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**PROCEEDINGS**

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# Concepts for a New Generation of Global Modelling Tools:
## Expanding our Capacity for Perception

prepared by the CACOR Global Modelling Project Team
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*It is now twenty years since the issues associated with the global 'problematique' were widely publicized by The Club of Rome. In the meantime much has been written, but real action that might lead to a more harmonious and sustainable future has not been forthcoming. Indeed there is evidence that these issues are becoming even more threatening to humankind. There is an apparent inability of human societies to address the global problems of sustainability identified by the Club of Rome twenty years ago.*

*This paper advocates the use of global modelling tools as a means of expanding our collective capacity for perception. What is proposed is not the development of another model but the establishment of a process consisting of the design and use of modelling tools to further the explication and communication of understanding, and thereby facilitating both individual and societal action. The proposed approach builds upon previous experience using modelling as a means of communications and seeks to take advantage of scientific and technological advances of the past decades.*

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***Editor's Note: This version has been slightly abridged to fit the available space. A complete version is available.***

## The Problem

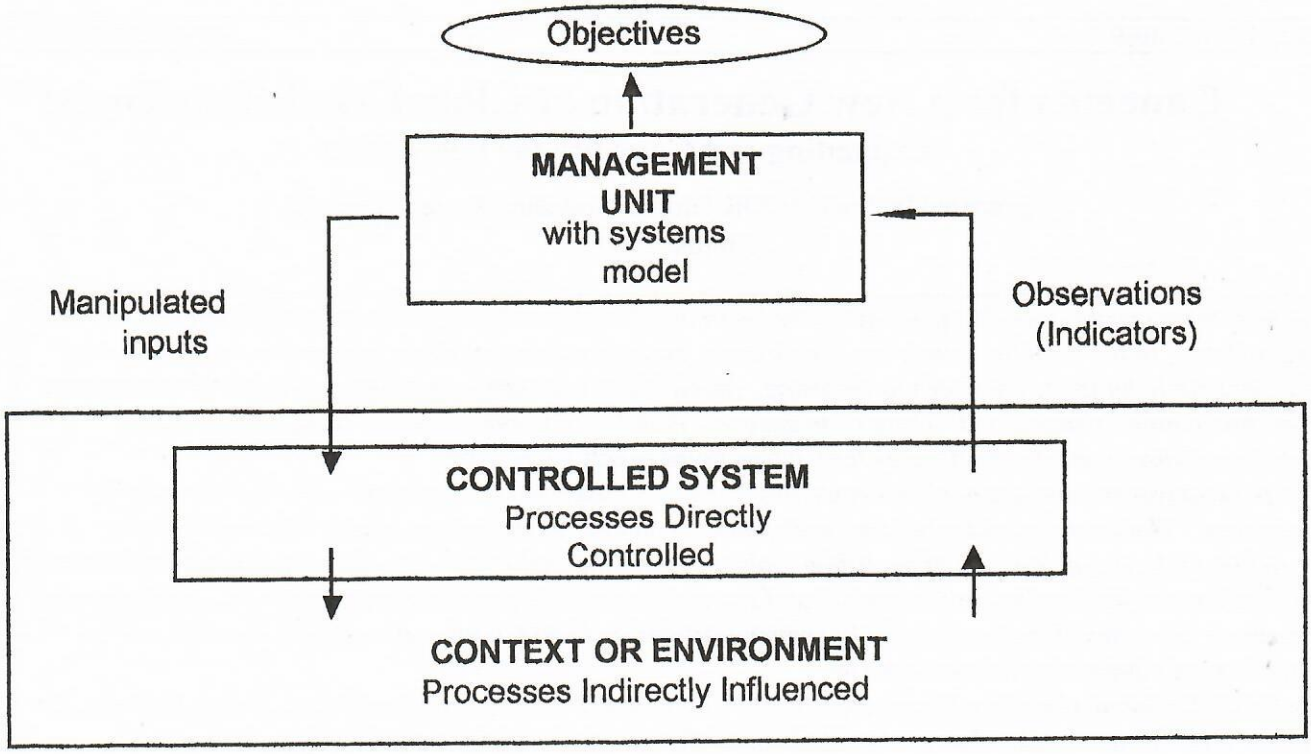
It is now twenty years since the issues associated with the global 'problematique' were widely publicized by the Club of Rome. Since *The Limits to Growth*, (Meadows 1972), the pioneering study which was based upon the original Word Dynamics Model (Forrester 1971), there have been several other global modelling projects in different countries including the work of Mesarovic and Pestel (1974) which was reported to the Club of Rome in *Mankind at the Turning Point*. Furthermore, much has been written on the global 'problematique' including the United Nations report of the World Commission on Environment and Development: *Our Common Future*, [WCED, 1987], the publications of the World Watch Institute, and more recently a Report by the Council of the Club of Rome, *The First Global Revolution*. [King, 1992]. Innumerable conferences on 'sustainable development' have been held, most recently culminating in UNCED in Rio de Janiero.

