

# Mastering the complexity of environmental problem solving by case study approach

**Working Paper**

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**Publication date:**

1995

**Permanent link:**

<https://doi.org/https://doi.org/10.3929/ethz-a-002039536>

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**Originally published in:**

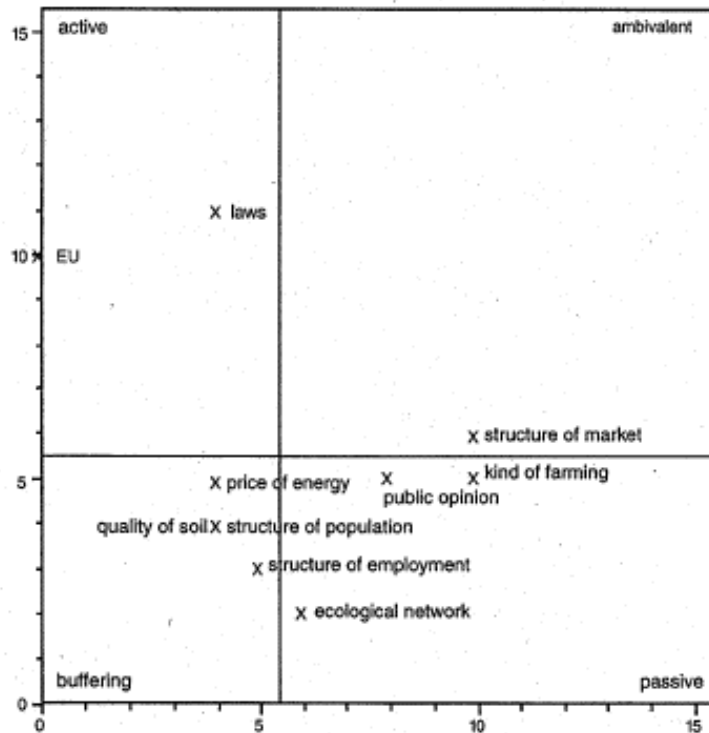
Arbeitspapier / UNS 7

**Working Paper  
Arbeitspapier  
No. 7**

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Juni 1995



## UNS Working Papers

**Publisher:**

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### **This text has been published as:**

Scholz, R.W., Mieg, H.A., and Weber, O. (1997). Mastering the complexity of environmental problem solving with the case study approach. *Psychologische Beiträge*, [Contributions to Psychology] 39, 169–186.

## 1. Introduction

The case study is considered both as a method to learn, to teach and to transfer knowledge as well as a research methodology. As a teaching strategy, the case study approach has been **developed** at the Harvard School of Business Administration for teaching behavior in business situations. As a research method it particularly permits a scientific treatment of vague (i.e. „ill-defined“) and complex real world problems and has first been applied in anthropology, the social sciences and law. We regard case analysis as a suitable paradigm to attain insights into the complexity of environmental decision making and also as a method of integrative decision making. Doing case analysis provides insight into qualitative aspects of environmental decision making.

## 2. Environmental Problem Solving

### *2.1. Environmental problem solving as a goal of education and research*

Is environmental problem solving a scientific challenge? Let us briefly consider the new framing and the constraints of decision making within environmental sciences at the ETH Zurich.

The department of environmental sciences has been founded after the Chernobyl and the Ciba Geigy Schweizerhalle disasters in the mid-eighties. One of the main objectives of research and education in that department is to develop a general environmental problem solving ability. The formula describing this ability is the subsequent (cf. also Frischknecht, 1995):

Starting from a natural science analysis of the systems water, air and soil, the environmental scientist should be able to analyze the relationships between these systems and the biosphere ,and anthroposphere in order to provide foundations for environmental problem solving, and decision making.

### *2.2. Type of problems*

Which types of problems are to be solved. Which decisions are to be made? What features do environmental problems and decisions have? Let us consider some examples:

- Recycling Problem  
If we are recycling old glass-bottles at the public collecting point, usually we are bringing them down by car. How many bottles do we have to collect to reach a positive eco-balance?
- Sustainable Development  
Which agricultural or political means and decisions are most efficient with respect to a sustainable development of the county of Zurich?
- Greenhouse Effect  
What should the Swiss Government do with respect to its energy policy to contribute to an abolishment of the greenhouse effect?

All three examples represent typical ill defined and open problems (cf. McCarthy, 1956; Mieg 1993). But, are all real world environmental problems "ill defined"?

