A Conceptual Model about the Application of Adaptive Management for Sustainable Development

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Abstract: This conceptual model is based on theoretical implications and analyses of empirical examples, and focuses on how functional processes in the environmental system affect decisions taken in the social system. Complex functional relationships at several temporal and spatial scales such as climate conditions or pollutant emissions characterise functional processes in the environmental system. Actions of humans in the environmental system are crucially constrained by limited information about system conditions, and limited predictability of system development. Both constraints are not equally valid for all functional processes, and all interactions between humans and the environmental system, because diverse human activities and interests lead to an array of interpretations regarding the environmental system. An active comparative exchange of partial views about the environmental system can enlarge social knowledge. These requirements cannot be satisfied solely by scientific investigations; observations and experiences of non-scientific human actors also have to be considered. Integrating the different types of knowledge by applying systems analysis methods delivers the basis for developing general management plans e.g. in urban planning, although uncertainty in decision-making cannot be eliminated fully through integration alone. It is nevertheless an essential precondition for applying the adaptive management instrument because it delivers, in addition to an improved understanding among stakeholders, an overview of functions such as impact-effect relationships and scales relevant for human actors in the environmental system. The adaptive management process is necessary in order to establish a functioning feedback system, to determine the type of organisational framework needed, and to ascertain which actor groups to involve in decisions and assessment procedures within the framework of sustainable development.

Keywords: conceptual model, systems theory, interaction loop, adaptive management, sustainability

1. INTRODUCTION

1.1 General introduction

Highly complex situations on the interface between human and environmental systems often present major challenges to those attempting to manage such systems. Examples include managers of natural resources who are charged with having to harmonise often conflicting objectives such as preserving a particular ecosystem and managing it sustainably while simultaneously extracting resources (e.g. forest). Urban planners, developers, housing specialists, social workers or others involved in e.g. regenerating derelict urban areas also face multiple challenges that can include reducing crime rates and unemployment by providing new jobs, engaging in environmental clean-up while attempting to attract industry and commerce, and physically improving a particular part of town thereby also improving a city's image.

These and many other situations exhibit similar characteristics. All situations affect numerous stakeholders and at the same time are influenced by a multitude of interested parties [Ander et al., 2001; Tomerius, 2000]. Environmental and human systems are inherently complex and attempts to understand them often fail, because of too many unknowns. Nevertheless, in order to be able to manage natural or urban areas more successfully, improved ways of dealing with information and information flows need to be found in settings that are characterised by complexity, uncertainty, and unexpected situations [Holling, 1978]. A conceptual model showing interactions between human and natural systems illustrates the conditions necessary for adaptive and flexible management approaches. Only then will it be possible to make informed and sensible decisions that allow those responsible to tackle the multiple issues at hand and achieve more sustainable outcomes.

1.2 Adaptive management

Adaptive management is an integrated, multi-disciplinary approach for managing natural resources such as wetlands or forests and can also be applied in other fields such as urban planning or environmental management. The instrument was conceived to develop more effective and more resilient policies [Holling 1978] acknowledging that natural systems always change as a result of human intervention and therefore require an adaptive approach that is capable of responding to such changes [Gunderson, 1999]. The approach attempts to find viable solutions in situations where many stakeholders with differing objectives facing limited information must make decisions.

Key elements of the instrument include the use of experiments which allows managers and stakeholders to learn from those experiments and assess successful or failing approaches [Walters and Holling, 1990]. Comprehensive monitoring throughout the management process is another crucial element that informs managers about the area under observation [Grumbine, 1996; Lessard, 1998]. In this particular approach, it is essential to employ system-relevant indicators ideally before, throughout, and for a period following the management process. Another very central feature of adaptive management is that all relevant stakeholders should be involved in the process, remain informed, provide input and take part in decision-making [McLain and Lee, 1996]. Adaptive management thus attempts to make learning through feedback more efficient and part of the management process, promotes flexibility, and involves all relevant stakeholders.

