Jul 1st, 12:00 AM

A Conceptual Model for Integrated Assessment

Markus Knoflacher

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Austrian Research Centres Seibersdorf, A – 2444 Seibersdorf

markus.knoflacher@arcs.ac.at

Abstract: The challenge of integrated assessment is the integration of scientific and social aspects for the preparation of decisions. On one hand it is necessary to find scientific and technologically sound solutions, on the other hand the results should meet the interests of social groups affected by the particular project. In large projects it is also necessary to consider the effects on sustainable development. The bandwidth of the different aspects is in practise confronted with problems in acquisition of data, inhomogeneity and incompleteness of information about the actual conditions and the effects of the project. To solve the task in a serious way it is necessary to reduce the uncertainties and to optimise between the physical possibilities and social interests. For these purposes a conceptual model was developed, and applied in several large infrastructure projects like motorway constructions, hydropower dams, and airport development. In this model the differences in temporal and spatial dynamics of physical environmental systems are considered by seven different partial systems. Based on the different characteristics of the partial systems it is possible to identify the basic properties of the existing physical system and the expected impacts of the project at a qualitative level. The results of these analyses are used for the definition of further detailed investigations and modelling needs for particular parts of the considered physical system. Differently to the physical system the social system is differentiated into eight rule systems. Because of the differences in the perception of the environment by different social groups, it is necessary to identify the actual status by appropriate methods. In this step of investigation it is essential to find out the different understandings of "reality" within the relevant social groups, so that it is possible to start necessary discussions among the groups and to present the results of physical investigations in a way which can be understood by the involved social groups. For the management of these processes it has to be clear, that there is a contradiction between the functional hierarchy of the physical environmental system and the perception or valuation within the social systems at temporal and spatial scales. So it is necessary to optimise between the outcomes of the investigations within the physical system and the outcomes of the social investigations, under consideration of the unavoidable uncertainties in both cases.

Keywords: Conceptual model; Integrated assessment; Public participation

1. INTRODUCTION

The need for integrated assessment in ex-ante prediction of effects in large technical projects or large intervention programs is in general accepted. However, the applied methods as well as the expectations on the results of integrated assessment are still different and under discussion.

Concerning the physical effects of a project or program it is evident that the accuracy of basic data is always limited in the spatio-temporal context. The accuracy of effect predictions depends on the properties of the considered objects. These problems are increasing rapidly with an extension of the considered area of investigation or time span of prediction. In addition to these problems it becomes evident from empirical observations, that scientific facts are interpreted by humans in quite different ways. Societal reactions to similar technical projects are therefore often different, and sometimes far from scientific viewpoints.

A common reaction on such turbulences is an inflationary increase in the number of involved experts and expertise, but often without any substantial reduction of emerging problems. Frustration of developers and experts as well as of the population impacted by the project is consequently very high. The questions to find the way out of these doldrums are in particular focused on the possibilities to increase the accuracy of the achieved results and on the reduction of irrationality in human reactions. In the following a conceptual approach, applied successfully in several integrated assessments will be presented and discussed.

2. DEFINITIONS AND THEORETICAL BACKGROUND

2. 1 Introduction

Environmental systems as a whole are complex because of the number of interdependencies and nonlinear reactions of its sub-systems. Additionally it has to be considered, that all human activities are occurring within the system. So, there is no possibility for undisturbed observations of the system. A solution of these problems can be found if it is possible to identify parts of the system with properties independent of human activities. Because of the high number of interrelationships within the environmental system, the solution can only be found analytically and not empirically. The identified entities are consequently not independent subsystems. These entities are defined as partial systems.

2.2 Definition of Partial Systems

Following the physical and structural properties within the environmental system without particular consideration of humans, it is possible to identify six partial systems. Planetary forces and solar radiation are assumed as external factors in this approach.

Three of the six partial systems are abiotic, and can be characterized predominantly by the aggregate state of its elements as solid, liquid, and gaseous. Corresponding to the structural properties and to scientific definitions the three partial systems are defined as:

- Geospheric partial system.
- Hydrospheric partial system.
- Atmospheric partial system.

Essential properties of the abiotic partial systems for applications in integrated assessment are the relationships in mass, dynamics, and energetic flow [Mason and More, 1985; Kleemann and Melіß, 1988; White et al., 1992; Knoflacher 2001] (Table 1).

Table 1. General relationships in mass (grams), dynamic (average system turnover rates in years), and energetic flow (joules per year) of abiotic partial systems, based on data in Mason and Moore [1985], Kleemann and Melіß [1988], White et al. [1992]

Partial system	Mass	Dynamics	Energetic flow
Geospheric	$5.9\ 10^{27}$	10^{3} - 10^{7}	$0.8\ 10^{24}$
Hydro-spheric	$1.4\ 10^{23}$	$10^{-2} – 10^{3}$	$1.8\ 10^{24}$
Atmo-spheric	$5\ 10^{21}$	$10^{-8} – 10^{-2}$	$1\ 10^{24}$

In biological partial systems the properties of elements, the organisms, are the main differences to the abiotic partial systems. All organisms are protected against environmental factors by semi-permeable surfaces, and autonomous systems. Under consideration of the internal structure, and processes three biotic partial systems can be defined as:

- Microbiological partial system.
- Botanical partial system.
- Zoological partial system.