We considered the process of problem solving as a transition from an initial state to a desired state, the goal. In contrast to mere tasks, problems imply that the transition is in some sense difficult; a barrier has to be passed (cf. Dörner, 1979). As to real world environmental problems, the goal of the problem-solving process is very often not well defined or even not known. For instance, what actually is meant by positive ecobalance or what has to be understood by sustainability is difficult to define if one requires quantitative measurement. Furthermore, the initial state, i.e. the starting point, very often is difficult to assess. How unsustainable is the current state of the Zurich county? What, for instance is the Swiss contribution to the Greenhouse effect? And, how may the barriers of the problem be passed? Which information have to be incorporated for the glass recycling problem or which degrees of freedom are allowed in the process of attaining a reasonable solution. Should we buy a caddy and bring the bottles down by feet?

**Table 1:** Structure of problem solving

initial state	operations to pass the barrier	goal
empty bottles	bringing them to the collecting point by car	positive eco-balance
the county of Zurich	agricultural and political means and decisions	sustainable development of the county of Zurich
greenhouse effect	changing energy policy	stopping the greenhouse effect

**2.3. The case study approach**

Can we master such general problems like. the Sustainable Development Problem? Three questions are implied: Is there a scientific approach to such a type of problem? Is there an analytic and/or definite solution or optimal solution for such problems? Can we develop a suitable strategy for teaching problem solving abilities for such ill-defined problems?

We could simply answer all of these questions with a definite "no" and stop further argumentations. However these questions have to be tackled at least from an environmental point of view. We will present the case study approach how it has been developed in our department in order to tackle these questions.

Case studies are both a strategy for teaching and a research methodology. The former has been developed at the Harvard Business School of Business Administration (cf. McNair, 1954) and hundreds of managers have been trained by case studies. However, it also may be conceived of as a methodology of 'research, analysis and for applied problem solving (Hamel, Dufor and Fortin, 1993; Robson, 1993; Yin, 1989, 1993). In the following, we will briefly describe the case study methodology. As introduced, we consider case analysis as a suitable paradigm for attaining insight into the complexity of environmental decision making and also as a method of integrative decision making. Case analysis provides insight into the process of the acquisition and integration of knowledge and into the qualitative aspects of environmental decision making.

Let us briefly sketch some stakes of the case study approach. Like other research methodologies, the case study approach starts from an understanding of the prior change of a well defined system. We will introduce five salient principles of case studies (for a more comprehensive list see Scholz, 1993). For research purposes, a case study analysis should meet the following principles:

Principle 1: Keeping the complexity of a problem: Description and analysis of the case should be ,complex, holistic, involving a myriad of not highly isolated variables from natural and social systems. Furthermore the data are likely to be gathered at least in part by personalistic observation..." (Stake, 1976, p. 8). The case study researcher should target to understand and to remain the identity of an environmental system.

Principle 2: Knowledge acquisition by the study of system change: "A case study ... is an attempt to focus attention on the process of change, especially the critical factors that influence the direction and the quality of the change effort" (Dalin, 1975). Thus the case study approach starts with an understanding of the prior change of a well defined system. Hence, doing case research for the environmental sciences necessarily includes historical analysis and a retrospective check of the validity of assumptions and hypothesis.

Principle 3: Generalization by analysis (rather than by data): Within the current social and natural sciences, there is a strong tendency in favor of generalization by statistics. In contrast to that, the researcher applying the case study approach should rather generalize on the basis of analysis and not of data. This principle should hold for both generalization and abstraction in the case analysis and in generalization from the case (Blumenberg, 1972).

Principle 4: Study of the relationship between the specific and the general: Though a case study is dealing with a concrete phenomenon, it is not restricted to singularities. Case analysis always includes the interaction between singular and general issues. As a case study is tied to a singular phenomenon,, the comparison with the activities of an artist is challenged. However one should acknowledge that there is no generalization without the specific. A separation of generalities and specificities, is an illusion. Like the fact that general concepts are a prerequisite of an understanding of the specific, understanding may only result from an understanding of the concrete (cf. Otte & Vogel, 1978, Otte 1994).

Principle 5: Integrating different horizons of knowledge: Compared to traditional research the relationship between the researcher and the object of research is different. We do not speak of subjects and objects, but rather of participants and agents of the case study. In order to attain a holistic perspective, from an epistemic point of view, it is necessary to integrate the knowledge of the persons most closely acquainted with the system.

### **3.Epistemic and Epistemological Problems**

Let us reveal the epistemological problems that are inherent in complex environmental decisions.

The basic problem consists in verification: How are we able to verify whether one strategy is better than another one in solving environmental problems? Any decision model requires a comparison of decision alternatives. This is true for both the descriptive and prescriptive modeling of decision making (cf. Scholz, 1983; Yates, 1990). Thus we will meet the epistemological verification problem not only in analytic models of decision making but also within descriptive modeling.

### 3.1. The analytic dilemma of complex decisions

To understand the analytic dilemma of decision models, we can switch to the current state on the controversy about a famous mathematical theorem in the field of number theory, i.e. Fermat's last theorem.

