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Collaboration Tools for Project Initiation

Introduction: Conceptual modeling of case-study systems

Projects involving complex systems are often transdisciplinary and involve diverse, societal stakeholders, especially when integrated cooperation and applied goals are in focus. Communication within and outside the project consortium can be challenging for academically trained specialists because terminology, observational documentation and scientific argumentation vary between disciplines and stakeholders have specific priorities. Quantitative and qualitative data often need to be combined for decision support. Although these issues are well recognized, there remain many barriers to effective cooperation. This is especially true in international cooperation due to language and cultural, economic and historical circumstances. At the same time, partner differences are advantages if they can be constructively combined. For instance, indigenous and site-specific knowledge are very important for both project realization and eventual application of the results. Conceptual modeling of the case study system can facilitate the identification and integration of necessary project components, but these need to be taken into play at an early stage in order to identify feasible goals, suitable partners and necessary project components and partners. Therefore, a platform to do this is suggested by an infrastructure of activities: 1) a web-based methodology, with actual initiation of case studies to exemplify the value of conceptual models as cooperative tools, and 2) workshops to highlight the cooperative platform functions and the case studies themselves.

This paper provides a step-wise approach to conceptual modeling. There are alternative definitions and approaches, but this “manual” is a simplification in that it describes a single modeling procedure. This is partly justified by the main objective: to provide an easily accessible platform for cooperation, effective communication and integration of perspectives. More comprehensive discussions of the modeling alternatives are provided by Keeney & Raiffa (1976), Scholtz & Tietje (2002), and Vester (2007).

Step-wise procedures for conceptual modeling

1. System characterization

Background

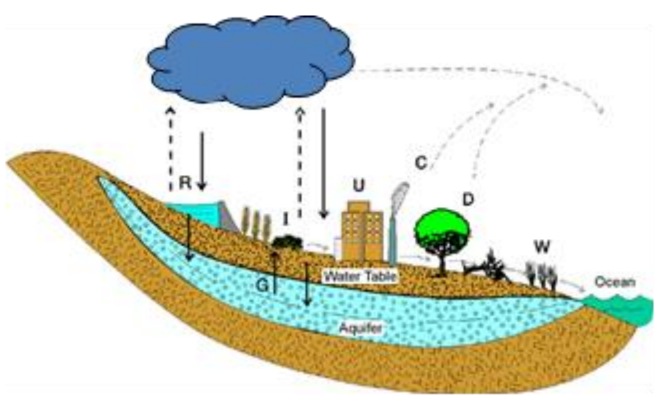

Fig. 1. *Example sketch of an environmental system.*

Before you begin building a model, you need to identify the goals, i.e. the need for understanding the system. If the environment or conditions associated with the problem are not known, these need to be defined as much as is feasible. Failure to properly identify the problem and the complexity of the setting will likely lead to an incorrect solution. Therefore, this first modeling activity, sometimes called the “gestation” stage involves the gathering of background information, learning about the system, identifying relevant information, familiarization with the problem and, if necessary, reviewing the science. It cannot be over emphasized that describing the system and devising a reasonable conceptual framework and boundary conditions will help keep the subsequent model realistic and in focus on the questions at hand.

Steps

1.1. Using words and one or more simple hand sketches, define the system within which the problem or issues of interest occur. Use a top-down approach where the outer limits of the system are initially not set, but rather the functionality of the parts is in focus to define the whole. A picture/cartoon of the system/environment will often help to visualize the components. Sometimes it is suitable to use a geographic map (sketch, satellite image or similar) of the area Add comments on the relationships between the components and processes in the system, which are needed for approximating the system processes. For example, subsystems might connected by flows of causality, matter, energy and/or information that can be roughly described. Note that this work is ideally done within a multidisciplinary group where perspectives and knowledge backgrounds will complement each other. However, the procedural aspects of conceptual modeling are important and beneficial for individual or small groups, as long as the risks resulting from a lack of diversity are.

