change, to evaluate its implications, and take remedial and where possible preventive action.

From the point of view of the decision maker, information must be timely, reliable, accessible and in a form and at a level of detail appropriate to his needs. To fulfil these requirements, the decision maker must not only be connected to the information resources available globally and nationally, he must also be in contact with a local body of expertise which can help him interpret and analyze the information in the light of local needs.

Because of the rapidly growing complexity which comes with issues of sustainability, an information need that is becoming pressing is that of the decision maker and the public for well-reasoned and unambiguous advice on technical issues from the scientific community. Emerging environmental issues are, by definition, characterised by inadequate data. The training and methods of science condition its practitioners generally to avoid drawing public conclusions from preliminary or uncertain data. On the other hand, those who have to decide in the face of difficult time and resource constraints need urgent, specific guidance on the basis of which they can formulate their decisions. This tension between the scientific community and the lay users of technical information may well itself be one of the important emerging issues of our time.

Science has a long history of disagreement, debate and disavowal of premature theories, and it is understandable that few scientists consider it a responsible act to give advice based on insufficient evidence, theoretical or empirical. Nevertheless, they are increasingly called upon to do so, and it is rapidly becoming necessary to develop the institutions and techniques to enable scientists to contribute positively to decision making without jeopardising the reputation of the scientific enterprise as a whole, or their individual or collective standing within it.

That the scientist has a responsibility to take a more active role in the decision making process must now go without question. Many of the issues of sustainability arise from the side effects of the extraordinary contributions which science itself has made to development, and it is only science that can address these issues satisfactorily. The environmental and phenomena and resource linkages which constrain further development can also only be dealt with by a deeper understanding of natural processes. As a well informed citizen, the scientist could play a special role in the development decision making process, to give early warning of emerging problems, to provide information and analytical tools, and in other ways to make a greater contribution as a strong influencer, if not maker, of policies.

In recognition of this special role, both policy makers and scientists have now to redefine their relationships with each other. It is for the scientific community to develop institutional mechanisms by which scientists can provide, either on their own initiative or on request, advice based on consensus and the best information available even in the absence of unanimity and certainty. At the international level moves in this direction were made when, in the early 1970's, ICSU set up SCOPE but, ironically, this is not the case at the national level, where scientists could make a far stronger contribution to decision making. To do so, the scientist will have to become much more responsive than before to the actual problems of society and the environment, and less afraid of doing cross-disciplinary work. In particular, the scientist will have to develop wholly new techniques to communicate, both with fellow scientists in other specialisations and with non-technical people.

The policy maker, on the other hand, is, or should be, a non-specialist, capable of sorting various scientific, economic and other inputs in a manner that is consistent with social values and goals. He will, therefore, have to establish the means by which outstanding scientists are encouraged to investigate phenomena of relevance to the problems of sustainable development, and to take an active part in the making of policy. The means to do this include not only the funding of research programmes, but also the building up of adequate research infrastructure, remuneration scales, and other incentives for scientists to take a more active part in the design of development strategies. The international and national implications of these changes in attitude are explored in the last part of this paper.

The public constitutes a vast reservoir of concern, knowledge and wisdom on matters relating to development. To ensure the fullest possible participation of people in the decision making process, deep changes are needed in most societies to permit them to have access to relevant information. Outdated concepts of intellectual property and "the public good" often stand in the way of a public which, if well-informed, could contribute greatly to the making of rational development decisions.

In recognition of the importance of information, international agencies and national governments have, from the early nineteen seventies, maintained programmes to make it more widely available. Because of the multi-disciplinary requirements of decision making aimed at sustainable development, it is now becoming essential that existing information systems be inter-connected in a manner which facilitates the delivery of the information needed in a form and format which can directly assist planners and decision makers in their work. In general terms, what is called for is an improvement of "top down" flows of information and analytical techniques from international bodies for the purpose of improving "bottom up" capabilities for national (and local) planning which encourages public participation. Universities, non-governmental and voluntary organisations and other research and action oriented agencies can play an important part in this type of effort. The services and technologies available to improve the access of decision makers to information are described in greater detail below.

Techniques and Tools

While the final decision on a development activity must be a "political" balancing of the needs and contributions of different constituencies, including inter-generational concerns (e.g..., through the use of discount rates), it invariably rests on a range of choices, from the purely technical to the broadly societal. In the assessment of a proposed industrial plant, for example, these choices would extend from the processes to be employed to the broad product-mix to be produced, and throughout this range there is usually considerably more freedom than has been traditionally assumed for the decision maker to select strategies which are environmentally sound.

While the imperatives of sustainable development demand a broader, more holistic view of societal processes, and require an anticipative, preventive approach to the design of development policies and programmes, the nature of decision making structures will continue for a long time to come base final decisions on specific projects. The composition and mix of these projects will, no doubt, be influenced by the general social, environmental and resource issues faced by society, but the specific actions to be taken will still have to be decided on the basis of an assessment of each project proposed in the light of these issues. Given the shortcomings listed above in the existing project appraisal procedures, these must now be revised to include the concerns of sustainability.

In order to arrive at a decision using the goals, objectives and criteria for sustainable development as determined by society, and the information available, the decision maker and his advisers need to use tools which present them with the various alternatives possible and their respective benefits, risks, and costs, both economically and environmentally.

To overcome some of these deficiencies several multipurpose appraisal methods have been developed which attempt to assess the ecological and social consequences of a project. These include techniques such as environmental Impact Assessment (EIA), Risk Assessment (RA) and Technology Assessment (TA). In many countries and international agencies, EIA is a mandatory requirement for various types of projects and there now exists a considerably body of experience with this techniques. Other kinds of assessment have been undertaken on a more restricted basis and have been more often the subjects of academic research than of decision making processes. A representative sample of the tools used to evaluate environmental impacts under different circumstances is listed in Table 3.

TABLE 2

TOOLS FOR ENVIRONMENTAL MANAGEMENT

METHOD		EXAMPLE
CHECKLISTS	SIMPLE	CANTER
	DESCRIPTIVE	US DEPT. OF TRANSPORT
	SCALING	RAMANATHAN
	WEIGHT-SCALING	BATTELLE COLUMBUS
MATRICES	DESCRIPTIVE	MANNING AND MONCRIEFF
	SYMBOLIZED	BOSTON TRANSPORT PLAN
	CHARACTERIZED	DELAWARE BASIN COMM.
	NUMERIC	LEOPOLD
	COMBINATIVE	FUGGLE
	MATHEMATICAL	PATERSON
	COMPONENT ANALYSIS	ENVIRONMENT CANADA CIM
	INPUT OUTPUT	LEONTIEFF
NETWORKS	DISPLAY	SORENSEN.
	SYSTEM DIAGRAM	ODUM
CARTOGRAPHIC	OVERLAY	McHARG
	PARAMETRIC	COOK
GEOGRAPHIC	REGIONAL PLANNING	ISARD
VISUAL GRAPHIC	SYSTEM LINKAGE	GUILLILAND AND RISSER
	CONCURRENCE GRAPH	COULLIARD
MODELLING	PREDICTIVE	GULDBERG
	DYNAMIC	REICHLE
	PROJECTIONS	MEADOWS
	SIMULATION	C.R.G.
	GLOBAL	FORRESTER
EVALUATION	SOCIAL COST-BENEFIT	HUFSCHMIDT
	RISK ANALYSIS	BURTON
	RISK/BENEFIT	KATES
ADAPTIVE	COMPATIBLE	C.E.Q, USA
	FLEXIBLE	CLARK
	STRUCTURED	HOLLING
DESIGN	SUSTAINABILITY	DEVELOPMENT ALTERNATIVES

Tools such as these have been extremely useful in extending the range of application of project appraisal methodology, though none of them has been able to offer the kind of comprehensive decision supports that would have permitted them to replace the earlier techniques. An additional limitation of these tools arises from their culture specific evaluation of environmental and social factors: they cannot be transferred from the developed country context in which they have evolved to a developing country decision environmental without considerable adaptation.

Institutional Structures

From the viewpoint of sustainable development, the institutional framework within which decisions are made can have significant impact on the quality of the decisions. The primary relevant characteristics of the institutional structure are the flows of information and administrative linkages - both hierarchically within a sector, and across sectors. The issues of information flows have already been dealt with above.

In terms of the decision making process described earlier in Figure 1, the societal goals, policies and programmes are generally made at a high political and administrative level. They generally involve macro-level considerations and deal with an aggregate view of the economy. Generally, they involve broad economy-wide, cross-sectoral concerns, generally developed through exchanges of views at the level of the Cabinet of Ministers, and Committees of heads of agencies.

Policy decision at this level usually affect a large number of people, and require a considerable amount of processing, and therefore time, to formulate and implement. At this level of decision making, adequate machineries generally exist in many countries today to ensure compatibility and consistency among decisions, although the specific inputs to inter-ministerial discussions from the sectors and agencies still sometimes tend to be based on too narrow a viewpoint of the sectoral interest.