The lawyer and amateur mathematician Pierre de Fermat discovered a lot of fundamental theorems about the structure of our number system.. When reading Diophant's Arithmetic, he noted at the margins of the book that there will be no solution for

$$X^n + y^n = Z^n$$

if  $x, y,$  and  $z$  are positive integers and  $n$  is greater 2. To many of us, this problem sounds very simple yet has driven lots of mathematicians into despair for more than 350 years. In order to change, this unwanted state, in 1905, for instance, the Göttinger Gesellschaft der Wissenschaften has offered a reward of 100.000 Marks for the solution of Fermat's last theorem.

In the last decades, the proof was attacked from two sides. On the one hand, the validity of Fermat's theorem could be shown for increasingly higher numbers. In 1987 one has reached  $n= 125080$ . On the other hand, a series of crucial theorems have been proved in different fields of mathematics like the theory of elliptic functions or commutative algebra. Via isomorphisms, these new knowledge may be used to approach a complete formal proof. In 1993, on July 23rd at half past ten, there was the following situation. The renowned mathematician Andrew J. Wiles provided a lecture to an extraordinary sophisticated audience of mathematicians and displayed a – presumably – complete proof Like many times before, the question has to be answered, whether Wiles has solved Fermat's puzzle or not. Does he receive the reward or not?

The difficulty in the presented proof of Fermat's last theorem is the incredible depth and range of arguments. This creates the following dilemma. Anybody who is able to understand a mathematical proof must have gathered so much knowledge that, basically, he might have found the proof by himself. Thus, if Wiles is currently the best and all of his knowledge is necessary to understand Fermat's. last theorem, no one else might be able to understand and to verify the proof Thus, due to the complexity of the proof, today, eventually no single person, and thus neither Wiles himself, might be able to verify reliably the set of theorems and, assumptions which brings them together. Actually, more than one year after Wiles presentation of the mathematical community, it was still ambiguous with respect to the verification problem of Fermat's last theorem. This can be taken from the controversy on the Gopher-mailbox-system. Today, the community presumably is more prone to argue for a remaining, gap in the proof Thus the decision, whether the mathematical proof is correct is a socially determined act or decision. It is finally governed and decided by those subjects who do have each of them partial insight into the different steps and structures necessary for a final solution.

**Note** that the, complexity of the environmental problems introduced, i.e. the sustainability problem and even the recycling problem, are of a much higher complexity than Fermat's last theorem, which only tries to treat a relation within the well structured set of positive integers. Thus, there is a general analytic dilemma of environmental decisions, as one, may usually find no sufficient sets of variables for which you may construct quantitative relationships 'Or probability functions.

We can conclude: We may neither expect any formal, quantitative analytic solution for problems like those presented nor may we expect that an individual will provide an optimally substantiated answer. Furthermore, like' in the case of Fermat's last theorem, for problems with high complexity, we must acknowledge the "social nature of truth". "Verification" is a collective, process. Similarly to the nature of environmental problems, problem. solving can also be A social, collective process (cf. Renn & Webler, 1992).

### **3.2. The dilemma of representation**

How is or how should environmental information be represented? From a cognitive point of view, we are used to distinguish between different types of representation. For instance one may discriminate between numeric, conceptual-verbal, pictorial (Paivio, 1971, **1978**) and episodic (Tullving, 1972; Hussy, 1993) information stored in the individual. For each of the different types of representation, one may create different models. For instance, the conceptual knowledge may be modeled as lists of attributes (Smith, Shoben & Rips, 1974) or semantic networks (Collins & Quillian, 1969).

However, in order to judge the ecological quality, sensation and pattern recognition are important sources of information for the environmental scientist. When investigating an environmental accident, e.g. a cocktail of pollutants in soil or water, the trained environmental scientist uses his nose and all channels of his sensory system. If a biologist has to judge the ecological quality of a certain location, he or she is trained to walk out in the very beginning of the studies in order to attain a holistic impression and after that he starts his analytical work.

From a plant sociologist's point of view, one crucial dimension of ecological quality is the degree of interlinkage of areas belonging to a bunch of different types of ecological quality. Thus the degree of ecological interlinkage is a highly complex and multidimensional pattern of ecological information which may not be sufficiently decomposed to certain dimensions. In the examples provided, we have to acknowledge that not only numerical or conceptual information are at work, rather more the interaction of the different modes of representation is necessary. We conclude: In order to model the information incorporated in environmental problem solving, all kinds of representations and their interactions have to be taken into account.

### **3.3. The inferential dilemma**

The representation problem may cause an inferential dilemma: a cognitive representation may involve different and conflicting cognitive inferences. We describe this problem in the framework of the Process and Structure Model of Thinking (Scholz, 1987).