2. EMPIRICAL INVESTIGATIONS

Empirical evidence from urban regeneration processes in different European cities shows that certain key aspects substantially contribute to successful revitalisation examples. Those include cooperation among stakeholders, a clear vision, provisions to remain flexible and adaptive throughout the process, and a regional and market-oriented approach [Ander et al., 2001; Seewer and Menzi, 1999]. Regenerating large, old, industrial inner city sites at a minimum requires large sums of money, a clear commitment by the owner(s) that the site should be redeveloped, a clear management strategy, and a time-frame. Additionally, those engaging in revitalisation need to strike a balance between investing in environmental clean-up, attracting industry and commercial enterprises to ensure employment opportunities and fulfilling short and long range goals of the city. The following examples illustrate the need to apply features of adaptive management in complex regeneration examples.

Planners and developers in Gothenburg, Sweden charged with redeveloping a former industrial site initially set out to attract strictly industrial users. In the span of the following decade, the first strategy being unsuccessful, they developed a vision and adapted their strategy and plan to one that was more responsive to the needs of Gothenburg and the region surrounding it. Instead of focusing on industry alone thereby homogenising the site, they promoted a more diverse and mixed use approach [Ander et al., 2001]. Project promoters also understood the need to observe market developments and adapt to potential changes over the long-term, in this case several decades, in contrast to traditional linear planning approaches. Thus, the stakeholders' initial experiment failed and they incorporated what they learned into the new vision and plans, simultaneously observed market conditions, dealt with the inherent uncertainty and acted according to the new requirements.

The same case also demonstrates the importance of involving all relevant stakeholders in the management process from the very beginning and fostering public-private partnerships (Ekman, pers. comm., 2003). Representatives from public and private organisations communicated needs, changes, and constraints throughout the process and cooperated closely on revitalising the site. Because the stakeholders had known one another for years working on common objectives, a certain level of trust had been built that was instrumental in successfully revitalising the site. Each stakeholder was informed about the planning process or took part in it, and most importantly, they each participated in decision-making.

A water resource management case study in the United States illustrates that lack of cooperation and trust can result in a disfunctional programme [Gigler, 1998]. Disagreements over monitoring plans and responsibilities, frequent institutional reorganisations with an unclear assignment of tasks, and personal disagreements among staff all led to deepening distrust among those responsible for the monitoring programme and resulted in poor execution of the prescribed monitoring and data analysis. Due to conflicts between staff, preserving the headwaters of two streams and their associated wetlands in an acceptable state and at a crucial time in spite of development in the vicinity was severely hampered.

3. THEORETICAL BACKGROUND

3.1 General relationships

Sustainable development depends on a long term balance between the ecological and the human social system. The realisation of this anthropocentric concept crucially depends on understanding the characteristics of particular systems and their interdependencies. Environmental systems are driven by the dynamic counteracting hierarchies of free energy and self organisation [Knoflacher et al., 2003], (Figure 1). Different balance levels of the counteracting processes can be classified as partial systems of the environmental system [Knoflacher, 2002].

During evolution, balance was achieved through losses and emergence of species and their ability to adapt to changing conditions continuously [Cockburn, 1995)]. The challenge of the sustainable development concept in this context is that it does not accept any losses of large portions of a population because of e.g. harmful environmental conditions [WCED, 1987].

The technological potential of the human population represents a benefit as well as a risk for sustainable development (Figure 1). In some cases, it enables human liberation from the energetic hierarchy. This enables human welfare and the development of particular characteristics of human societies. However, it also increases the risk of adverse effects because of critical changes of environmental conditions or because of self destruction during conflicts in the human population.

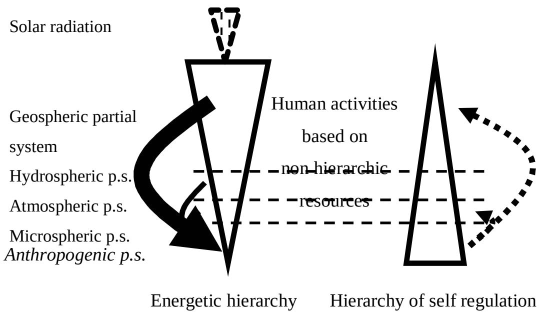

Figure 1. Systems framework conditions for the sustainable development concept.

These systems framework conditions illustrate that there is a strong need for a better understanding of the affected partial systems. The entire human population also needs to make use of its high potential to adapt to dynamic system constraints within a certain region.