To broaden this viewpoint, information feed-back is needed from the meso-level of programme decision making, usually at the middle to senior administrative level of government ministerial decision making. The decision makers at this meso-level serve as the mediators between the higher level policy makers in the ministry on the one hand the implementers of decision at the project and action level. Decision making at the meso-level has the responsibility of ensuring vertical compatibility that the intended results of the policies are achieved and to process feed-back information on successes and failures.

Perhaps an even more important function of the meso-level decision maker is to ensure compatibility among the policies and decisions of different sectoral agencies. It is therefore at this level that environmental considerations and inter-sectoral impacts can best the understood and dealt with.

Since the time of the Stockholm Conference, a number of national governments with ministries or administrative agencies bearing environmental responsibilities has grown from less than a dozen to more than 120. These new governmental machineries have assisted in creating broader awareness on environmental matters and in persuading other ministries to take environmental considerations into account in their respective sectoral responsibilities. Where they have been given adequate powers, they have been able to take a relatively strong role in the approval or otherwise of specific development projects. However, the experience of the past decade has shown that unless environmental concerns are closely internalised into the thinking of sectoral decision makers, and higher level policy planning, they continue to be "add on" activities which are usually introduced too late in the project appraisal process to make a consideration of major alternatives possible and therefore usually leads to unnecessarily adversarial positions.

To facilitate the incorporation of sustainability issues more effectively and at a much earlier stage of the decision making process, it is becoming evident that each sectoral ministry or agency must develop its own inhouse environmental capacity. Such an inhouse capacity is most needed at the meso, programme decision making level. This permits the upward and downward linkages within the ministry needed to ensure compatibility between policies and actions and also the most effective linkages within the ministry needed to ensure compatibility between policies and actions and also the most effective linkages across sectors to ensure a sufficiently high level of both technical and administrative responsibility and authority.

At the micro level, project and action decisions are usually made on the basis of specific standards, codes and guidelines set by the decision makers at the programme level and therefore environmental and cross-sectoral concerns are of lower importance. Nevertheless, if useful information on unintended side effects is to be passed up the decision making chain, even operatives at this level, need to have an increasing level of environmental awareness.

Table 4 sets forth some of the major institutional issues which Governments should consider if they wish to ensure the incorporation of sustainability issues into decision making. Table 5 lists some of the institutional means to overcome the obstacles to sustainable development which result from the root causes of environmental problems described in Table 2.

TABLE 1

MAJOR INSTITUTIONAL ISSUES

POLICY MAKING

- CONSTITUTIONAL IMPERATIVES
- NATIONAL POLICY AND LEGISLATION
- NATIONAL CONSERVATION STRATEGY
- ALLOCATION OF RESPONSIBILITIES
    - CENTRAL MINISTRIES
    - STATES
    - OTHER AUTHORITIES
- ENVIRONMENTAL MACHINERIES OF GOVERNMENT
    - SUPPORT PROCESSES
    - POLICY PAPERS
    - STRATEGIES FOR IMPLEMENTATION

PLANNING

- KNOWLEDGE OF STATE OF ENVIRONMENT
    - NATIONAL, REGIONAL AND STATE LEVEL
    - SECTORAL
    - BIOME
- INTER-REGIONAL AND INTER-SECTORAL CONSIDERATIONS
- PROJECT APPRAISAL METHODS
    - DESIGN AND APPROVAL
    - SAFEGUARD CONDITIONS AND VALIDATION PROCEDURES
    - INCORPORATION OF ENVIRONMENTAL VALUES

IMPLEMENTATION

- STANDARD SETTING
- MANPOWER DEVELOPMENT
- EXECUTION
- MONITORING
- ENFORCEMENT
    - LEGAL
    - PUBLIC OPINION
- SUPPORT SYSTEMS
    - INFORMATION
    - RESEARCH

FOLLOW-UP

- EVALUATION
- AUDIT
- FEEDBACK TO HIGHER POLICY LEVELS

[illegible]

MEANS TO OVERCOME THE OBSTACLES TO SUSTAINABLE DEVELOPMENT

ESTABLISH NATIONAL ENVIRONMENT POLICY

- NATIONAL POLICY STATEMENT
- NATIONAL AND STATE CONSERVATION STRATEGIES
- SECTORAL ENVIRONMENTAL PAPERS

DEVELOP PLANS FOR SUSTAINABLE DEVELOPMENT

- STATE OF ENVIRONMENT REPORTS
  - NATIONAL AND STATE LEVEL
  - SECTORAL
  - BIOMIC
  - INTER-REGIONAL AND INTER-SECTORAL PLANS
  - REGIONAL PLANS AND PROGRAMMES
  - SECTORAL PLANS AND PROGRAMMES

CREATE WIDESPREAD ENVIRONMENTAL PARTICIPATION

- EDUCATION AND TRAINING
- INFORMATION SYSTEMS
- PUBLIC INFORMATION

INTERNALISE THE ENVIRONMENTAL DIMENSION INTO SECTORAL ACTION

- STRENGTHEN ENVIRONMENTAL UNITS IN MINISTRIES, STATES
- MANDATE ENVIRONMENTAL UNITS IN LARGE INDUSTRIES
- REFORM PROJECT APPRAISAL PROCESS

ESTABLISH COMPREHENSIVE ENVIRONMENTAL MANAGEMENT SYSTEMS

- TEST AND EVALUATE THE EXISTING TOOLS
- DESIGN REQUISITE TOOLS AND TECHNIQUES
- BUILD INDIGENOUS CAPACITY

DEMONSTRATE THE ECONOMIC VALUE OF ENVIRONMENTAL ACTION

- BENEFITS AND COSTS
- IMMEDIACY

DECISION MAKING INFRASTRUCTURE

Indicators

It is evident, in terms of the model for decision making described earlier, that to gain an understanding of the initial state, accurate information is needed on the existing state of factors bearing critically on sustainable development. This is most easily gathered and specified in terms of carefully defined indicators which are variables chosen to represent the primary concerns of society. The identification of such indicators has only just begun, but there are a number of useful studies which already show their value in both understanding and communicating significant environmental issues.

Precisely the same indicators are needed to identify and select among the possible future state, Z.

Concrete examples of indicators which can assist the decision maker in selecting among alternative development options are given in Table 6.

While identification of the initial states A(i) is primarily a matter of having access to reliable and timely information, and setting of the desired states Z(j) is primarily a matter of defining social goals and objectives, the transformation function T mainly consists of the bag of tools, of the type listed in Table 2 above, which enable the decision making to select - and preferably design - the social, political economic and technological instruments by which the objectives of society are met.

TABLE [illegible]

EXAMPLES OF INDICATORS OF QUALITY OF LIFE AND SUSTAINABILITY USEFUL AT DIFFERENT LEVELS OF DECISION MAKING

Decision Maker	Typical Indicators of Q.O.L. and Sustainability
Individual	Likelihood of avoiding illness Range of choice of workplace Opportunities for intellectual growth Mobility Amenities for recreation *Productiveness*
Enterprise	Process choices available Access to skills Range of products in demand *Innovativeness*
Sectoral	Efficiency of creating sectoral outputs Accessibility to sectoral outputs *Number of formal links with other sectors* *Flexibility of sectoral boundaries*
National	Life expectancy Infant survival Physical quality of life Degree to which basic human needs met Renewable resource utilisation *Nonrenewable resource reserves* *Degree of self-reliance* *Ability to [illegible]*
Global	Health of the global commons *Species diversity* *Climate stability* *Degree of interdependence* *Institutions to achieve consensus*
Societal	*Cultural diversity* *Range of lifestyles* *Range of world views* *Community [illegible]* *[illegible]*

In designing the policies, programmes and projects which constitute the policy interventions T, it becomes necessary to formulate norms and standards which guide and permit evaluation of specific action on the ground. Such norms could be specified in regulatory terms when appropriate, but generally constitute the wide range of procedures and practices which are established for operational activities.

It is clear that each society must set, in the light of its own resources and needs, its norms and standards for social development. However, there is considerable scope for the international community to help develop the principles and the possible alternatives, on the basis of which a similar effort at the national or local level can be facilitated.

The present state of art in the development of indicators, norms and standards is still rudimentary and much work is needed at both international and national levels before they can contribute to more rational decision making. The greatest need at present is for the development of indicators and (even terminology) which adequately represents the specific concerns of the people at the periphery--among nations and, and even more particularly within them. Without these, both the identification of problems and their solutions are likely to be incomplete.

Information Systems

The value of relevant information has long been recognised in the industrialized countries. Many such systems have been established in every advanced economy to cater to the needs of government, industry, the media and the public.

Scientists and engineers also have access to a large number of specialised services which expeditiously deliver information of interest to them. However, most technical information systems are highly specialized and in themselves generally inadequate for the needs of development decision makers or their advisers.