Most cognitive theories distinguish between declarative and procedural knowledge (cf. Anderson, 1980). Similarly, in the Process and Structure Model (PSM), there is the distinction between a knowledge base and a heuristic structure. Additionally, the model postulates a goal system and an evaluative structure (cf. also Hussy, 1984).

The knowledge base contains the non-operative knowledge. For instance, numbers, concepts, episodes, formulas, pictorial knowledge etc. Within this knowledge base, we particularly discriminate between concrete, easily accessible concepts or knowledge, which is close to percep-

tion concepts and higher ordered knowledge. The latter usually is not only spontaneously accessible by an individual but has to be activated by a series of intermediate steps.

A similar distinction is made with respect to the operative knowledge. The operative knowledge contains heuristics, i.e. inferential methods of solution which, in contrast to an algorithm, do not guarantee that a solution will be found (cf. Kahneman & Tversky, 1982). The PSM discriminates between simple everyday heuristics and higher ordered heuristics. The latter are usually not spontaneously acquired within formal education.

Within this framework of a problem solving or decision process, different items or chunks from the knowledge base are initialized and different heuristics are activated depending on the load of the short term memory (cf. Klahr, Langley & Neches 1987).

An inferential dilemma may be caused by the elicitation problem. Within the model proposed, we assume that the heuristics are activated according to the short term memory load with issues from the knowledge base. If there is a mixture of direct accessible pictorial knowledge and higher ordered knowledge, different and conflicting heuristics may be elicited. One may apply a representativeness heuristic based on features of similarity or use an analytic, inference based on mathematical operations, when referring to the numerical information activated.

#### Intuitive vs. analytic modes of thought

There is no need to go into any details of the theory of modes of thought in human thinking, but we want to point out that there are different types of inference and that these types of inference are based on different types of representation. Clearly, this is nothing new and may be seen as a differentiated and cognitive view based on some fundamentals of Immanuel Kants epistemology on "Begriff und Anschauung":

Gedanken ohne Inhalt sind leer. Anschauung ohne Begriffe sind blind. Daher ist es notwendig seine Begriffe *sinnlich* zu machen. D.i. ihnen einen Gegenstand *in* der Anschauung beizufügen, als seine Anschauung verständlich zu machen. D.i. sie unter Begriffe zu bringen. Beide Vermögen, oder Fähigkeiten können auch ihre Funktionen nicht vertauschen. Der Verstand vermag nichts anzuschauen und die Sinne nichts zu denken. Nur daraus, dass sie sich vereinigen, kann Erkenntnis, entspringen (Kant, 1968, p. 98)<sup>1</sup>.

From an epistemological (and not from an epistemic) view, we consider Kant's distinction on the complementarities of the two domains of the knowledge base to be important for both, the representational dilemma and an understanding of the case study approach. In principle, we may distinguish between different modes of thought, e.g. the analytic and the intuitive mode, which are – among others – featured by different elements and domains of the declarative and procedural knowledge applied. This means that we consider both modes of thought as different states of activation of one and the same system, described through the Process and Structure Model. Within the intuitive mode, which is normally existing, the individual is processing with

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<sup>1</sup> Thoughts without content are empty. Sensations without concepts are blind. Hence, it is necessary to make one's concepts sensual, that is to supplement the them by an object in sensation, to make one's intuition comprehensible, that is to bring it under concepts. These two abilities or capabilities cannot exchange their functions either. Reason is unable to percept/intuit, and the senses are unable to think. Only from their uniting may knowledge spring.

the direct accessible knowledge and simple everyday heuristics, whereas within the analytic mode, higher ordered knowledge and the goal and evaluative system are activated (cf. Scholz, 1987).

Which type of inference to be superior is very difficult to decide. In general, this very much depends on the relation between the task and the knowledge available in the decision maker. Very, often the holistic intuitive judgment based on a brief visual information is superior, especially if you consider the trained expert. Many physicians immediately know, when facing a client whether he or she has a severe disease, even if the laboratory values are o.k. (for discussion cf. Shanteau, 1988).

Of course the same is true for the trained environmental scientists. Thus some currently planned environmental monitoring program in Switzerland will incorporate the holistic judgment. Usually in environmental science there are just but few simple problems in which we may assume a general superiority of analytic procedures. We will label this problem as inferential dilemma. In *a nutshell, the inferential dilemma consists in the following: The use of the intuitive mode of thinking counteracts the common scientific methods which are committed to analytical rationality; but the analytic mode of thought is completely lost facing environmental problems.* We can conclude: different modes of thought may provide different solutions or decisions without knowledge about which mode is superior (in general). The question is: What to do with conflicting results from different modes of thought?