As mentioned in Knoflacher [2001] humans in their biological existence are part of the zoological partial system. Essential properties for practical applications are the differences in gathering of energy, ranges of reproduction cycles, and active sprawling speed [Swingland and Greenwood, 1983; Odum, 1983; Peters, 1986; Schulze and Caldwell, 1995; Bonn and Poschold, 1998; Daley and Gani, 1999; Fritsche, 2002]. Gathering of energy is differentiated in gathering of energy by chemical reactions (chemotrophy), by photosynthesis (autotrophy), and by consumption of organic substances (hetrotrophy). The values presented in Table 2 are related to the autonomous potentials of the organisms, and without consideration of additional supporting factors like wind or water flow.

Table 2. General relationships in gathering of energy (process characteristics), temporal ranges of reproduction cycles (years), and active sprawling speed of populations (meters) of biotic partial systems, based on data of several authors

Partial system	Gathering of energy	Ranges of reproduction cycles	Active sprawling speed
Micro-biological	Chemo-, auto-, hetero-troph	10^{-6} - 10^{3}	$10^{-3} – 10^{2}$
Botanical	Autotroph	$10^{-1} – 10^{2}$	$10^{-2} – 10^{1}$
Zoological	Hetero-troph	$10^{-1} – 10^{1}$	$10^{1} – 10^{3}$

For practical applications it is necessary to define additionally the Anthropogenic partial system. This partial system comprises all physical entities made by human, such as buildings, engines, vehicles, monuments, books or computers. Not included in this partial systems are humans in their biological existence, and virtual expressions of humans, as for example laws, values including economic values, or knowledge.

Interaction among several partial systems is common in real environmental systems. Consequently, empirical observations and descriptions can not be made on isolated, but on dominating partial systems. Examples for such approaches are hydro-geological processes. Much harder to identify are the interactions among several partial systems, if the dominance of one partial system is not evident. Examples are ecological processes or processes in human dominated landscapes. In such cases the relationships among partial systems can be identified through a step by step analysis under particular consideration of the underlying spatial and temporal scales.

2.3 Definition of Rule Systems

Integrated assessment has to consider the objectives and interests of peoples with different knowledge and involvement to the proposed project or programme. Abstract rational approaches [Chernoff and Moses, 1959] do not meet sufficiently the reality of such processes. Much better foundations of human actions can be found in theories concerning knowledge and motivation [Weiner, 1994; Popper, 1995; Bourdieu, 1997; Watzlawick, 1998; Foerster, 1999], as also in theories of acting and decision under uncertainties [Malik, 1992; Bacharach and Hurley, 1994; Habermas, 1995].

The transformation of these theories in a conceptual model can be made by application of the theory of automata [Laux, 1980]. By this way it is possible to present human decisions and reactions in a generalised way by a set of rule systems:

- Individual rule system.
- Social rule system.
- Cultural rule system.
- Economic rule system.
- Knowledge rule system.
- Religious rule system.
- Legal rule system.
- Political rule system.

The individual rule system comprises the individual set of rules and the individual neuro-physiological structure. The social rule system comprises the rules of the social group interacting regularly with an individual person and the structural conditions of the group. The cultural rule system comprises the rules and structural conditions of the culture. The economic rule system consists of economic rules and structural conditions of the economic system. The knowledge rule system comprises the rules and structure of education and application of knowledge, including research and science. Religious, legal and political rule systems are self explanatory.

Each rule system operates with a particular code. Acceptance and decoding of available information from the individual environment is consequently constrained by hierarchy of the rule systems. Individual perception of environmental systems, and individual assessment of impacts and effects are therefore strongly dependent on the individual relationships of the rule systems.

Hierarchical relationships among the rule systems are depending on the context of activity, and are not stable. However, within one culture a compliance of regular hierarchical sets of rule systems can be observed in different social groups. Based on empirical observations it is therefore possible to predict the applied rule system hierarchy of potentially involved groups in an integrated assessment procedure. Not predictable, but identifiable by appropriate procedures like mediation [Geißler and Rückert, 2000] are the actual applied rules of the involved groups.

2.4 Concept of Interaction between Physical System and Human Recognition

The central challenge of integrated assessment is the acquisition of relevant information from a complex system. The task comprises three basic steps:

- The acquisition of information about relevant properties of the system.
- The acquisition of information about relevant effects of planned measures.
- The preparation of decisions for concrete measures.

In all steps it is necessary to consider the interaction between physical properties and human recognition. In integrated assessment this concerns in particular the transformation of physical properties to human knowledge. Under consideration of the involvement of humans with different knowledge in the whole process, two different kinds of system representation have to be distinguished. Representations of systems by application of the system theory [Bertalanffy, 1968] are defined here as models. Other representations, as for example the individual knowledge about the system are defined here as images. Models and images are different representations of an environmental system, because the structure of models is based on observed properties of the system, and images are based on the individual knowledge of humans. Based on information theory [Reza, 1961] the differences can be explained by different decoding procedures for the preparation of models or images.