1.2. Based on Step 1, list a set of assumptions and simplifications regarding relationships between the various factors and processes defining your system. The robustness of a model depends largely on the validity and scope of these assumptions. The quality of any assumption will depend of the level of scientific knowledge underpinning it. It is not necessary that all the assumptions are correct. However, any and all assumptions should be well understood and clearly stated. With an appropriate (feasible but realistic) level of detail, include and all the processes necessary for describing the system. It is vital that inaccurate assumptions do not seriously affect the desired results. Start with a simple structure for your model. Performance can later be improved by deliberately and accurately increasing the model's complexity.

1.3. On the basis of the system sketch, suggest the parameters that appear most appropriate for modeling. As much as possible, the parameters should be taken from the same level within the hierarchy of the system. Again, a multidisciplinary group can be necessary to provide alternative perspectives and knowledge. Brainstorming to produce a list of parameters by combining these perspectives is often a way forward. It will probably be necessary to separate parameters into subsets and according to scale (or other hierarchical systems). A "mind-map" might be suitable for representing these relationships. Modeling will usually require a prioritization and reduction of the parameters. A set of 5-10 parameters might be used in the first models, remembering that modeling is usually an iterative processes, where parameters can added or subtracted as might be justified by their importance, interdependence or frequency.

2. System structural analysis

Background

Influence diagrams (such as Fig. 2) are a typical conceptual presentation of system interactions between parameters. These can be, and often are, drawn without clearly specifying the actual relationships (arrows) between the parameters. The diagram then relies largely upon the understanding

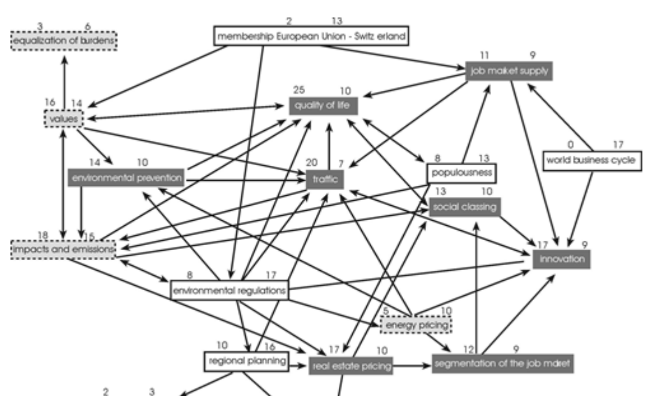

Fig. 2. *Example of an "Influence Diagram" illustrating the variables and their impacts on each other within the "Zurich North Shell Scenario" (Scholz & Tietje 2002).*

that the individual or group has of the system. The trouble with this is that the unidentified and non-structured information behind these relationships is not easily transferred to others and if knowledge of the system improves it is also difficult to successively add this information to the diagram. In fact, a proper system analysis usually results itself in a better understanding of the system because it forces a review of the parameters and assumptions and a closer comparison between the different parts.

This step in the conceptual modeling aims to provide a structured approach to identifying and specifying the parameter relationships in a system. This work assumes that the system (environmental setting or the general framework of the problem) has been defined and the need for building a model and the general aim of the analysis are known (see *System characterization*, above). A list of priority parameters that best characterize the system should also exist. The specific objectives are and the relevant scenarios that are to be considered may be already decided, or they may develop and change as the system analysis clarifies relationships.

Steps

2.1. Using the system parameters on both axes, construct a "system interaction matrix" (sometimes called an impact matrix) where the impact of each of the row parameters on each column parameters is given in the respective off-diagonal cells of the matrix (see the examples in the literature references provided). The diagonal cells do not have values since these represent the same parameter in the rows and columns. The matrix is not symmetrical, since the impact of A on B is not necessarily the same as B on A. The scale for the impact value can suitably be 0-3, but more or less differentiation can be appropriate, depending on how well the relationships are known. In a very well-known system, these relationships might be physically identified and quantified, but this is seldom fully possible with environmental settings and similarly complex systems. The impact estimations can nevertheless be built upon the relevant documentation available. Also, multidisciplinary groups will increase the knowledge base for these evaluations.