#### No rapid switches between modes of thought.

Obviously subjects are not very prone to switch between the different type of representations and/or modes of thought when working at one and the same problem. In a series of experiments (cf. Scholz, 1987), we collected written protocols on the thinking of subjects working on base rate problems. A rating on the type of used representation and on the applied mode of thought not only showed a high reliability but also revealed that, when working at one and the same problem, subjects usually do not change the modal type of representation, e.g. switching from numerical representation to a pictorial one. This also holds true, if the subjects repeat working at the same problem on subsequent days.

#### A note on the evolutionary aspect.

Many people like Switzerland, particularly the Mountains and the wonderful valleys with cows and the 'green meadows. And very often laypersons and even for a long time the farmers considered deep sound green meadows as' a typical signal for natural health. However, today, the environmental scientist knows that deep green and the absence of flowers and herbs is a clear indicator for particularly intense fertilization and thus has to be judged negatively from an environmental point of view. 'there we have no biodiversity which would be a sign of a positive environmental state.

The environmental expert of today prefers soft green. It is most interesting to see that the value systems of many farmers has shown some change. Recently a colleague of mine, together with a group of farmers, was standing on a hill looking around a screening the fields and meadows. He was told: "Look at the dark green lawn down there, this is still intensively cultivated. Today we like the pastel colors."

### **3.4. The knowledge integration problem**

What has been outlined about the different types of representation and the inferential dilemma may be considered as one specific aspect of knowledge integration in decision making. The proceeding remarks however all refer to the individual.

However, beforehand, environmental decision making is a social affair and so is the problem of knowledge integration. In order to understand what has to be integrated from a perspective of using the collective resources, we will just name the two most important dimensions within the collective knowledge integration:

1. Disciplinary integration
2. Integration of interests and qualities of knowledge present in different individuals and communities

*The dilemma of the arising knowledge integration problem consists in the following: As an environmental scientist, you have to rely on data sources which do usually not deserve scientific recognition.*

Furthermore, from an environmental point of view, there may be the problem of system integration. This and the practical problems of knowledge integration will be explained in the context of the case study 94 "Grosses Moos".

## **4. The case of the case study "Grosses Moos"**

### **4.1. Initial goal formation**

The so-called Grosses Moos („Great Swamp") is a region in Switzerland consisting of three connected lakes west from the Capitol Berne. In former times, the area between these lakes was a mire. The mire has been repeatedly drained in the last 130 years by huge melioration programs. Nowadays, between the three lakes, there is a large plane of about 500 square kilometers, and there are about 30 communities with a little less than 50 thousand inhabitants.

The problem or major question and the initial goal formation of the 1994 case study "Perspektive Grosses Moos" can be summarized by the following two sentences:

*Which decisions and changes have to be targeted for the future use of agricultural land in the Grosses Moos in order to attain a sustainable development of the entire regional ecosystem, within the existing legal framework? What is the contribution of the Article 31b of the Swiss Agriculture Act in particular?*

According to this new article, each farmer will receive a direct reimbursement for all acres which are cultivated according to the rules of biological agriculture or to another form of soft agriculture, called Integrierte Produktion. However, in order to get this payoff, the farmer has to re-nature 5% of his area.

The Grosses Moos may serve as an example of a region where the major problems cannot be solved by an immediate, clearly defined technical action plan or decision, since the area is subject to long term dynamic changes including soil subsidence, ground water problems, use of fertilizers, etc. These problems cannot be ignored in future but should be solved. Objectives and

concerns of the 1994 case study has been formulated by a commission of 15 students and half a dozen of researchers of the Department of Environmental Sciences.

Normally, problems of the Grosses Moos type have been banned as objectives from problem solving and decision research as well as from natural sciences due to their complexity and vagueness. Stuff like the Grosses Moos story thus has been abandoned to the field of politics. The choice of the topic Grosses Moos was motivated by the aim to find a prototypical example for complex environmental problem solving. This attempt was motivated by the failure of the traditional disciplines to contribute to an understanding and governing of environmental problems.

#### **4.2. Design of the study**

In principle, one may distinguish between holistic and embedded case studies (Yin, 1989). Within embedded case studies, different analysis methods are applied to attain insight into the system and its characteristics, while keeping the holistic perspective. In contrast, pure holistic case study designs only provide for a single unit of analysis.

The design of the Grosses Moos case study (figure 1) is an embedded one. It is structured in four systems, first the ecological aspect, second agriculture, third economy and politics, and fourth the social aspect. For each system, there are various sub-perspectives or subprojects. These subjects present the disciplinary perspectives, for instance hydrology (cf. project 1.1.), pedology (cf project 1.5), economics (cf. project 3.2), and social psychology (see project 4.1).