Many countries today have national documentation centres, primarily for scientific literature, and statistical organizations which collect and publish data on demographic, economic and other social parameters. The technologically more advanced countries have learned the value of on-line information systems capable of quickly retrieving and delivering a variety of medical, engineering, economic and scientific information.

At the international level, the agencies of the United Nations have established a large number of information systems dealing with environmental management (INFOTERRA), toxic chemicals (IRPTC), agricultural sciences (AGRIS), nuclear sciences and engineering (INIS), sanitation and public health (POETRI), etc. Some of these are documentation based systems, and others work on the principle of referral. Only one or two of them provide on-line services world-wide.

It should be recognized, however, that apart from a few inter-disciplinary systems (INFOTERRA, DEVSIS and SPINES) most of the information available is restricted to specific disciplines or sectors and must be synthesized by the user with information from other sources. From the view of the development decisions on guesswork, hunch, or convenience rather than to wait for more reliable information which takes time, analysis and expense.

In addition to these systems, which are designed to store and retrieve existing information, the United Nations agencies also have programmes which generate and make available information of value to environmental decision makers. These include the programmes of the United Nations Environment Programme for monitoring and mapping (GEMS, GRID) the World Meteorological organization for climate and weather information (WWW), the Food and Agricultural Organization for fisheries information (ASFIS), and the Inter-Govermental Oceanographic Commission for Marine Sciences (IOC).

To make information systems capable of responding to the inter-sectoral needs of decision makers, new techniques for storage and retrieval of information are needed. These will require the building up of multi-sectoral thesauri, data-processing software and techniques of presentation geared to making the necessary inter-disciplinary linkages. Such tools are in their infancy, but if the demand from environmental decision-makers is felt by their designers, they can be easily developed.

A need that will become increasingly apparent with accelerating economic growth and environmental awareness is for the generation of timely signals and early warnings of potentially undesirable events. The remote-sensing and other new technologies are described below are increasingly able to monitor and spot both opportunities -- such as for agriculture -- as well as warn of manmade disasters. But even though remote sensing images may reveal information about, say, vegetation vitality which is useful for estimating food crop yields, the task of warning about impending famine conditions is far more complex and relies on many other sources of data. Far more difficult to anticipate are localized environmental accidents and methodologies need to be developed for assessing more accurately the risks of such accidents and the measures needed to prevent them.

In a higher scale of anticipation and prevention, the development decision maker must have access to information to a much wider set of alternatives and of their consequences than has been available to him in the past. This means that the information about each possible development project that might take place and the relevant environmental considerations are incorporated and evaluated before the implementation of the project reaches a point of no return.

In their present design, most information systems function passively. They generally provide no more than the data asked for, usually somewhat less. In improving the information available to the environmental decision maker, new types of systems have to be designed which not only facilitate access to information but provoke curiosity on the part of the user for information on new and more subtle relationships among environment and development variables, and even have the effect of forcing more relevant data out in the open.

Decision making aimed at sustainable development depends on the flow of information among the decision maker, the specialist and the public. The existing patterns of information flow among these groups are inadequate, and new methods of analysis, presentation and reporting are urgently needed. The specialist, particularly, will now be increasingly required to communicate more clearly and unambiguously with his administrative counterparts on the one hand, and with citizen groups on the other.

The New Technologies

Recent developments in electronics and space technology have opened up dramatic possibilities for handling the complex information now needed by decision makers. Remote sensing platforms in space, augmented by digital communications and advanced information analysis techniques are now capable of providing detailed and up-to-date knowledge on a wide variety of resource, demographic, climatic and other variables. High speed electronic data-communications technologies are now already in place which permit the sharing of technical information rapidly and accurately.

The availability of these new technologies makes possible a quantum leap in the ability of nations, both rich and poor, to have access to information which is necessary for planning sustainable development strategies. The time is rapidly approaching when the actual availability of relevant information need not be a primary bottleneck in the making of environmentally sound decisions.

One of the most valuable information packages resulting from these technologies is the geographic information system (GIS) which is based on a marriage of remote sensing from space and ground based mapping techniques. GIS packages make possible new insights about conditions on earth by merging data resulting from conventional land-based collection efforts, with that obtained from remote sensing platforms in space. With the use of powerful digital techniques capable of analysing and sythensizing these data in a highly communicable visual form, they can provide information of vital interest to both the scientific community and decision makers.

Planners and decision makers require access to widely distributed data bases so that remote sensing data and other, more conventional forms of data can be assembled for analysis. The usefulness of digitized data from outer space depends not so much on any single image, as on combinations of sets of data, put together from a variety of space sensors working at different spatial and temporal resolutions, sensing energy levels at different spectral frequencies. Once analyzed, these have to be compared and correlated with more conventional socio-economic data and statistics pertaining to specific geographical locations, topographic maps, census data, land-use maps, soil, vegetation, health, climate, and many other 'thematic' projections. Thanks to sophisticated hardware and software assemblies now becoming available which permit the alignment of various data sets against a common geographic reference, the spatial distribution and the changes overtime can be assessed and predicted with growing confidence. Thus we are now increasingly able to measure such variables as the 'health' of biomass and ecosystems, the productivity of agricultural lands, and even future crop yields.

The combination of data obtained by remote sensors and digital analytical capabilities in GIS enhances the value of each, and creates new information and knowledge which brings together scientific and technical workers in many disciplines and spread over many institutions in different parts of the world, in useful collaboration on major problems which cannot be solved, or even diagnosed, by any single discipline or institution acting alone.

Largely because of the planetary view from space, attention has tended to focus on global-scale processes and issues which must be better understood if the implications for future generations of actions taken today are to be grasped. The goal set by governments for the UN Environment Programme in 1972 was to preserve and enhance the quality of the environment for present and future generations, and global scale programmes, such as GEMS - the Global Environmental Monitoring System - were set up towards this end. Their immediate aim was to monitor - to measure and detect changes - such international problems as planetary deforestation, the loss of arable soil, of genetic diversity, changing levels of toxic compounds.

In 1985, UNEP established GRID, a computerised geographic information system based in Geneva and Nairobi which is shared with other UN System agencies and programmes. Its purpose is to collect, analyse and make available to Governments information on environmental resources and to demonstrate the value and effectiveness of the new technologies. Other UN programmes such as World Weather Watch (coordinated by WMO) and GEMS (coordinated by UNEP) involved virtually all agencies of the UN system as well as many other international and national organisations. Among them, they contribute to the acquisition of information and assessments ranging from rates of deforestation to levels of pesticides residuals in human milk. While their data analysis is generally on a global scale, they rely on work carried out in laboratories and research stations at the national level which are linked in sectoral networks coordinated and inter-calibration to ensure compatibility and quality of data.

GIS capabilities now available to the international community through GRID in Geneva will help national and local decision makers by improving the quality of the information base globally and regionally. The real need, however, is to improve each country's domestic capability to run its own GRID at a national scale. Many of the minicomputer systems increasingly in use in third world universities and other institutions would be sufficient for use at the national planning level. To build the skills required and purchase the software packages capable of doing this now cost no more than a few thousand dollars.

The active sharing of data in these programmes has repeatedly demonstrated the value to the global community as a whole and to each individual nation of the collective action and pooling of resources. National sensitivities about outsider access to national data are largely resolved by the fact that only coarse-scale data are useful and economical to deal with at the global level, and a country can control the scale of data it releases for international purposes. On the other hand, some data at the international level, such as meteorological, covering neighboring countries at appropriate scales, is routinely passed from the international level to the national level in a form which makes it useful for national planning and decision making. Above all experience with data sharing has demonstrated clearly the need to build the capacity in each country of collecting data, processing it using high speed computers and exchanging it to build and validate models for analysis and prediction.

As a means to exchange information, one of the most useful advances is that of computer networking through 'packet switching' techniques. This technology has brought the cost of transmitting large quantities of data down dramatically in comparison with traditional methods such as mail, telephone, telex, or telegraph. In North America and Europe, and increasingly elsewhere, large scale networks of telecommunication channels are now able to connect computers in different parts of the world at only nominal charges. With this network it is possible rapidly and reliably to exchange scientific information and raw data.

For these reasons, the years ahead will undoubtedly see the growth of international networks which can speed the flow of data and services now becoming available on the international scene. In many countries, however, this process may be limited by the tendency on the part of PTTs to resist change.

At the domestic level, the new technologies are already making it possible for national leaders to receive and analyse the views of large numbers of their citizens, permitting a level of public participation unimaginable only a few years earlier. Properly used, these technologies can contribute information to the decision maker which not only responds more closely to the needs and expectations of the people, but also incorporates their broad-based, collective knowledge of the resource-base factors essential to the planning of sustainable development.

Public Participation

The concern for environmental values and the need to satisfy a wide variety of constituencies with different interests provide perhaps for the first time a real, non-ideological imperative for a broad based participation in the development decision process. Whatever the political system and the cultural patterns, it is further becoming clear that participative planning for sustainable development can only be based on widespread knowledge of the major issues which underlie the achievement of such a development.