*The Global Modelling Project described in this paper is an important element in the program of the Canadian Association for the Club of Rome. The project is in its initial stages and by its very nature - exploration of Global problems - it will require wide collaboration both within Canada and abroad. This paper deals with the conceptual aspects and is presented to elicit comment from the Club of Rome membership and as a step in identifying potential collaborators*

But real action that might lead to a more harmonious and sustainable future has not been forthcoming. Indeed there is evidence that these issues are becoming even more difficult to deal with and more threatening to humankind. There is an apparent inability of human societies to address the global problems of sustainability identified by the Club of Rome twenty years ago.

## Why is this the case?

In the answer to this question lies the key to the current impasse. We approach this question from the perspective of control theory: Effective action arises from a decision process that has three necessary ingredients: a well-defined objective, an understanding of how the system in question upon works, including, most importantly, how it interacts with its environment, and continuing observations of the state of the system that provide feedback to the system manager.




The understanding, whether it is a mental image or an explicit model of the system - a systems model - plays a pivotal role in the decision process. It serves to identify the set of state variables or indicators and the values of the connectors to be observed or monitored and relates the observed state variables to the objective, in this way providing feedback to the decision making process as to altering the system so as to achieve a desired performance.. The systems model also supports the choice of objectives by facilitating the definition and exploration of alternatives.

In this context, it is worth recalling the cybernetic theorem, the Law of Requisite Variety, which states that the regulation that the regulator can achieve is only as good as the model of the reality that it contains. [Ashby, 1956]

> *It comes down to this: we cannot regulate our interaction with any aspect of reality that our model of reality does not include - whether as to its theoretical range or as to its observational facilities and resolution - because we cannot by definition be conscious of it.* Beer [1980].

The systems models associated with the decision processes which give rise to individual actions are seldom explicit, nor is the individual even conscious of their existence. [Maturana and Varella, 1980, Senge, 1992, Erlich and Ornstein, 1989]

In the application of this framework to the issues of the global problematique, a number of problems become apparent.

a) If we accept the concept of sustainability as the 'objective', three complicating features arise. First, sustainability is a concept that is comprehensive in that it is a property that applies to a system as whole. Just as 'temperature' and 'pressure' are properties that apply to a gas, not to the individual molecules that constitute the gas,

sustainability is a property of the global ecosystem, not its constituent processes. Second, sustainability has a clear reference to the future in that it is concerned with the persistence of harmonious relationships between human activities and the environment indefinitely into the future. Third, the sustainability of the human species as an objective is potentially in conflict with the objectives of individuals.

b) In the case of global problems, the 'manager' or controller is humanity itself composed of individuals and the institutions of society that have been delegated responsibility for managing various aspects of human activities. Since this 'manager' system is obviously not monolithic, effective action will depend upon managers having a common understanding or shared systems model.

c) The understanding of the system is (i) incomplete to the extent that specific processes are not understood and (ii) fragmented in that partial systems models exist in narrowly defined disciplines. These various systems models are uncoordinated with the consequence that understanding of the system as a whole is impeded.