#### **4.3. Knowledge acquisition**

In the beginning of the study a project committee designed plans of data acquisition and disciplinary analysis for all 18 subprojects. The framework was set by economical and social considerations, but also by the environmental system Grosses Moos itself. The objective was to investigate the framed "reality" in the Grosses Moos as extensively as possible. For this purpose not only the interdisciplinary scientific cooperation is important. From the very beginning, we established an involvement of municipalities, public authorities and interest groups. This cooperation was established by two reasons:

First, when integrating the different knowledge of the stakeholders and the people who live and work in the area, the "goal of competence" of the case study agents can be met (cf. Renn & Webler, 1992, p. 86). This competence will be used in the process of finding a collectively consented problem solving strategy.

Second, when looking for an environmental problem solving, the people from the area are the most crucial ones, as in the end it is their share to realize problem solving strategies towards a sustainable development. However one of the most important goals is the implementation of the strategies (cf. Scholz & Weber, 1993).

**Figure 1:** Design of the Grosses Moos case study

<b>CASE STUDY '94</b>			
Future use of the agricultural area 'Grosses Moos', within the legal framework aiming at a Sustainable development. Perspectives and their consequences for, nature and society.			
<b>1. ECOLOGICAL ASPECTS</b>	<b>2. ASSESSMENT OF AGRICULTURE</b>	<b>3. ECONOMY AND POLITICS</b>	<b>4. SOCIAL ASPECTS</b>
<p style="text-align: center;"><b>1.1</b> Control of the water balance: Artificial changes of the hydrological system</p> <p style="text-align: center;"><b>1.2</b> Lakes, rivers and canals: Near natural realization of the canal system</p> <p style="text-align: center;"><b>1.3</b> Other habitats: Ecological potential of the settlement area and of the agricultural area</p> <p style="text-align: center;"><b>1.4</b> Wind protection trips, hedges and forest: Proposals to enhance the ecological status</p> <p style="text-align: center;"><b>1.5</b> Soil development: Conflicts with the soil use</p>	<p style="text-align: center;"><b>2.1</b> Agricultural diversity: interrelation between the diversity of use and the ecological situation</p> <p style="text-align: center;"><b>2.2</b> Aerial aspects: Interrelation between field size and ecology</p> <p style="text-align: center;"><b>2.3</b> Energy balance: A tool for the ecological assessment of the agriculture</p> <p style="text-align: center;"><b>2.4</b> Nutrient balance: Comparison of different types of cultivation</p> <p style="text-align: center;"><b>2.5</b> Further matter balances: Dynamics of regional matter fluxes</p> <p style="text-align: center;"><b>2.6</b> Analysis of business management: The effect of different measures</p>	<p style="text-align: center;"><b>3.1</b> Agricultural commodities market: Position of and perspective for the 'Grosses Moos region within the agricultural commodities market</p> <p style="text-align: center;"><b>3.2</b> Other economical branches: Economy and ecology</p> <p style="text-align: center;"><b>3.3</b> Administration: Enforcement of agricultural ecological laws</p> <p style="text-align: center;"><b>3.4</b> Interest groups and parliaments: Agriculture within the 'Grosses Moos' region</p>	<p style="text-align: center;"><b>4.1</b> Population: Ecological attitude; acceptance of ecological laws</p> <p style="text-align: center;"><b>4.2</b> Information and education: Effectiveness of programs for information, advice and education</p> <p style="text-align: center;"><b>4.3</b> Change of social values: Conflicts between amelioration programs and change of social values</p>
Media-Group: internal and public information		Synthesis-Moderation-Group: Moderation of the synthesis process	

Most surprising for many people was the fact that the case study Grosses Moos has been organized as a training course. The case study is a component of the curriculum in Environmental Sciences at the ETH Zurich. It covers 18 hours per week in the eighth semester. In 1994 exactly 105 students were working for about 13 weeks in the case study. Thus the knowledge acquisi-

tion (as involved by the design in figure 1) was not organized by 18 experts as one might assume, rather more by 18 groups of about 3 students, which were supervised by sophisticated researchers. The overall target was to analyze the region Grosses Moos in order to develop a midterm basic orientation and problem solving for the ecological development of the region Grosses Moos, and this target was accompanying the work in the different subprojects. However, the methods and tools applied were highly discipline oriented with the range from piezometer studies for measuring the water potential of the soil, differential equation models for the groundwater modeling, through historical surveys on ecological history to inquiries on the evaluation of the acceptance of direct payoff for the farmers. Thus in some respect the process of knowledge acquisition has been organized as a three dimensional bootstrapping with the dimensions:

- System view
- Disciplinary organization and
- Type of knowledge in the different agents of the case study

The kind of knowledge acquisition had implications for the knowledge integration.