If rational decisions are to be made by the policy makers or to be contributed to meaningfully by the public, it is important that they all have access to reliable information concerning environmental and resource management issues. There is a growing belief in many parts of the world that public participation in development decision making is a necessary pre-condition for achieving sustainable development. While the technologies are increasingly becoming available to achieve a high level of communication between decision makers and the public, the legislative and institutional frameworks now need to be strengthened.

The redistributive impacts and sometimes extreme threats that environmental events can pose to an unsuspecting public are additional reasons for citizens to be made aware of the hazards, often beyond their personal control, to which they are subjected. Study of the issues relating to accessibility and the right to know are only in its infancy. Several countries have, however, recently enacted legislation which empowers members of the public to have much greater access to information than before, and the broad contours of a basic framework for keeping the public informed on environmental matters is beginning to emerge.

It is fortunate that just at the time that the need for wider availability of development related information is being perceive, the technologies and institutional instruments are also coming into being which can facilitate the ability of the public to obtain and digest such information. Examples of these technologies are discussed earlier in this paper.

It is also relevant that governments throughout the world, irrespective of their political views, are beginning to recognize the necessity for both decision makers and the public to be better informed about the issues on which they must decide. Access to information on environmental matters including particularly natural or man-made disasters is crucial for governments to be able to react expeditiously and effectively to events which threaten the well-being of their citizens. It is no less important for the citizens themselves to know when and how to respond.

The new technologies created by the micro-electronic revolution offer wholly new possibilities to respond much more extensively to the "right to know" and to extend it to all levels of society on a cost-effective basis. The great inadequacy which still exists in these technologies is not in the hardware but its ability to process the information fed into it in a manner which makes it accessible to all.

Inspite of the general consensus that greater and more widely distributed awareness is essential at all levels -- international, national, local, factory or in the field -- there nevertheless exist major barriers to the extension in practice of the concept of right to know. Governments and enterprises often feel that information relating to their projects will be used by the public against the implementation of these projects, at best to delay them and at worst to stop them. This is sometimes the case, but given the growing environmental awareness worldwide, it is going to become increasingly costly to operate projects which the public cannot live with once they are implemented.

Appropriate national legislation can be an important measure in generating and promoting public participation in development decision making. An increasing number of countries is now enacting laws which permit the citizen to take environmental offenders to court. Properly formulated to protect the legitimate interest of development, such laws can provide a solid basis for public participation by encouraging both Government and enterprises to bring concerned parties more closely into the appraisal process.

International agreements and conventions serve an extremely important role in encouraging Governments to establish national legislation aimed at improved environmental management, as demonstrated by the effective response of countries to the Stockholm Conference. The global nature of environmental concerns has led to building up of large networks of governmental and non-governmental groups concerned with environmental issues. Such international initiatives have, over the decade of the Seventies, clearly shown the value of international effort in raising national level public awareness.

Perhaps the most important factor contributing to this awareness is the interest shown by the media throughout the world in environmental subjects. While the immediate impact of wider media coverage of environmental issues may well be difficult for governments to handle, it is certainly in the interests of sustainable development for them to encourage responsible reporting on such issues.

DECISION MAKING AND DESIGN

While few would deny that development should be sustainable, the concept of sustainability itself is subject to many different interpretations. The variety of definitions possible is implicit in the number of different lifestyles and development paths that societies, consciously or otherwise, have chosen. Yet, despite a great apparent diversity among and within the nations of the world, the paths taken by most demonstrate at least one underlying commonality. In a nutshell, they tend to indicate considerable basic faith in the ability of the biosphere to recover from gross ecological insult, and in human ingenuity to find technological solutions to the unintended societal, economic and environmental problems which the so-called development strategies themselves may create.

These assumptions are no longer justified, and a framework is now needed within which the decision maker can identify, for each problem, clear objectives which are consonant with the requirements of sustainable development. To be useful the framework must, further, enable the decision maker to generate plausible alternatives for meeting these objectives, and to develop the tools for selecting the best possible option among these. In doing this, the decision maker takes on the role of a designer, for whom the act of making a selection is only the final act of a process which comprises a continuous series of creative adjustments and adaptations to match resources to needs.

The average designer will, of course, need tools which are much more specific than a generalised "conceptual framework", and these are, at the moment, rather rudimentary. This is perhaps the major reason for the little progress made in implementing conservation based design. At the same time, the nature of the design and decision making problem and its inherent complexity also requires methods which cannot be simply reduced to rules of thumb or formulae of convenience. The trade-offs implicit in most conservation issues are rarely simple, and the ability to design for sustainable development must be built on the solid foundation of a capacity to innovate.

Some of the existing methodologies are quite actionable, and give the designer useful operational guidance, particularly to meet the criteria of economic efficiency. They are, however, good primarily for solving the immediate problem given to a designer, generally by a client, or to a decision maker by the mandate of his office. They help him very little in designing to anticipate or pre-empt situations which are not predefined in the design brief or remit of office. They help him much less in designing a solution which satisfies the less tangible criteria of sustainability, such as rational management of resources, equity and self-reliance. Most of these methods are too literal and mechanistic to provide a theory of the underlying causal factors without which the design process can only address a narrowly-conceived, specific and usually superficial problem.

On the other hand, the environmental concerns which have become increasingly visible over the past decade have led to the evolution of paradigms which place more direct emphasis on global, societal and resource issues. Considerable effort has gone into the development of planning approaches capable of addressing environmental issues, but even so very few methods or tools are available which are practical and useful.

What are needed now are tools, and the meta-tools to shape them, which allow the designer and decision maker to identify and solve the specific problem posed to him, while at the same time satisfying the requirements of sustainable development.

Sustainable Development

Figure 3 presents a simple taxonomy of the factors which must underlie design for sustainable development. It attempts to connect (rather than logically deduce) such factors at successive levels of increasing operationality.

It is the patterns and rearrangements of the underlying structures and functions of a system which determine whether changes in it are likely to be sustainable, not the immediately observable phenomenal behaviour it exhibits on the surface. These structures and functions are represented by the state variables and flows within the system and the number of possible states, flows and connections among them represents the "variety" of the system.

The basis of sustainable development lies in change (for development), and resilience (for sustainability). The term "Modulation" is used to represent the concept of change through regulation, adaptation and moderation. "Resilience" is used with its ecological connotation of an ability to deal with perturbations without major structural change.

Modulation depends on the "Variety" of the system being designed and its environment, and to some extent on the method by which changes in this variety are selected. By contrast, resilience is achieved by the "Selection" process, within the general constraints set by the potential modulation of the system/environment complex.

Variety in turn consists of two component factors, "Diversity" and "Connectedness". In simple terms, diversity is the number of states, a term which describes the richness of the system in terms of the number of its major constituents -- for example,