d) The implicit perceptual apparatus that guides individual actions is dysfunctional in that is far too limited in time and space. Peter Senge argues that

> *if we're really trying to create a whole new domain of behaviour, actions and possibilities, ... then we have to become conscious about it.* [Senge, 1992]

e) In the absence of widely shared understanding or common systems model, the feedback loop from observations of the system to the system manager is weak. This feedback link is fundamental. For most effective use in communicating and learning about the system behaviour, it must operate as effectively as any other link in the model, thus incorporating the user as an integral element into the heart of the model.

f) The property of sustainability cannot be directly observed or monitored because it is a property that applies to the future of the actual system. However, the possible futures of the system model can be observed by the various alterations which the user (manager or controller) may make based on an assessment as to how to alter the system model in response to having observed prior performance..

From the discussion above, it is clear that a conscious and explicit systems model can play a crucial role in developing and communicating a common understanding needed for effective interpretation of the observations and for both individual and collective action.

It is equally clear that the written word has failed to develop this common understanding. Much of the writing on the subject of the 'problematique' takes the form of expert analysis followed by prescription, a form that combines elements of verbal description and persuasion. Verbal description, relying on the linear subject/predicate cause/effect constructs of language, has not proven to be effective in describing acausal and complex systems; persuasion, relying on rhetorical technique and selective arguments, may trigger action, but seldom conveys understanding. Prescriptions made by 'experts' are increasingly suspect by a vast majority of people who believe they are not capable of understanding but have learned through experience not trust such pronouncements. Argument, according to Northrop Frye, relies on the arrangement of data. Arrangement means selecting for emphasis, and selecting for emphasis can never be definitively right or wrong. [Frye, 1990]

This point is neatly stated by John Ralston Saul in his book, *Voltaire's Bastards*, when he observes, with respect to the Western world, that:

> *Our unquenchable thirst for answers (for 'answers' read 'prescriptions') has become one of the obvious characteristics of the West in the second half of the twentieth century. But what are answers when there is neither memory nor general understanding to give them meaning? This running together of the right answer with the search for truth (for 'truth' read 'understanding') is perhaps the most poignant sign of our confusion.* [Saul, 1992]

The scientific method, relying as it does on controlled and repeatable experiments, does offer a powerful means of communicating understanding. But the scientific method is reductionist and by itself is inappropriate for holistic analysis of ecological systems (of which humanity is an integral part) which are structures in space time, evolutionary and subject to constant and irreversible change.

We believe that the success of the world dynamics model may be attributed to ability to communicate an understanding of a complex and dynamic system through the description of the structure of a mathematical systems model. [Forrester, 1971]. This experience suggests that a computer based simulation model that can be used to explore the future consequences of societal actions may be an effective means to communicate the understanding needed for effective societal action.

## A New Approach

What is needed is a new approach that builds on previous modelling efforts, one that emphasizes the process of designing and using computer-based global modelling tools as a means for developing the common base of understanding needed for effective societal action. This approach is in contrast to the traditional approach which emphasized prediction and prescription.

Such an approach is feasible because of advances in our understanding of ecological systems, the emergence of an evolutionary paradigm to augment the Newtonian paradigm, and a revolution in computer technology.

The evolutionary paradigm reflects advancements in the fields of general system theory, information theory, control theory, and ecology. References are provided in the bibliography. See particularly the work of Jantsch, Prigogine, Bateson. The evolutionary paradigm is described by Erwin Laszlo in the following terms:

> *The evolutionary paradigm challenges concepts of equilibrium and determinacy in scientific theories; and it modifies the classical deterministic conception of scientific laws. The laws conceptualized in the evolutionary context are not deterministic and prescriptive: they do not uniquely determine the coarse of evolution. Rather, they state ensembles of possibilities within which evolutionary processes can unfold.* [Laszlo, 1987]

From this it follows that what is required is a set of tools for exploring the 'ensemble of possibilities' of the evolutionary paradigm. The need is not for a 'better' model that might be developed within the confines of a small group to further the advocacy power of that group; rather it is to use the process of designing and applying global modelling tools to facilitate the communication of understanding within as broad a group of actors as possible.