#### **4.4. Knowledge integration through syntheses**

As shown by the design of the case study in figure 1, 'we organized the knowledge acquisition along a kind of a four factors system times discipline matrix. Before the integration of the knowledge could be arranged, the researchers, i.e. the students, had to analyze the Grosses Moos from the compartmentalized perspectives in different subprojects according to the concepts and methods of the different disciplines. Note that in this process the knowledge of the people living in the Grosses Moos and the agents of the case study who are not belonging to the scientific team have been repeatedly incorporated in all subprojects by many interviews and informal encounters.

The case study Grosses Moos can provide sufficient insight into the architecture of knowledge integration with respect to representation formats, disciplines, perspectives, and personal knowledge. As described, the scientific staff of the 1994 case study worked for more than eight weeks in the predominantly discipline oriented subprojects. After this, we arranged seven syntheses or knowledge integration processes. All these syntheses were arranged in the same manner. According to the range of synthesis or problems to be dealt with, experts from the different projects were forming teams of 5 to 20 researchers. As all the different subproject perspectives are present in the respective groups, you may speak about a kind of collective bootstrapping within the case study.

The most encompassing types of knowledge integration were concerned in area negotiation and scenario analysis. The area negotiation should develop a problem solving strategy for an optimal concept and design for the 5% of ground which should be re-natured within the whole area of the Grosses Moos. This approach is full of inferential dilemmas and social conflicts. This is particularly caused by the exchange of grounds and fields which might be necessary to inter-link ecological areas.

The scenario-analysis is a semi-quantitative method for long term, strategic planning. Mostly it is used in economics (cf. Götze, 1991; Segner, 1976; von Reibnitz, 1992) but also in politics (BUWAL, 1994). The objective of our scenario-analysis was close to the initial goal of the case study. It was to suggest activities for the agriculture and the authorities to attain a sustainable development (cf. Meadows & Meadows, 1992; Simonis, 1990) of the whole area. We will exemplarily review the process of this synthesis or knowledge integration and will outline, how we tried to master the complexity of the Grosses Moos in our case study by the method of scenario-analysis:

The first step consisted in achieving a collectively consented conception of the general goal of our case study. This was a redefinition of the concept of sustainability with respect to its ecological, economical and societal dimensions. Note that sustainability itself is a concept, which is much more on the holistic side (cf. Meadows & Meadows, 1992; Simonis, 1990), however, we again tried to get insight and understanding by an analytic decomposition.

The second step was a concept driven one and thus the individual analytic decomposition of the whole. We had to deal with questions like: What are the most important variables that affect the logic, development and change of the Grosses Moos? Which external and internal impact-variables govern the quality and the Gestalt of the Grosses Moos today and what will govern the change in the future? Like in the first step and similarly like in the mediation projects of Ortwin Renn (cf. Renn & Webler, 1992), this process also was a mixture of individual, small group and plenary activities.

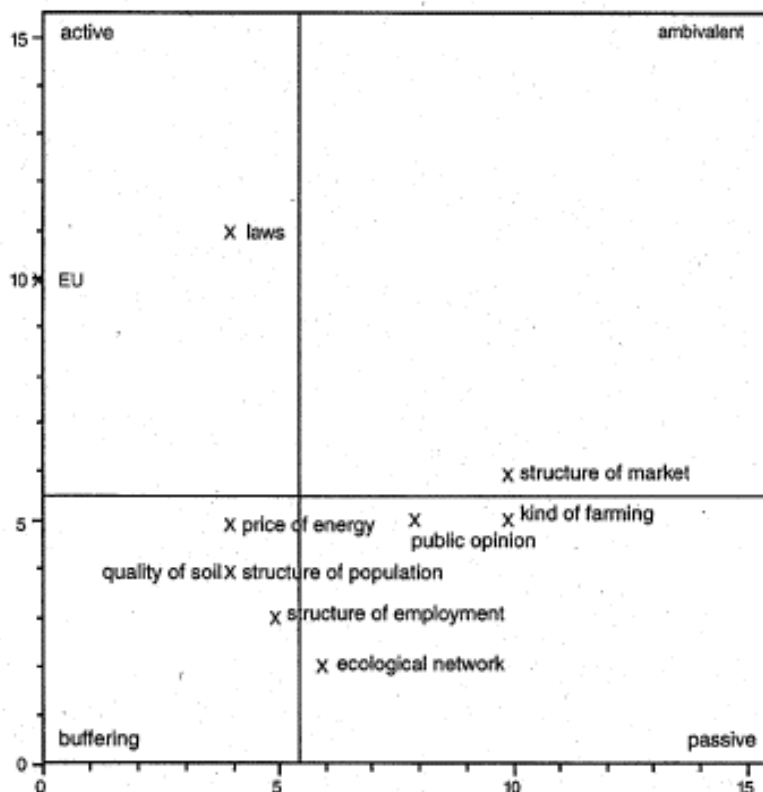
In order to construct a myriad of not isolated variables, a table of 24 impact variables was created in an iterated process. Initially, in three parallel groups, different generating schemata were created – we will not go in detail into this process, which provides many interesting questions for experimental research in social psychology (for details see Scholz, Koller, Mieg & Schmidlin, 1995). Then, for all the impact variables, written definitions have been developed and consented in the synthesis team, to allow a common conversational basis. Then, the variables were intuitively grouped. Again, this grouping process is a collective one. Finally, when considering the whole area and incorporating all the knowledge inherent in the group, we tried to select the variables believed to most sufficiently present the system and its dynamics.