Interactions between the human social system and the environmental system are asymmetric. Basics for human life are the exchange of energy and chemical compounds between the human social system and the environmental system. These exchanges are increasing entropy in the environmental system, which can only be compensated by self organising processes in ecosystems. Of particular interest for sustainable development is how humans perceive information coming from the environmental systems and their impacts on environmental systems beyond basic interactions.

3.2 System characteristics

In spite of voluminous literature about characteristics of environmental systems [Odum, 1983; Mason and Moore, 1985; White et al., 1992; Joergensen, 1992] and social systems [Giddens, 1993; Luhmann, 1994; Habermas, 1995; Bourdieu, 1997] relatively few publications deal with interactions between information flows and physical impacts. This is particularly valid for considering conditions of complexity in this context.

Environmental systems are at least complex in their structure and functions. Structural complexity can be found in the composition of system elements at a huge bandwidth of spatial and temporal scales, also including relationships among different elements. A typical example is the composition of a natural forest ecosystem with biotic and abiotic components and their relationships. Functional complexity is characterised by the different qualities entailed in processes within environmental systems. It is expressed in the example mentioned e.g. in energetic webs combined with material flows.

Human social systems are at least complex in their functions. Recent human societies are characterised by interactions of human actors with different responsibilities and competences [Luhmann, 1994]. In addition, human actors can change their functional membership to distinct functional groups. A typical example for that is an individual person switching between the professional and the private role.

Complex interactions also result from systems complexity. This will be familiar to anybody who has attempted to bring environmental effects into a consistent order. But it becomes also apparent through numerous and parallel running individual interactions e.g. within a large region. Several thousands of people can work at the same time in their garden, are cutting wood in the forest, or drive cars. Each interaction is based on an individual decision and will be related to individual targets. Such individual interactions can be influenced by general laws only to a limited extent for the following reasons. 1. Due to complexity of structural conditions; each individual is living under different framework conditions, in part because of social interactions. 2. Due to variability of individual targets and values; e.g. different values a forest has for forest owners versus tourists. 3. Because of probability to get punished if the general rule is neglected. This probability will be strongly reduced with an increasing number of adverse activities taking place and with a decreasing difference in individually caused effects.

4. THE CONCEPTUAL MODEL

4.1 The basic interaction loop

Individual human interactions with the environmental system can be interpreted as a regulation loop (Figure 2).

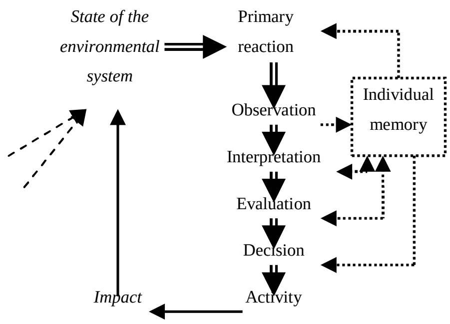

Figure 2. Basic feedback loop of human interactions with the environmental system.

Essential preconditions for a first reaction to environmental state conditions are a person's physiological and psychological perceptibility. Physiological perceptibility depends on specific characteristics of the human sensory system [Schmidt and Thews, 1980]. Psychological perceptibility depends on the specific awareness of an individual, influenced by former experiences, individual objectives, and information from the social system [Hoffmann, 1976; Popper, 1995]. It is presented in Figure 2 as individual memory.

A more detailed observation of the actual environmental state depends on information from the first reaction and on the general interest of the individual. It delivers comprehensive information about the environmental system in relation to an individual's expectations. This information is used for individual interpretation of actual conditions of the environmental system, and potential reasons for it. Interactions with other persons can modify the individual interpretation.

An individual evaluation differs from interpretation. In this step results of the interpretation are compared with individual objectives that take into account additional information about social framework conditions. An individual decision depends on outcomes of the evaluation. Basically, a decision has to be made about whether to act. Additional decisions about specific activities would follow if the decision was to move forward.

The subsequent activity is not directly related to the individual. At a minimum, the individual only has to give instructions to other persons for implementing an action. At a maximum, the individual has to act personally.

The reaction of the environmental system to specific impacts depends on the qualitative and quantitative characteristics of the impact and the specific characteristics of the affected environmental system, and the occurrence of additional impacts caused by other persons.