The word 'tool' is used deliberately as a tool is an extension of the user of the tool. The use of well designed tools enhances the ability of the user to accomplish explicit tasks. A shovel facilitates the task of digging a hole and extends mechanical capabilities; a ruler makes more accurate the recording of the property of length of objects; a telescope enables visual perception of objects that could otherwise not be seen. Knowledge of the availability of tools suggests tasks or objectives that would not otherwise have been considered. The Global Exploration Tools herein proposed are intended to enhance the ability of individuals and societies to understand the full implications of societal actions and to explore alternative global futures.

With this background, we conclude that there is both need and potential for the development of a generation of global modelling tools that can serve to facilitate and communicate a more appropriate model of reality such that human society can perceive the full consequences of actions. Such modelling tools can take advantage of both theoretical and scientific advances and advances in computer technology.

What follows is an outline of the features and characteristics of such global modelling tools and a discussion of the strategies for the organization of their development.

## Features of the Proposed Global Modelling Tools

- **The User/Society as an Integral Part of the System**

  The systems model consists of two components: an open ***simulation framework*** that represents the ***processes*** of the system to be managed with their context and the user/society which is the source of novelty or learning. Through interaction with the ***framework***, the user/society explores the implications of decisions and changes in the environment. Exploration is a learning process that enables the user/society to increase his understanding of the system. In this way learning from experience can be incorporated into the framework.

- **The Concepts of System, Process, Dynamics**

  A simulation framework is a representation of the processes that constitute a system. The system of concern for the issues of the problematique are human activities and the naturally occurring biological and geological processes that sustain human populations. A fundamental concept of systems theory is that

  > *(The concept of) process is primary . . . every structure we observe is a manifestation of an underlying process.* [Capra, 1985]

  'Process' is a dynamic concept concerned with the transformation of input streams into output streams within an arbitrary system boundary. The properties of the system as whole, such as sustainability, emerge from the interactions among the constituent processes and are not simply the properties of the component parts. The representation of time structure is essential.

  > *Interactions among component processes take the form of causal chains that may be complex. When sequences of cause and effect become circular, then the mapping of those sequences onto timeless logic becomes self-contradictory or paradoxical.* [Bateson, 1980]

- **Stocks and Flows**

  > *Another taxonomic and conceptual problem that has plagued economics from the time of Adam Smith is the confusion between stocks and flows . . . The capital stock is a population of items, production is births into that population, consumption is deaths . . . Furthermore , the idea that production is consumption is only partly true. What we get satisfaction from for the most part is use, not consumption . . . This has led to . . . the absurd view that it is income which is the only measure of riches.* [Boulding, 1978]

  The simulation framework should keep track of the evolution of stocks of human population, the stocks of artifacts constructed by those populations for their use, stocks of land, stocks biological resources, and stocks of geological resources, and it should keep track of the flows of materials and energy from the environment as they are transformed into the artifacts used by human populations and returned to the environment as material and thermal waste. Stock/flow accounting identities are used to maintain coherence over time; supply/disposition flow identities are used to maintain coherence within time periods.

- **Disequilibrium and Tension**

  The simulation framework should be designed in such a way that the system of feedbacks among the processes represented in the framework is incomplete. To the extent that the feedback mechanisms are incomplete, the possibility of discord or disequilibrium among the constituent processes arises. This discord creates tension in the mind of actor or framework user that invites a creative response. It is this idea of tension arising from disequilibrium that makes the user of the framework an integral part of the model.

  > *Equilibrium has become a kind of holy sacrament in economics and has seriously diverted attention from the real world of Heraclitean flux . . . The economic system is a structure in space-time. Consequently, it is evolutionary, subject to constant and irreversible change.* [Boulding, 1988]

- **Spatial Scale**

  The spatial scale of the simulation framework should of course be global, but the world should be subdivided into a sufficient number of regions to reflect differences in culture, lifestyle, resource endowments, and power. The framework should represent the flows of people, materials and energy that cross the regional boundaries. The number of regions to be represented will also depend on the nature of the processes to be included. The simulation framework will be designed so that more detailed representations involving more regions could readily be developed as the framework evolves.