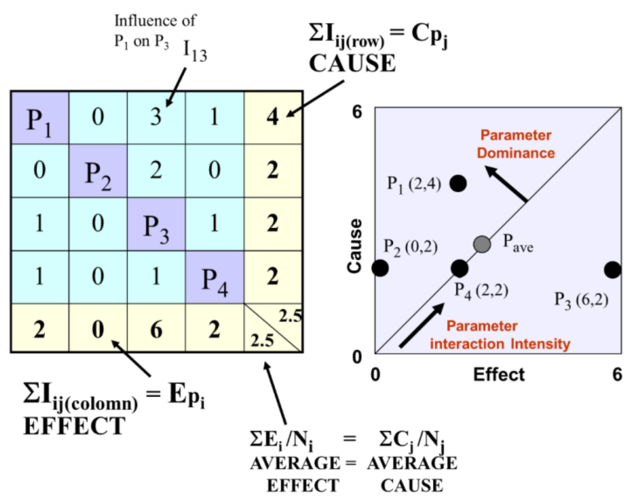

Fig. 3. *Typical influence matrix and "cause-and-effect" diagram representing the results.*

2.2. Using the row sums to represent the combined impact of each parameter on all the other parameters, and the column sums to represent the effect of the other parameters on each of the individual parameters, plot these values in a "Cause and Effect" diagram (the terms "activity" and "passivity" are used instead). The position in the diagram can be discussed in terms of the relative impact and the volatility (changeability/responsiveness) of each parameter. The intensity of the combined parameter interaction increases along the diagonal and is greatest for parameters plotting in the upper right corner. Those in the lower left corner are less influential and less responsive, but they may still be very important for the overall system functions.

2.3. An influence diagram can now be constructed using different arrows to show the strength of the relationships. This diagram is then based on the values in the interaction matrix. It is usually necessary to limit the number of arrow by not showing the weakest connections in order to maintain simplicity, although these relationships are still represented in the influence matrix.

2.4. Using the influence diagram (but also checking back to the influence matrix), list all (or the relatively strong) the feedback loops that you can identify. These also provide a good basis for considering the dynamics of the system, where positive feedback loops tend to destabilize and negative loops tend to stabilize the system.

Note: Mic-Mac analysis and consistency analysis of the influence matrix are appropriate, but are not initially dealt with in this example.

3. Synthesis modeling (using Multi-Criteria Evaluation, MCE)

Background

In this step, constructive modeling is done using Multi-Criteria Evaluation, which is a very useful tool for combining the impact of different parameters (or variable) within a system. Up to now we have focused upon the internal relationships and interactions between the parameters, but now this focus shifts to the actual problems. The parameter impacts will be evaluated RELATIVE to the stated problem or scenario issue.

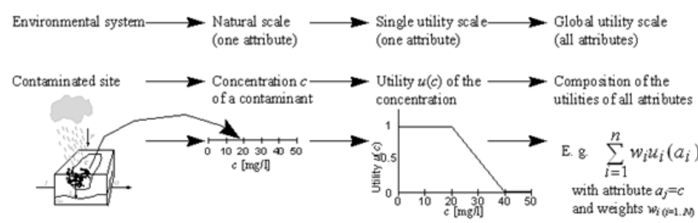

Fig. 4. *The structure of a MCE (Scholz & Tierje 2002). See text for explanation.*