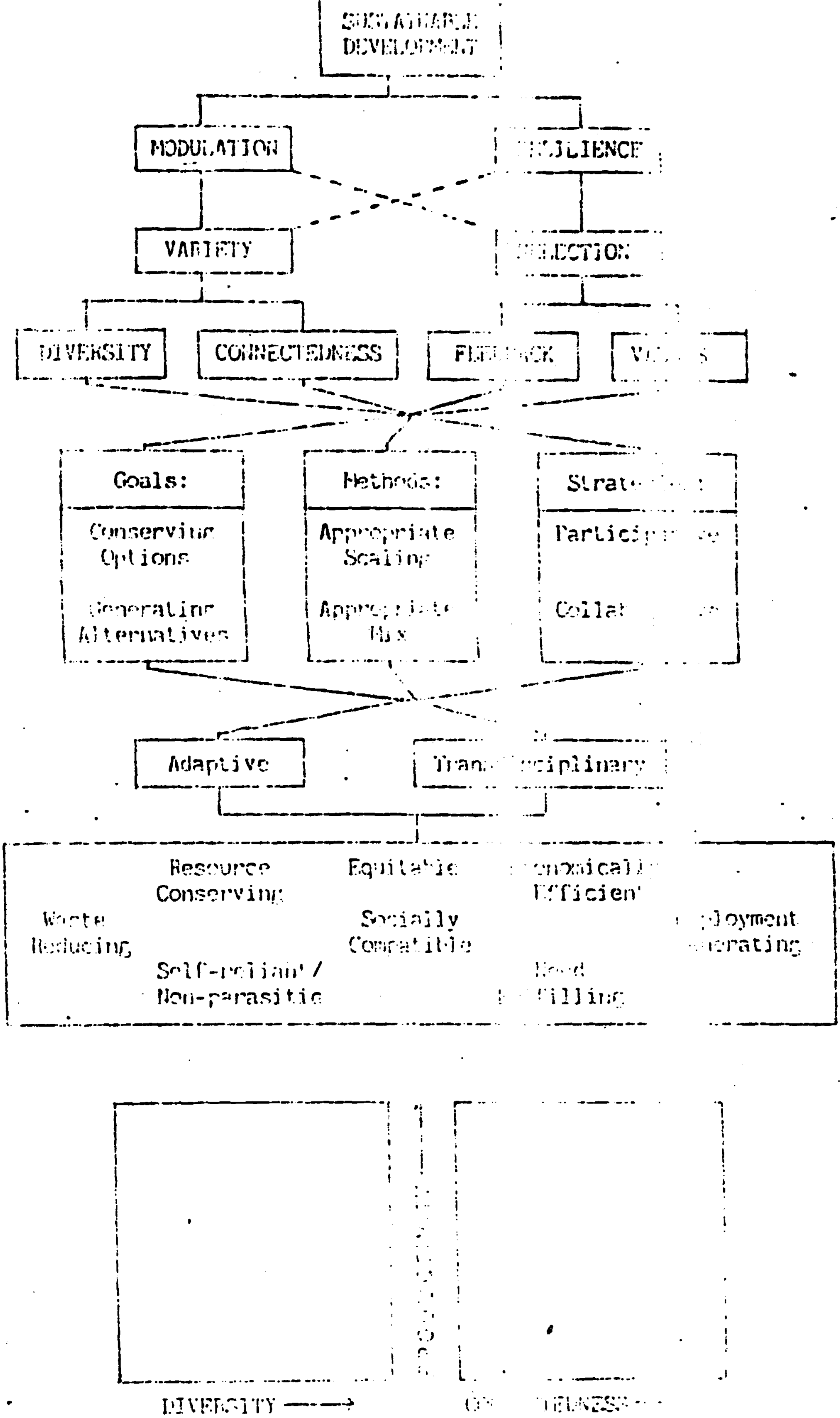


Fig 3. T... operationalis... component... Sustainable ...elopment.

species, food products, employment opportunities, or cultures. Connectedness is the number and strength of the flows or links between these constituents. In an economic system, the connectedness would be represented by the number and types of financial transactions.

Selections of desirable options are made on the basis of the information received through "Feedback" loops in the system, using "Values" (and criteria) chosen so as to increase the likelihood of sustainability. Feedback loops provide information on the performance of the system, often in response to external inputs. The values provide the basis for selection in terms of pre-defined objectives, aimed at achieving resilience and modulation.

There are, therefore, four fundamental variables which are necessary bases for good design:

- diversity
- connectedness
- feedback
- values

Design for Sustainable Development

From the point of view of decision making, the application of selection procedures (feedback and criteria) to the variety variables (diversity and connectedness) lead to three pairs of operating concepts for good Design: the first for its Goals, the second for its Methods, and the third for its Strategies.

In the short space available here it is not possible to demonstrate the full operationality of these concepts. However, while existing decision making systems have not often taken these factors into account, there is a growing body of evidence that they will have a growing importance to the development decision maker. The Sahelian drought, for instance, provides a host of examples underlining the need to implement sustainable development practices not only at the regional and national level, but also within the local community.

Design goals

The two fundamental goals of design for sustainability appear to be one, the generation of feasible and desirable Alternatives and two, the conservation of Options.

An alternative can be seen as one possible set of states which in itself constitutes an entire development path and contains a viable range of potential for change and flexibility within it. Each alternative contains within it a complete set of options which are feasible within the constraints of society and resources. The art of design lies in generating the maximum possible set of meaningful alternatives -- ones which are in broad consonance with the objectives of the problem solving process in hand, yet substantively different in their primary inputs. Existing design methodology has addressed this issue in some depth, although it has not yet been able to incorporate the broader societal issues adequately into the definition of the design objectives.

The conservation of options, in close analogy with the conservation of genetic resources, implies a process of keeping open any option which is currently, or might in future be, of value. In addition to the basic requirement of not closing important options, particularly those which may be irreversibly lost, conservation also implies making maximum use of the potential of the biosphere to satisfy human needs. This is the part of a designer's work which might be called the science of design.

Design methods

Two basic methods for effective design, often overlooked, are the application of appropriate Scale in matching tools to problems, and the conjunction of a viable Mix of final solutions. The concept of scale is relevant to the generation of feasible alternatives, and the term mix pertains to an appropriate combination of options. At the simplest level of spatial scale, the planning of land use employs tools extending from garden design to regional planning as appropriate at different scales of planning, from the micro level to the macro.

The concepts of scale and mix are even more general, and refer not only to spatial, temporal, quantitative and organisational variables, but also to levels of aggregation in information analysis and hierarchy in the decision making process. Many design problems are mishandled because the tools chosen are inappropriate at the actual scale and mix of the problem. Others can be made trivial or non-existent by viewing them from a vantage point of higher level policy.

The quest for appropriateness should not be seen as an exercise in finding a single "correct" scale, but as a resonant combination of different levels, all of which take part in providing a resilient, viable solution, not unlike Bohr's Complementarity Principle in Physics which sees the wave and particle as equally correct, coexisting facets of the same electron. For the designer, this concept offers important new insights and opportunities, and will be explored further in the discussion below on the proposed model for sustainable development.

Designers have all too often ignored the higher levels of design and decision making within which their own design activity is embedded and the levels below them which will be affected by the product of their work. Unless the flows of information up and down between the different levels are substantially improved, from the societal point of view, design can at best be sub-optimal. A transport systems designer who ignores the possibilities of reducing peak loads through interventions at the community level such as staggered working hours, and at the operating level such as improved motivation of line staff through appropriate incentive schemes, may well improve the routes and schedules but will still fall far short of the possible improvements in overall service.

Design strategies

The two work strategies which the designer today needs are Participative design and Collaborative design. The interplay of variety and selection make it increasingly necessary for the designer to work in a cooperative environment. The needs of the client and the complexities of satisfying large numbers of societal criteria, many possible conflicting, and the necessity of feedback in selection and operation, require the closest possible participation of those who will be affected by the outcome of the design effort.

The increasing variety of societal considerations and technical information which must be accessed now make it virtually impossible for the single designer to manage the data he requires and the criteria he has to use. Design must therefore necessarily involve an increasing amount of team work and collaboration. Collaborative teams also carry the responsibility of representing interests, usually of longer term values, not likely to be represented by participation alone.

A variable which designers most often ignore, yet perhaps the most important, is the institutional environment within which the design is to be created, implemented, maintained and evaluated. Unless carefully incorporated into the design or appropriately circumvented, external factors ranging from narrowly defined political objectives to operational realities such as frictional losses, time delays, and cost escalations, result in risks which can neutralise the benefits that the design was originally expected to produce. These risks can only be avoided if the complete man-machine-resource-nature-society nexus is taken at the basis of the solution to be designed.

The principles of design elucidated here have as much relevance to the design of institutions a they have for the design of landscapes, industrial products or agricultural projects. Within any activity, the design process incorporates a host of individual decisions, each contributing to a broadly conceived picture of the whole. Equally important, the concepts of scale and mix underlie the contention that the (quite valid) emphasis on the formulation of policies for sustainable development must now be made not only at the national level, but also increasingly supplemented by like-minded measures at other levels, and lead to internalising of these policies at all political levels:

- Regions
- Biomes
- Sheds
- Sectors
- Institutions

Correct scaling is essential to meaningful participation (and, of course, vice versa). For example, large centralised municipal corporations cannot expect participative feedback from citizens if they do not set up the intermediate levels which can connect them through proper information flows with the people. It is for the lack of these interfacing institutions, that municipalities so often end up making regulations at the micro-level, and then setting up wasteful and futile policing systems to enforce them.

The concept of adaptive management attempts to develop an operational methodology based on transdisciplinary, non-competitive and collaborative strategies for the generation of alternatives and the conservation of options. It offers excellent opportunities for developing solutions whose variety matches that of the problem, and to anticipate and design rather than to react.

Design criteria

In view of the foregoing argument for the integration of goals, methods and strategies, it appears to us that the concerns of the professional designer must be broadened and made more inclusive.

Experience in developing countries shows that to meet the goals, and develop these methods and strategies for design, decision makers need to generate and choose alternatives which fulfil the economic, social and environmental criteria listed in the final box of Figure 3.

The derivation of these criteria from the axiom of sustainability is not difficult. For instance, the threats to the rational management of the resource base come from both the consumerism of the affluent and the satisfaction of basic needs of the poor, demonstrating the importance of the equity criterion not simply on ethical or ideological grounds, but as a simple matter of planetary survival.

Any design that is likely to succeed in fulfilling both the expectations of the client and the requirement of sustainability must in some way optimise its contribution to these criteria. A fundamental requirement to achieve this is that the design and management process be adaptive and transdisciplinary.

Models

Study of the behaviour of a real world system (physical, social or any other) can be greatly aided by the use of models which describe its evolution in terms of the interaction of the variables and parameters which constitute those models. For a model to be useful, it must at the least be able to describe faithfully the system's known behaviour, and for values of he variables outside the ranges for which empirical data exist, it must be able accurately to predict its behaviour.