- **Temporal Scale**

  The temporal scale of the simulation framework should span a sufficient past that we can see where we are coming from and a sufficient future that the possibilities for sustainability can be explored. The accumulation of past actions to the stocks that presently exist must provide the starting point for future explorations; in this sense, future possibilities are constrained by past actions.

*Trying to sharpen one's sense of the future is useless, as the future has no existence; trying to see the present as an interim in which anything may go at any time merely adds to the mood of destruction. Not everything that can happen will happen: we have to understand what kind of people we are before we can begin to guess what we shall do. What kind of people we are is perhaps determined, and certainly conditioned, by what we realize of the past, and sharpening our sense of the past is the only way of meeting the future.* [Frye, 1982]

Different processes have different time dynamics; very slow moving processes such as geological processes may be ignored or represented as stocks; fast moving processes may exhibit seasonal or cyclical patterns and are represented as stock/flow structures.

- **Structure**

  The simulation framework should focus on the representation of those physical transformation processes that are of significance for the relationships between human population and the natural resource base. Of great importance are processes associated with the renewable resource base; processes affecting soil quality, forest growth, processes yielding nutrients, processes transforming primary sources of renewable energy into useful energy forms. In the final analysis, the level of human population that can be sustained will be determined by renewable resources and the effectiveness with which they can be used to provide nutrition and energy for extracting and recycling materials.

  Since it is difficult to foresee all the structures and transformation processes that need be represented, the simulation framework must be open ended with respect to the addition of processes. Each process or group of processes can be independently modelled; these sub-models can be linked together to form the simulation framework. This module management process should support the creation and modification of sub-models as well as the linking of these new or changed sub-models in a manner as flexible and transparent as possible.

## Development Strategy

A key feature of the proposed approach is that the understanding arises from interaction with the framework in the process of exploration. The communication of understanding is achieved when a number of people share the experience of interaction. If common understanding is to lead to improved societal decision making, the correspondence between the framework and reality must be accepted both in terms of the processes that constitute the framework and the representation of those processes.

The acceptability and impact of the proposed decision tools will be greatly enhanced through involvement of as wide and as diverse a set of interests as possible in the process of designing the structure of the framework. This key assumption reflects extensive experience with complex decision systems involving diverse and competing interests.

The primary task will be conceptualization and construction of sub-models. This task will require people with expertise in modelling, theoretical knowledge of the sub-model issues and relevant field experience. Many of these will be potential users of the Global Exploration Tools. University groups or research institutes are best equipped to take the lead in the conceptualization and associated data collection and calibration tasks. A key requirement in the management of sub-projects would be to ensure the on-going participation of organizations with interest and experience in the subject area concerned.

Since the proposed Global Exploration Tools have the capability of "learning", their utility will increase through use. Thus, users will become collaborators in future development of the framework. Mechanisms for feedback and up-date of the framework will thus need to be developed.

At each stage in the development process, it is important to consider potential users of future generations of the framework and seek their involvement. Conceptually, the Project could be viewed as a knowledge system in which knowledge development is integrally linked with knowledge application within a structure which encourages feedback through rewards of utility. Identification of knowledge networks and involvement of key players in such networks becomes an important component of development strategy.

## Epilogue

The authors are aware that this paper is itself an example of an argument intended to persuade the reader, and, as such, is subject to the weaknesses implied by Frye's criticism. In the spirit of learning through experience, we invite the reader to explore the concepts described in this paper using a computer-based simulation framework, the Sustainable Development Demonstration Framework, developed by ROBBERT Associates. SDDF is a process based global simulation framework that embodies many of these concepts. If you are interested in pursuing this invitation, please contact Robert Hoffman at (613) 232-5613.

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