Non-linear relationships can be expected between the individual impact and effects in the ecosystem. Time lags and delocalisation effects can camouflage substantially the real effects in the environmental system. Counter- intuitive reactions of the environmental system can cause misinterpretations. Hence, the basic interaction loop can only support a first guess about the actual state of the environmental system and the effects of a certain impact. Through repeated interactions under different circumstances, it is possible that the accuracy of the first guess can be improved gradually, but not to complete certainty. Uncertainty will increase again, if attempts are made to predict the long term effects of an impact [Knoflacher, 2002].

4.2 Adaptive connections of the basic loop

Different experiences and interests exist within a larger population, because of different individual tasks and objectives. As a result, one can expect variability in individual memory and first reactions. However, the variability is limited because of common biological and cultural constraints [Berger and Luckmann, 1991]. By applying scientific methods, a slight extension of the breadth of individual memory and primary reactions can be achieved [Speck, 1980].

Consequences of this variability are different perceptions and interpretations of the environmental system. The a priori exchange of information among different actor groups is very limited because of social barriers [Luhmann, 1994].

Traditional technocratic approaches are overcoming this problem by a hierarchical interpretation of the environmental system, where scientific interpretation ranks at the top. Functionally, that reduces the potential variability of interaction loops to one dominant loop with severe consequences. Considering the multiple interactions that are possible between the environmental and the social system, this approach neglects structural complexity. Most of the affected actor groups will not benefit from scientific findings, because of different acting scales and different contextual conditions. Well known social reactions are that actor groups negatively react to decisions and doubt expert opinion.

The challenge in attempting to overcome these problems is the difference of spatial and temporal scales of different individual basic loops. Hence, harmonisation is only possible at certain points in basic loops. Different actors within a region can only react adaptively, if a common understanding of relevant environmental system properties is achieved. This in turn needs a transformation of individual interpretations $\left(I_i\right)$ to a common interpretation $\left(I_C\right)$ of the system state.

$$I_i \rightarrow I_C \qquad (1)$$

Several methods can be applied for identifying a common interpretation among key persons of different actor groups [Kruse et al., 1996; Seifert, 1999; Geißler and Rückert, 2000]. Results of these processes have to include quantitative and qualitative properties as well as relevant indicators for different actors of the environmental system that is being considered.

Systems analyses of these results have to be carried out in order to identify potential risks for further development, and optimised solutions. This task should also be carried out by involving representatives of the affected actor groups to avoid misinterpretations, and in particular to develop a common understanding about constraints and risks. Formally individual memory $\left(IM_i\right)$ is extended to more integrated individual memory $\left(IM_i^{'}\right)$ in this process.

$$IM_i \rightarrow IM_i^{'} \qquad (2)$$

This process can result in a structural adaptation of all relevant interactions between environmental and social systems. A formal criterion for fulfilling this objective is to integrate all relevant actor groups in the whole process.

Clarifying functional roles of different actors provides the framework for defining targets and indicators for future activities. Crucial for acceptance of individual targets is the agreement on a common target for future development of the region. The common target should be observable and easy to understand for all relevant actors.

Subsequent definitions of interaction rules among involved actors are necessary to implement outcomes. Interaction rules can be defined as agreements or contracts that depend on actor requirements. In this context, it has to be clear, that accuracy in forecasting future developments is limited because of basic characteristics of ecological and social systems [Green et al., 2003].

All agreements about interactions and targets are therefore only first guesses in relation to any future development. Therefore it is a big challenge to agree on dates and reasons for common assessment procedures in the future. Such assessment procedures should support adaptability to changes in framework conditions by considering the general strategy, and methodically they should be based on principles of adaptive connections in basic loops.

4. CONCLUSIONS

Adaptive management offers a very promising approach for managing human and natural systems as demonstrated in the case studies described. The interaction loop provides the theoretical basis for understanding typical interactions between humans and the environment. Only by introducing the adaptive element, however, does it become possible to accurately portray and understand typical interactions between humans and the environmental system. Acting adaptively is therefore imperative when dealing with complex, highly uncertain situations with many unknown variables.

Remaining flexible throughout the development process, experimenting, involving stakeholders and adapting to the needs dictated by partners, the market or the regulatory framework was an explicit objective of at least three of the four case studies. The studies demonstrate that managing regeneration adaptively enables stakeholders to deal with inherent uncertainty more successfully and can contribute to sustainable outcomes even in a setting where sustainability is not an explicit goal.

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