Because of the differences between models and images it is necessary to establish transformation procedures between both types of representation in each step of integrated assessment. The main objective of the transformation procedures is the iterative approximation of models and images. A successful approximation is therefore strongly dependent on the adjustment of the different decoding procedures.

The structural interface for the approximation is the general matrix of the partial systems and the general relations to the rule systems. All relevant information from empirical investigations and human recognition have to be compared on this conceptual background. For further approximation steps the identified gaps and redundancies of information has to be reduced. These task can be solved by feed back loops between the comparison step and the modelling procedure on one hand and the image generation on the other hand.

2.5 Structure of Information of the Physical System

A central tool for structure of available scientific or empirical information about the selected physical system is the matrix of the partial systems. Additionally all information has to be ordered by temporal and spatial scales of the observed entities or processes. The effects of a certain impact are depending on the structural impact position in the existing system, and the dimension of the impact. Consequently, the check list of needs for detailed investigations has to be based on information about the intended impact.

If the procedure is integrated in a participatory process, than it is necessary also to consider human interest.

Uncertainties in the prediction of effects are strongly dependent on the functional and dynamic characteristics of the impacted partial systems. Consequently, the accuracy of predictions depends on the characteristics of the considered processes. A solution of these problems can be found by hierarchic calculations of predictions. The highest level of the hierarchy is related to the process with the highest accuracy in the prediction, the lowest level by the process with the lowest accuracy.

The general result of the procedure are qualitative models of the physical system and the expected impacts. System parts of particular importance have to be analysed by quantitative models, so that the in- and output is integrated into the structure of the qualitative model.

2.6 Structure of Human Knowledge

Information acquisition skills are dependent on individual experiences and education. Consequently, individual perception of system conditions is constrained by the particular history and the actual state of interests. However, these constraints can be surmounted if individuals with different knowledge background are working together within a process. The efficiency of the interaction among different participants increases with reduction of disturbance in information exchanges.

The variety of actual human perception of a particular system or effects of an expected project can be identified by analyses of individual rule hierarchies. The analyses can be carried out on the basis of questionnaires or structured interviews focussed on the hierarchy of individual interests in relation to the effects of the considered project.

Human presentation of images from physical systems is in general fuzzy, and has to be treated under consideration of fuzzy set theory [Gupta et al., 1979]. To avoid ambiguities it is necessary to defuzzify [Bothe, 1993] human presentations before comparison with models. According to the related scale it is additionally necessary to structure the information from images in a similar way as results from empirical observations of the physical system.

2.7 Comparison of Information from Models and Images

The basic orientation structure for comparison of information from models and images is the conceptual model of partial system, and its principal relations to the rule systems, adapted to the particular case. For spatially heterogeneous effects it can be necessary to modify the conceptual model locally, so that differences in interactions can be considered.

The biggest challenge in comparison between models and images is the clarification, to which process and to which temporal and spatial scales the information is related. Careful analyses of the applied information and logical checks of the relations to other information are essential preconditions for identification of real gaps and redundancies. The relation between information in Images (I) and Models (M) can be accepted, if the set of information in images is a partial set of information in models (1).

$$M \supseteq I \qquad (1)$$

Otherwise the causes of the divergence have to be investigated. If the differences are caused by information, which can not be realised by models or empirical investigations, it is necessary to document the causes of that fact. If information can also be realised by models or empirical investigations, than it is necessary to extend the models in a proper way.

Information feedback to involved persons must be adapted to the average potential of complexity recognition. A presentation of three relations among different factors is in general the accepted maximum of complexity in relationships. In cases of nonlinear interactions it is necessary to present typical examples in diagrams.

3. EXPERIENCES IN EMPIRICAL APPLICATION OF THE CONCEPTUAL MODEL

The conceptual model was developed by the author and successfully applied at different stages of development in integrated assessment of highway and hydropower projects in Austria. Preliminary versions were used in integrated assessment of sections of the motorways 2 and 10, and of the planned hydropower dam at the river Drau close to Spittal an der Drau in Austria. By application of the conceptual model, even also in the preliminary versions it was possible to achieve sound and consistent results, and also to save time and money in the assessment. The version, published in this paper is applied in the mediation process for the development plan of the Vienna airport.

The strength of the conceptual model is the adaptability to particular conditions, and the strong support of comparisons among different scientific investigations as also among different human viewpoints of a particular project.

4. DISCUSSION

The methodological back bones of the conceptual model are the general system theory of Bertalanffy [1968] the information theory [Reza, 1961], and in the actual version the automata theory [Laux, 1980]. Integration of the theories was made by an heuristic approach, and proofed in practical applications.

Despite the potential for developing dynamic models, the conceptual model is a tool by itself for integrated assessment in particular for integration and comparison of information from different sources. The handicap in the distribution of this method is the large effort to learn its applications, and the need to have basic knowledge in several disciplines.

5. ACKNOWLEDGEMENTS

The author wished to thank all the people involved in several integrated assessment projects in which the conceptual model was applied and tested.

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