The great success of science comes from the ability it has developed to map the real world onto continually improving abstract images (models). The growing capacity of scientists and engineers to transform information from real world systems to ever more abstract spaces, and then to retransform them back into operational reality has made possible extraordinary contributions to human welfare.

The higher level models are not ends in themselves, but means to expanding the designer's horizons, to enable him better to cope with higher level effects, increasing complexity, proliferating variety and the broad sweep of time. Such models do not always depend on abstruse formal mathematical constructs, and they are often most useful simply for heuristic and communication purposes, to generate insights and to make interactive collaboration and participation possible. Self-regulating systems must have the ability to use feedback on error a an method to avoid failure. Indeed, since the test of a model can be based only on falsification, the designer must be able to handle error without ignoring it. This concept is fundamental for the design of adaptive techniques for designing and managing the development process.

The development model

Among the most useful models is one based on an analogy with the phase space approach which has been so successful in the physical sciences. It draws on recent theoretical advances on several fronts, and in a number of different disciplines, including particularly information theory, cybernetics, fuzzy sets, cluster analysis, non-equilibrum statistical mechanics and dissipative systems.

The model is still clearly far from complete. As yet, it might be more accurately described as an approach rather than a model. But even in its present, rather rudimentary state of development, the model clearly offers considerable potential for illuminating the process which affect sustainability in a great many types of systems.

In its simplest form (see Figure 4), the model describes an environmental system by four independent variables: variety along the X-axis), productivity (Y), wealth (Z) and time (t). The meaning of these variables are summarised in the figure, and in more detail in Table 7. This model provides a means for plotting variables of importance to the design objectives over time on a volume in X-Y-Z space, each point of which denotes a different situation with respect to wealth, productivity and diversity. While traditional economics has largely been concerned with productivity and wealth, it is the relationship between the resulting variables variety and productivity which primarily determine the sustainability of an action.

The interesting feature of this space is that the evolutionary path of a system over time can be plotted on it to yield valuable insights into its behaviour and potential. The space is characterised by gradients which represent various forces of nature and society, and these can be modified by policy interventions, institutional mechanisms and technological advances. A system acted upon by such a field would tend towards the state with the lowest potential.

The transforms (i.e., interventions) which act upon the system and attract it towards any one of the four corners are also named in the figure. These transforms, which are like the topography which can channel and direct the movement of the main course of a river, are simply the combined effects of different combinations of action and feedback. The Y-Z plane, viewed alone, represents the general perception of the feudal/industrial society and may be adequate when X (variety) is small and changing slowly. However, where X is large or changing rapidly, a view limited to the Y-Z plane cannot explain the stagnations or catastrophes which can easily be understood by looking at the X-Y plane. At a time of transition such as the present, the previously neglected view along the Z-axis at he X-Y plane becomes imperative, and the basis for any design for sustainable development.

To make the foregoing analysis more concrete, and demonstrate the application of this model, consider the possible proposals for the use and management of a tract in the hinterland of a large city. The solid curve in Figure 5 represents the natural development of a general terrestrial ecosystem. The hinterland under consideration will have to be characterised on the X-Y plane by an appropriate point (state), in this case say the point A. The options available can then be analysed in terms f the effect that their respective transforms have on this initial state.

For example, a decision to use the site for a landfill will be retrogressive, taking the system "Assessively" back to the more Static and therefore less valuable state D (see Figure 5). The decision to convert the land to a Eucalyptus plantation for fuelwood would Administer the system to the Growth (boom) State B. Preservation by fencing the site would allow the system to mature into stable Homoeostasis E. By a well-designed mix of aquaculture, cropping, landfill and protection, the area can be Conserved into a Developing system C, which is likely to be more sustainable than most other options.

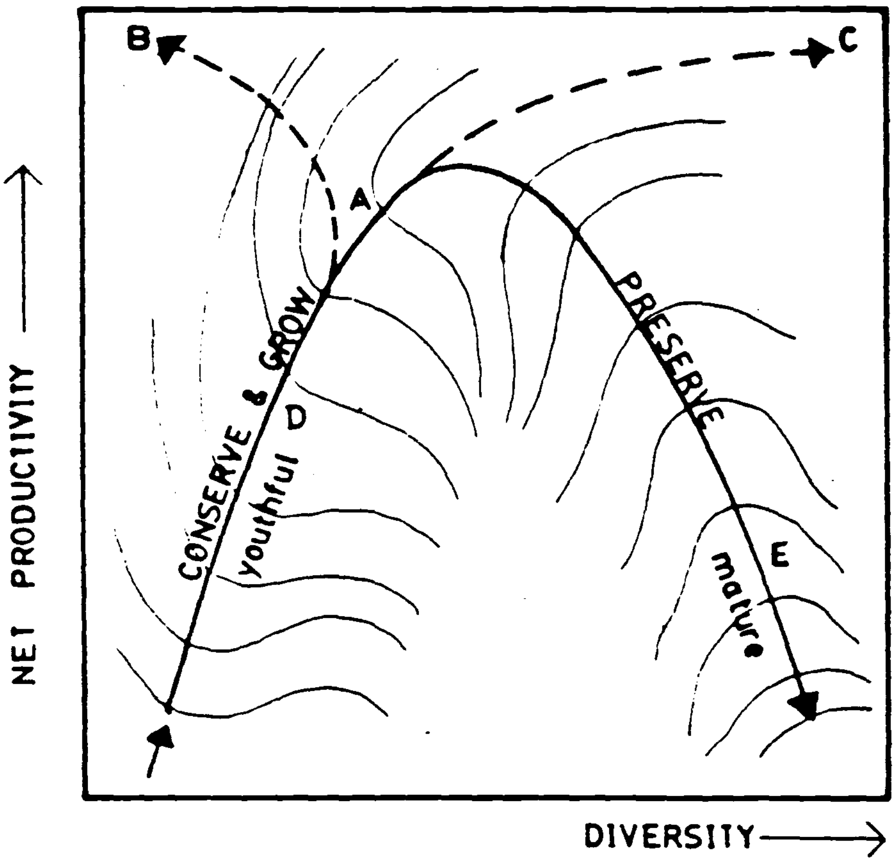

B
C
A
D
E
CONSERVE & GROW
youthful
PRESERVE
mature
NET PRODUCTIVITY
DIVERSITY

Figure 5

Incidentally, the generality of this method is demonstrable by a completely different example to which this same figure applies, where B represents the "Green Revolution" in the Punjab, C the "no till agriculture" of Wijewardene in Sri Lanka or the "One Straw Revolution" of Fukuoka in Japan and the E the slash and burn of PNG tribes.

ThE DESIGNER AS A PROFESSIONAL

Why should the designer as a decision maker subscribe to the values of sustainable development, for which the tools described above have been designed? Ultimately, the answer to this question lies in the values held by society, and in how well its educational and reward systems help the designer incorporate these values into his own.

Sustainable development on a global scale can only be achieved if each society chooses development options which respond to its aspirations and needs within the opportunities and constraints of its resources. Countries of the third world have now, therefore, to evolve their design priorities in the light of their own realities, instead of continuing to use borrowed ones either from other traditions whose context is entirely different, or from former colonial masters whose aim was to exploit resources, without regard to the future needs of local inhabitants. It is for this reason that self-reliance, the capacity to choose and design one's own future, becomes a necessary pre-condition for sustainable development.

For a society to design its development path, in other words, to formulate its own A, Z, and T, it must build new kinds of institutions which deal with administrative, scientific, and technical issues. Foremost among these is the need of all societies to establish responsive systems for education information exchange and research. In this effort, it is the more powerful agents of change, and particularly the design professions which must play a leadership role.

In both developed and developing countries, the existing professional systems tend to legitimise decision making practices which are:

- Sub-optimal: The decision maker operates with a narrow brief to satisfy the terms of his office, even if that means consciously or unconsciously sub-optimising the larger system which he works.

- Non-systemic: The decision maker is not expected to anticipate, adapt, or innovate for changed circumstances or threshold effects and he can blame these acceptably on "chance".

- Non-collaborative: The decision maker does not consult other specialists, nor offers his special knowledge to them, either because of the obligations of office or professional insecurity.

- Non-participatory: The decision maker, as a designer avoids participation of manufacturers, users, and operators of his products and society at large by claiming to know better, to save costs, or simply to avoid information overload. He also cuts off longer term feedback loops, since his mandate is generally narrow and of short term.

- Unsustainable: The decision maker does not work for a term longer than or a frame of reference larger than given by his immediate client. He need not take the burden of action on behalf of a future society for a sustainable future.

Some good design and decision making practices, on the other hand, discouraged by the existing punishment systems are:

- giving priority to societal and environmental values
- designing for variety
- designing through collaboration and participation

As shown by three centuries of western science, a reward system administered by the pressure of peers is perhaps the most effective way to ensure quality and integrity, without hurting creativity. But even the scientist has not been totally successful in internalising societal values into his enterprise. What both the scientific and design communities now have to develop are value systems, enforced if possibly by their own internal mechanisms, to ensure that their work does not undermine the objectives of the wider society within which they operate, but rather reinforces them.