In the Fig. 4 the overall structure of a MCE is illustrated, where the variation each parameter within an environmental system will vary on a scale and with units that are likely different from other parameters. Therefore, an important step in the MCE is to "standardize" these measures to a "unity scale" of 0 to 1 by using a function graph that relates the original values (e.g. in mg/liter for a contaminant) to the new 0 to 1 values so that they can be compared and combined with the other parameters. The parameter "utility" is then an expression for how the impact of this particular parameter varies relative to the specified question, from 0 (no importance) to 1 (the maximum importance for this individual parameter). If the question in the example above was to evaluate the impact on soil (legal) suitability for a playground site, the graph suggests that contaminate concentrations below 20 mg/l do not negatively affect the suitability, but higher concentrations do. This function can be based on well-known relationships, but in many cases it may involve experience, legislation, public opinion or common sense as well. A straight line function can be used if you do not feel that that you can motivate a more detailed relationship. Remember that even relative trends (such as a negative relationship) say something important and are usually better to include rather than saying that you do not know "enough". Nevertheless, the uncertainties need to be noted.

The parameter utilities are then multiplied by the weighted importance of each parameter relative to the others (see steps below and in the literature examples). Even this procedure is not without some subjectivity, but this can be limited by multi-disciplinary input of information from project participants, new empirical data and from the literature, and from theoretical arguments. This may be hard to initially appreciate, but think of your model as a work-in-progress, where the first results reflect a simplified system that you can ideally continue to be improved once you see how it functions.

Based upon the prior "environmental sketch" and the system analysis, clearly identify the issue/problem is to be addressed. This could, for instance, involve a comparison of different scenarios where the system parameters are different and would give different developments or consequences.

Steps

3.1. If not already done, select the scenarios that represent important variations or alternatives and define the specific question you want to evaluate. Whereas the system analysis, above, aims to provide an understanding of the dynamics of the system, the MCE intends to provide predictive scenarios for comparison and decision support. Although both used matrices to tabulate the weighted relationships, the system-analysis matrix deals with internal influences of the parameters on each other and the MCE matrix records the relative importance of the parameters for the scenarios in question.

3.2. Derive the parameter "weights" by constructing a matrix with pair-wise comparisons between the different parameters regarding their relative importance for the "question". The most commonly used scale for this comparison is using the values: 1/9 – 1/7 – 1/5 – 1/3 – 1 – 3 – 5 – 7 – 9 (from least to most important in comparison to the second parameter). The sum of the rows is an estimation of their overall importance, and this value can be used as the parameter "weight" (normalization of these values is often done). Matrix eigenvectors are actually more correct to use, but the row sums approximate these in most cases.

3.3. Derive the standardized "utility" for each parameter by drawing the relationship (estimated or calculated from empirical information) between the range of actual values that can be expected to occur and the relative change in impact (0 to 1 scale) that this parameter has on the scenarios being considered (see Fig. 4). This is different from the parameter "weight" (Step 3.2) in that the "utility" is the parameter's changing impact relative to itself.

3.4. Multiply the "weight" and the "utility" for each parameter and sum these products for all parameters for each of the scenarios. The sum is often called the "Total Utility" and is used to rank the different scenarios (Fig. 4).

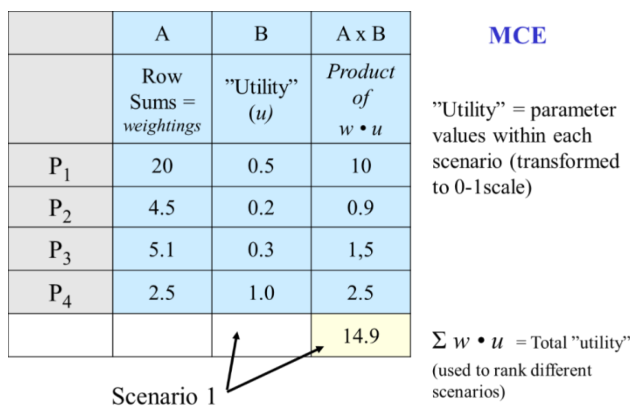

Fig. 5. *Derivation of the total utility by summing the products of weightings and utilities for each parameter, specific for each scenario to be considered.*