The third step of our journey into the knowledge integration was the construction of a cross-impact matrix. According to the method of scenario analysis (see Götze, 1991), we tried a semi quantitative approach. The mutual impacts of the different variables are rated on a three level scale with the levels "no impact", "medium impact", "strong impact". As a side product, this process rendered a deep insight into the structure and dynamics of the system. It must be noted that we rated the current degrees of **direct** impacts. The indirect impact, e.g. if variable K is affecting a variable M via L, are not considered and rated. Also the relative importance of the different variables are only conceived by the degrees of influence and not by other characteristics. Figure 2 shows the reduced cross-impact matrix of the impact variables and figure 3 shows the according system grid.

**Figure 2: Reduced cross-impact matrix**

	Structure of market	costs of energy	Structure of employment	EU	laws	kind of fanning	Ecological network	quality of soil	Population structure	public opinion	
structure of market	0	0	2	0	1	1	0	0	1	1	6
costs of energy	2	0	0	0	0	2	0	0	0	1	5
structure of employment	1	0	0	0	0	0	1	0	1	0	3
EU	2	2	0	0	2	1	0	0	1	2	10
laws	2	2	1	0	0	2	1	1	1	1	11
kind of fanning	1	0	0	0	0	0	1	2	0	1	5
ecological network	0	0	0	0	0	1	0	1	0	0	2
quality of soil	1	0	0	0	0	2	0	0	0	1	4
population structure	1	0	1	0	0	0	1	0	0	1	4
public opinion	0	0	1	0	1	1	2	0	0	0	5
	10	4	5	0	4	10	6	4	4	8	55

**Figure 3: System grid**



The fourth step may be denoted as "analysis with intuitive judgments". Even this rough analytic cross impact matrix allows for operations on the sign level. If we accept the fuzziness in the change of representations, we may attain further insights into our conception of the system by formal operations. For instance, if we simplify this cross impact matrix to a matrix A having only two degrees of impact, say 0 for no or small and medium impact and 1 for strong impact, matrix algebra might be helpful as it conceives of the system as of a discrete automat. By multiplying matrix A with itself, according to the method of MICMAC-Analysis (Godet, 1986; Godet, 1987), we are able to attain information by the matrix  $A^n$  about the order of the 24 impact variables according to the extent they are incorporated into the network of impact variables.

**Table 2:** Order of higher ordered linkage variables

1. EU	12. kind of farming
2. laws	13. <b>pests</b>
3. interest groups	14. additives
4. administration	15. unemployment
5. structure of the market	16. <b>quality of soil</b>
6. costs of energy	17. <b>level of lake water</b>
7. greenhouse effect	18. structure of population
8. yield	19. traffic engineering
9. commuters	structure of employment
10. well-being	21. <b>soil treatability</b>
11. innovation	22. ecological network

It is most interesting that this analytic mathematical modeling, using an intuitively generated group consensus about the cross-impact of the relevant variables, serves us to derive evidence that some hypotheses disputed within environmental science may be valid. In particular, we were able to substantiate that environmental variables like ecological network, soil treatability, quality of soil – within a 20 year perspective – are of minor importance. They are less embedded and inter-linked within the network of impact variables compared to variables of social systems like laws and interest groups. Table 1 contains the 24 variables ordered according to the importance of variables in our matrix algebra. This means that they are ordered according to their long term impact according to our semi- quantitative matrix algebra. As a result, the ecological variables are of secondary importance with respect to the whole system.

## 5. Conclusions

Generally speaking, environmental problems are a special type of ill defined problems. They are complex problems which involve a severe verification dilemma. we concluded that there is the necessity of collective problem solving-problem. Furthermore, environmental problems face the epistemological dilemma of representation („intuitive" or „analytic") and the inferential dilemma (conflicting heuristics).

The case study approach is a methodology for environmental problem solving and decision making that allows knowledge integration through synthesis with respect to various dimensions, i.e.

- disciplines,
- environmental components or systems and
- the roles and types of knowledge in the agents of the case study.

Thus problem solving or decision making is not only conceived as an epistemic or epistemological problem but also as an organizational one. In general, the organization and the integration of different types of knowledge is the essential both of integrative decision making and the methodology of case study research.

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