What are the rewards (or punishments) which motivate the individual designer? In a developing country, they certainly include, in rough order of influence, job opportunities (or loss of them), loss of status, either in the bureaucracy within which he works, or more widely, publication in the scholarly press (or non-publication), development of personal and intellectual integrity (or its erosion). Probably at a lower level, but still important, are recognition by various constituencies ranging from governmental, actual or potential clients, peer groups and the public.

CAPACITY BUILDING

As the discussion in this paper attempts to demonstrate, if each society is to set its own objectives, to understand accurately its needs and resources, and further, to be in a position to develop the means by which it can achieve a self-defined and self-reliant development, it must have the political and technical capacity to identify and deal with its problems. In other words, it must be able to formulate clear concepts in its own terms regarding A, Z and T.

The more advanced economies have been relatively successful in understanding A, and in developing their responses T. The environmental problematique has now increasingly brought home to them the need to define more explicitly and carefully their future choices, Z.

In developing countries, particularly those with a national planning machinery, the situation is largely reversed. Many of them have been able to formulate a reasonable clear (though not necessary appropriate) idea of where they wish to go, but they have neither adequate access to information regarding the means to transform these to the desired state, T.

From the point of view of achieving sustainable development on a planetary scale, there is perhaps no requirement of grater urgency than the building up of the capacity of each nation to identify, within its own cultural and values system, the variables A, Z and T. This requires new paradigms for the building of institutions which deal with administrative, scientific and technical issues.

The interlinkages and complexities of environmental issues cannot be dealt with by contemporary knowledge systems, which are based on compartmentalised disciplines unable to deal with the totality of a natural or social system. While the need for multisectoral , transdisciplinary, cross-cutting approaches has been a commonplace statement for some decades, the exigencies of making decisions for environmentally sound development makes this, perhaps for the first time, a concrete imperative.

The educational institutions responsible for scientific and technical training are beginning to recognize and make provision for a broader education, but the process has a long way to go. No doubt it will be accelerated as the demand for broad spectrum but technically competent environmental managers grows.

Throughout the world, and more particularly in the developing countries, there is an urgent need to reorient the scientific enterprises so as to make it more responsive to the realities of each society and at the same time to make it more attractive for the best minds to make part in it.

A society can benefit from science (as knowledge or as the basis of technological change) only if it directly and actively participates in the global scientific discourse and is not simply a passive recipient of scientific information from elsewhere. It is of course not necessary to have a completely exhaustive subject coverage - but meaningful exchange requires participative collaboration between the giver and the receiver of scientific knowledge.

Building-up indigenous capacity in each country to enable it to participate meaningfully in the global scientific effort is also important for:

a. identification of problems for research

b. developmental of techniques to respond to societal problems

c. building a critical scientistific effort and a viable research environment

d. adapting scientific curricula to the context of local needs and resources

e. having available local scientific advice on issues of national concern

f. building absorptive capacity for imported technologies

g. assisting in the negotiation of technology transfer transactions.

To achieve this goal, science must become a meaningful, viable and respectable career option for young people. The fun, excitement and satisfaction of curiosity which doing science bring are motivating factors for achieving excellence and depth in research but are probably rarely the reasons why someone chooses science as a profession.

To promote the acceptability of a scientific career that is relevant and contributes to better planning and decision making especially at the local level, each society needs to:

- examine the professional reward system, with a view to its redesign

- develop the basic "infrastructure " of science including the information base, instrumentation and the wide variety of necessary intangibles such as

  critical mass of scientists to generate a chain reaction and provide an adequate group of peers

- improve scientific educational opportunities, preferably at the national level

- generate job opportunities for scientists.

Above all, it is only to be expected that society will value science as much as science provides to society what it wants. If science is to grow, it is not useful to maintain traditional shiboleths regarding the purity, of "basic science", or the isolation of science that these concepts promote.

The contribution science has made to and the support it has received from Western society results largely from its direct contact with realities of nature, society and the economy. Developing country science must now also learn that it is not enough to superficially imitative and reactive, taking its cue from the fashions and modalities set by the publications of others - which are mainly reflective of the current preoccupations of western science. While the driving force of western science may be a desire to investigate nature and society, the realities of Third World science today are of a second order, determined by the intellectual and practical interests of others. It is for this reason that scientists in developing countries are so little able to help their national decision-makers to address the pressing issues confronting them.

Third World science has also accepted some of the basic paradigms of its counterpart in advanced countries. These have little or no relevance to the realities of the societies to which they are transplanted. Especially counter-productive are the outdated dichotomies of:

- basic versus applied
- theoretical versus experimental
- modern science versus "ethno-science"

Among the motivating factors which produce excellence in science, one which is extremely powerful, though often underrated, is the reward system which has evolved within the scientific profession over the centuries. At a superficial level, such rewards relate to professional remuneration, possibilities for career development, prizes and awards, invitations to meetings and visiting professorships, publications in reputable journals and, broadly, peer recognition. At a more subtle level, and possibly more important in the Third World, are the intangible rewards of social status, advisory positions and public recognition.

One of the greatest barriers to the doing of good science is the lack of local research capacity and working environment. This includes, of course, what is known as "infrastructure" such as the buildings, instruments, libraries and other hardware which scientists need. Much more important, a nation´s capacity to do good science depends on public attitutdes, communications channels, a community of scientists to interact with and, above all, a widespread credibility of science as a profession, an understanding that science is an important component of development.

Throughout the world, and more particularly in the developing countries, there is an urgent need to reorient the design professions so as to make them more responsive to social reality, and more attractive to the most creative minds. When the professional institutions, such as the value and reward systems, succeed in reorienting the designer's basic approach towards issues of sustainability, the types of tools developed in this paper become useful., and even necessary. They might even be of some help in designing the institutions themselves.

DECISION SUPPORT SYSTEMS

EXECUTIVE SUMMARY

! In reconciling the short-term interests of socio-economic development with the longer term imperatives of the environment, the concept of sustainable development provides the powerful unifying theme needed to reorient development programmes in all parts of the world. To achieve the broad goal of sustainability, it is becoming clear from the work of the World Commission on Environment and Development that decisions at any level of society must now be made so as to lead not only to greater economic efficiency, but also to social equity and environmental stability.

! However, the usefulness of these concepts as decision-making criteria is still limited by the inadequate understanding we have of their more specific, operational requirements. These requirements will only be elucidated gradually with the accumulation of more experience in implementing alternative types of development programmes. At the same time, it is becoming apparent that a decision support system aimed at promoting sustainable development must have certain basic characteristics.

! Each society must now develop the means to design and manage its future in the light of its own resources and aspirations. To do so in a sustainable manner, it will generally need to introduce fundamental changes in many of its value systems, social organizations, and knowledge structures. More immediately, it must also evolve the support systems - goal setting mechanisms, information systems, methods of analysis, and institutions - and the capacity to make the types of decisions needed to deal with current, and often pressing, societal concerns.

! The traditional approach to development decision making has been based on the appraisal of projects, primarily using benefit - cost analysis. Over the years, this methodology has proved to be of considerable value, particularly in highlighting economic efficiency considerations; however, from the viewpoint of social equity and environmental factors, it has also shown considerable limitations.

! Decision making is a hierarchical process in which decisions at increasing levels of specificity are passed down by the political-administrative process, and information which is increasingly analysed and filtered is fed back up in the reverse direction. Existing decision-making structures tend to work within strict sectoral boundaries, and often suffer from inadequate feedback from operational experience to higher levels of policy making. The planning methods of the future must be able to identify, forecast and pre-emptively act upon an ever wider set of developmental variables and will have to rest on dynamic, multi-level decision-making structures capable of formulating the mix of interventions needed.

! Decision supports fall into four major categories: societal goal setting, information systems, techniques and tools, and institutional structures. To achieve development that is sustainable, significant changes have to be introduced into each of these categories.

! Societal goals have tended to be implicit, ill-defined and often divergent. New methods for identifying and establishing a consensus on such goals is now becoming essential and will require far more effective methods of communication between the decision maker, the technical expert and the citizen.

! Technical, resource and social information is now, more than ever before, essential to permit society to detect change, evaluate its implications, and take remedial and where possible preventive action. New software and hardware technologies are therefore needed to provide decision makers with timely, reliable and accessible information in a form and at a scale appropriate to his needs.

! Starting with the environmental impact assessment techniques of the early 1970's, many new instruments have been developed to assist decision makers in arriving at environmentally sound decisions. These include such methods as risk analysis, technology assessment, adaptive management, and a variety of more detailed tools which have been extremely useful in extending the range and application of project appraisal methodology. However, much work still remains to be done to make these decision-making tools truly universally and unambiguously useful.

