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Water Management Strategies in Urban Regions Analyzed by Partial Orders

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ABSTRACT

In contrast to conventional multicriteria decision aids we take the point of view of environmetrics: Let first the data speak, and then let us derive a ranking. In the present paper we introduce an improved "lab-version" of the decision support system METEOR (Method of evaluation by order theory). The basis of the method is a data matrix, whose objects are characterized by indicators. By means of the indicators a partial order is derived. In subsequent steps indicators are aggregated by a step-by-step weighting procedure, allowing a high degree of participation of stakeholders and other participants of the planning process. Hence a set of partial orders is obtained. The aim is to find finally either a linear order or (in order theoretical terms) a greatest element, i.e. an object which is the best in comparison with all others.

As example four indicators are derived and assigned to 14 river sections in the urban area of Berlin/Potsdam.

Categories and Subject Descriptors

H4. Information systems applications

General Terms

Algorithms, Management

Keywords

posets, water management, urban area, decision support systems

1. INTRODUCTION

Decisions concerning management of surface waters need to be supported by information about potential chemical pollution. Especially in cities, a spatial and temporal exposure pattern of various substances is to be expected. For the evaluation of management strategies with respect to the chemical pollution many methodological approaches are available with the following working steps: 1. The definition of options; in our case water management strategies 2. Modelling the effect of options and derivation of indicators 3. Evaluation of the management strategies, characterized by the indicators, derived in step 2.

As generally management strategies are characterized by more than one indicator a multi-attributive decision problem arises. The actually chosen evaluation procedure might however influence the final evaluation result and depends on the participation of stakeholders. The benefit of participation of stakeholders in turn depends on the transparency of the evaluation procedure and on the way how subjective preferences can be operationalized. Most of the decision support systems include as a methodological step the aggregation of all indicators (or of functions of the indicators) at once. The advantage of such an aggregation is that a linear order for the different management strategies and hence a unique decision is obtained. The aggregation usually needs parameters which express the preferences and by which the role of indicators can be weighted. We call these parameters weights.

Aggregation, however implies a compensation among the indicators: A "good" numerical value of one indicator can compensate "bad" values of other indicators. Often indicators are related to fundamental different aspects as for example economy and ecology. Therefore it is difficult and often controversely discussed, how to find the numerical values for the weights. Even worse: depending on the transparency of the evaluation method the influence of weights on the final result is hardly understood.

In this paper a "lab-version" of a decision support system is presented, which is based on simple elements of partial order theory (so called "Hassediagram technique" [1] (abbr. HDT), and in which the weighting procedure is not done at once but by a step-by-step procedure. This lab-version is called METEOR (Method of evaluation by order theory) and several publications are already available (see e.g. [2]).

2. MATERIAL AND METHODS

The study site is the region Berlin and Brandenburg in Germany. (for a detailed description see [2] and references therein). In order to define geo-referenced indicators the surface water system of this urban area was divided into 14 river sections. Each river section was evaluated by a set of four indicators. Two of these four indicators are the nitrogen concentration in water and the difference of the phosphate concentration in water to a target value. The effect of each strategy is estimated by the model MONERIS (MOdelling Nutrient Emissions in River Systems (see [2] and references therein). A full evaluation procedure by METEOR based on a decision matrix of 504 entries is already published [2]. For the sake of the convenience of the reader the basic steps are explained (for more information about partial order theory, see [1]. Start with the special partial order, namely the product (or component-wise) order. 2. Aggregate subsets of indicators to "super-indicators" and analyze the new partial order based on those super - indicators. 3. Repeat the step 2 until a linear order for a subset of actually interesting strategies is found, or a greatest or least strategy can be identified

Here we focus more on the role of weights and their interplay with order structures. In order to keep the things simple we only selected 4 river sections No 1, 2, 3 and 10 (following the labels of the already published results) and one indicator, namely the nitrogen concentration of each of the four river sections.

There are 9 water management strategies available (in other publications also called "scenarios") which are to be evaluated. In order to avoid lengthy description of the strategies, we enumerate them simply by 1a (the today's state), 1, 2, …,6 . The number 6 is representing an equivalence class of three different alternative sanitation techniques.

3. RESULTS

3.1 Partial Order (Step 1)

Based on four indicators and seven strategies (strategy classes) a decision matrix of six rows (strategies) and four columns (nitrogen concentration in the different river sections) is obtained.

In the first step three pairs of strategies could not be ordered because the comparability condition was not fulfilled. The corresponding Hassediagram is shown in Figure 1.

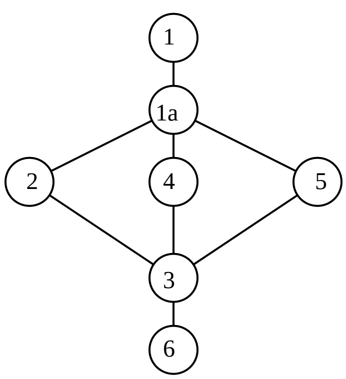

Figure 1: Partial order of the seven strategies, characterized by the nitrogen concentrations in the four river sections.

There are several possibilities to find new super-indicators. One may aggregate any two river sections, for example River section 1 and 2 on the one side and 3 and 10 on the other side. Hence one has to discuss only two normalized weights and the potentially difficult trade - off between protection of river section 1 (or 2) at the cost of section 3 (or 10) and vice versa can be avoided.

3.2 Aggregation (Step 2)

If we follow this aggregation strategy the variation of one weight (say g(1) for the first super-indicator) within the closed interval [0,1]) can be done independently of that of weight g(2) which is used for the second super-indicator. As result one obtains five rectangular areas in an coordinate system, spanned by g(1) and g(2) (Figure 2).

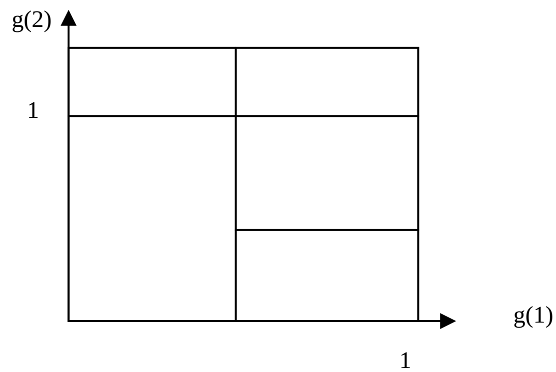

Figure 2: Stability fields (see text) found for the poset, visualized in Figure 1.

In any of these areas the weights may be varied without an influence on the resulting poset. If however boundaries are crossed then another poset based on the two super-indicators is obtained. Therefore we call the fields of an invariant poset "stability fields". Their extent and their geometrical location in the coordinate system of weights relieves on potentially controverse discussions about numerical values of the weights.

4. SUMMARY AND OUTLOOK

The construction of a poset, based on measured or simulated indicators is the most objective step within a decision support analysis. However this poset may not helpful for decisions, albeit of high interest in environmetrics. Therefore a step-by-step aggregation is recommended. The coupling of order structures with continuous variables, like the weights leads to geometrical structures in an weight's coordinate system which can be analyzed either with respect to embeddings of posets or - somewhat relaxed- with respect to similarity measures among the posets characterizing the stability fields.

The concept of posets, depending on tuples of numbers, which themselves belong to a metric space can be still further generalized. Hence we propose to denote posets depending on additional parameters "g-posets".

5. REFERENCES

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