! The making and implementation of decisions, whether governmental, corporate or other, requires an institutional framework. This framework must be designed, first, to internalize the environmental dimension into the decision-making process, and second, to establish the vertical and horizontal linkages which are needed within and among sectors. While a specific body to deal with environment (e.g. the Environmental Ministry in Government or the Environmental Unit in the Headquarters of an Enterprise) has great value in raising consciousness of the issues, full incorporation of environment into decision making can only occur when it becomes a central objective and operational responsibility of the respective organization. This can be achieved by establishing explicit societal and environmental goals at a high policy level, environmental expertise at middle levels of management and specific operational rules based on these at the project and action level.

! These decision supports in turn rest on an institutional and technical foundation which might be termed the infrastructure of decision making. This infrastructure can be quite complex, but from the viewpoint of sustainable development, the components of greatest interest are: development indicators; information systems; technologies for gathering, analysing and communicating data; and institutions to ensure public participation.

! All stages of decision making, from the setting of goals to the monitoring, evaluating and reporting of development projects, rely on the use of indicators. In the past, such indicators have usually been implicit, and despite some two decades of work in this area, the science of development indicators is still in its infancy. A far more systematic approach to the use of such indicators is needed, both to facilitate a proper flow of information to the decision maker, and to establish the basis for evaluation.

! Recent breakthroughs in space technology, electronics and data analysis techniques have brought forth dramatic possibilities for handling the wide range of information needed by today's decision makers. These hardware and software technologies open up wholly new opportunities for carrying out complex studies for environmental management. They also offer new ways of communicating between the decision maker, the technical expert and the public.

! Because of the complexity of the issues involved, it is unlikely that sustainable development can be achieved without adequate public participation in the decision-making process. Partly in recognition of this, new legislation on "the right to know" and other measures to inform and involve the public are being introduced in many countries. Increasingly, governments will also have to evolve institutional frameworks for bringing about broad-based public consensus on environment and development concerns, and many of these will undoubtedly have to be based on innovative, non-adversarial methods of negotiation among the groups affected.

! Sustainability considerations can have quite specific impact on the design approach to be used, particularly in the matter of setting the goals, establishing the strategies and selecting the methods of the design effort itself. The purpose of design has to be to generate alternatives and to conserve options. In choosing among design methods, the two primary considerations become the application of the right scale in matching tools to problems, and the achievement of a viable mix of final solutions. The strategies which the designer needs most in the context of sustainability are participation of the public, and collaboration with experts from different disciplines.

! To make these concepts more operational, specific criteria are needed by which the designer can select desirable options. In a nutshell, sustainable development requires options that are: resource conserving, equitable, economically efficient, waste reducing, socially compatible, self-reliant and non-parasitic. In developing countries, need fulfilment and employment generation are also of fundamental importance. Many of these criteria have been on the ideological platforms of political parties and the planning agendas of governments for decades. However, it is only recently, that their resource basis and their importance to national development and, indeed, to planetary survival is becoming evident.

! New models of development are now needed which give emphasis not only to productivity and the creation of economic wealth, but are equally able to strengthen the resilience of social and environmental systems through the conscious making of decisions which increase the "variety" of these systems. The acceptability of these models will rest on substantial changes in the relative priority societies place on maintaining existing patterns of development and lifestyles.

! If each society is to set its own objectives, understand accurately its needs and resources, and be in a position to develop the means by which it can achieve a self-defined and self-reliant development, it must have the political and technical capacity to identify and deal with its problems. Building this capacity, is the highest responsibility governments have, and its absence is the primary threat to sustainable development.

! To summarize, design and decision making for sustainable development must be:

- adaptive, self-regulating and evolutionary, and should not close options valued or likely to be valued by society;

- based on the convergence of individual and societal interests; and should in turn reinforce these;

- in tune with the variety, scale and institutional environment of the problem;

- able to synthesize opposing or dichotomous objectives into an integral whole;

- collaborative and multidisciplinary to handle the complexity of societal and technical issues involved;

- participative, and should enable people to choose and guide their future rather than have it imposed on them.

DRAFT
RECOMMENDATIONS

To Governments:

1. Internalize environmental expertise in each economic ministry, generally at the middle administrative level and establish strong statutorily defined links among sectoral agencies;

2. Encourage professional design and scientific associations to develop strong indigenous bases for work of excellence and relevance;

3. Facilitate, enable and encourage public participation in development decision making;

4. Establish innovative project appraisal methods which transcend the limitations of the existing ones, and a well articulated decision-making process which permits continual policy level adjustments in the light of past performance.

To the Design Professions:

1. Develop codes of conduct, norms of practice, and standards of excellence which fully include the responsibilities of a practitioner to ensure that his design does not undermine the sustainability of development.

2. Develop and promote innovative methods of participative and collaborative working and encourage these by appropriately modifying the existing professional reward systems;

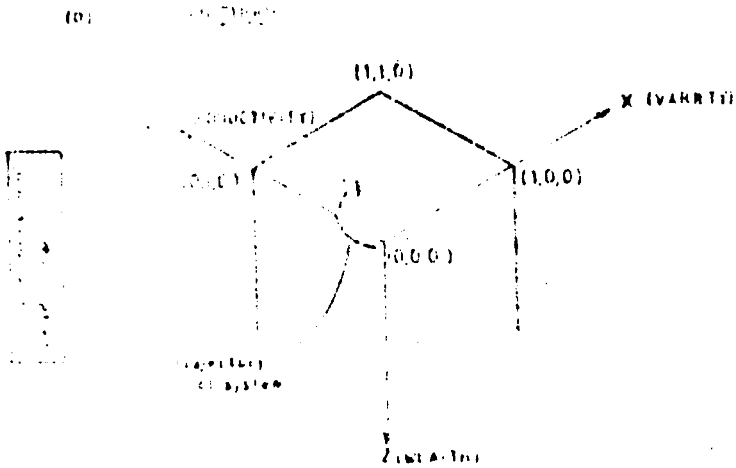
3. Develop specific tools and methodologies, and the indicators, information bases and design criteria needed to ensure the relevance of the design activity.

<u>To the Scientific Community</u>

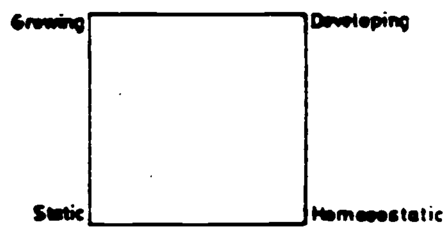
1. Establish reliable and credible early warning systems and channels for communicating the findings of these to decision makers promptly and reliably;

2. Establish mechanisms to provide actionable and reliable guidance to decision makers on emerging issues for which they seek technical advice.

3. Establish reward systems which encourage high quality inter-disciplinary work in areas of relevance to national development.



(a) STATE OF SYSTEM AT THE CORNERS OF X-Y PLANE



(b) TYPE OF METHOD (TRANSFORMS AND FEEDBACK) REQUIRED TO REACH CORNERS OF X-Y PLANE

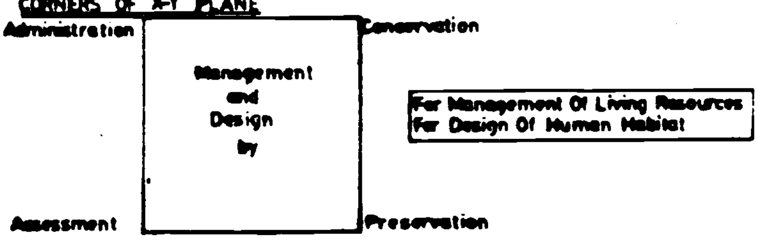


Figure 4

Table 7

AXIS	X	Y	Z
GENERAL	VARIETY	PRODUCTIVITY	WEALTH
ANALOGY	"Quality"	"Rate"	"Quantity"
MEANING FOR DESIGN	Options	Connectedness	Resilience
ECOSYSTEM (States)	Number of Species	Net Production	Standing Biomass
ECOSYSTEM (Processes)	Number of Links in Trophic Chains	Change in Quantity of Flows	Quantity of Flows
SOCIAL SYSTEM	Number of Informal Structures	Degree of Dynamic Change	Social Capital or Heritage
ECONOMICS	Mix of Technologies Creating GNP	Addition to GNP	Total Wealth, Assets, or Resources

A. Important Socio-Economic Variables

X,Y:	1 , 0	0 , 0	0 , 1	1 ,
VARIETY (X)	High	Low	Low	High
CHANGE (Y)	Low	Low	High	High
TYPE	Stable	Stable	Dynamic	Dynam
SYSTEMIC LEVEL	Structural	Operational	Operational	Struc
TYPE OF TRANSFORM	PRESERVE	ASSESS	ADMINISTER	CONS
STATE OF SYSTEM	HOMOEOSTATIC	STATIC	GROWING	DEVEL

B. The Four Corners: the possible extreme states of a society