Title: ***A Multicriteria Model for Optimal Control of an Environmental System***

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Abstract:

In controlling the development of an environmental system, for each decision variable several objectives have to be examined. In this paper, the objectives are first assessed by the use of fuzzy attributes and AHP/ANP method. Then, the optimal control of the system is presented in the form of a discrete dynamic model and the sequence of optimal decisions is determined by the iteration method of Bellman's type.

Key words:

environmental system, optimal control, decision support model, multiple criteria decision making, fuzziness, BOCR, AHP/ANP, DEA, network, dynamic programming.

Summary

Strategic, as well as tactical and operational planning for optimal management of environmental systems is a very complex task. The key matter is to use the resources efficiently and to control them in an economical, ecologically aware and socially acceptable way. Every decision/scenario undertaken in an environmental system affects several wide-ranging criteria, such as economic (crops, timber, wildlife, forage, etc.), ecological (biodiversity, water, soil, air control, carbon sequestration, etc.) and social (recreation, education, employment, etc.), ([2]). Therefore, for dealing with an environmental optimization problem, we have formulated and solved the problem by generating the decision support model from the multiple criteria decision making (MCDM), fuzzy and dynamic perspective.

Controlling of an environmental system consists of decisions over a long time horizon. These decisions optimize several objectives. Thus, in the model we are searching for the sequence of decisions, that jointly maximizes all objectives, respects prescribed constraints and imprecision, and takes the system from its existing state to the goal state, ([9]). The determination of the goal state requires an extremely high level of expertise, knowledge in environmental, economic and social issues, and above all a compromise among all parties involved in a decision process. It may even happen that for a particular system there does not exist a goal state which is able to fulfil the demands which, in general, are in conflict. In such a situation, the involved parties have to come to an agreement through a long set of negotiations to allow a goal state of the system to be defined. In cases like this, the Delphi method is often used to reach the agreement, [10]. Because the states and objectives of the system are also described with subjective and uncertain variables we use for these uncertainties and imprecision fuzzy methods. In order to assess the objectives, we first define the criteria, and then, divide the criteria into benefits, opportunities, costs and risks (BOCR), i.e. BOCR merits, ([3]). Their values portray short-term, long-term, evident, potential, positive, negative, tangible and intangible attributes of outcomes. Further, the criteria weights are determined by the use of analytic hierarchy process (AHP), ([5]), on the basis of experts' surveys. In AHP strict hierarchy relations between the criteria and the decisions are required. Due to the fact that in environmental problems the criteria can be interdependent and the decisions may provide feedback to the criteria, we adopt analytic network process (ANP), ([5]). Thus, ANP is closer to real situation and gives more flexibility for constructing the decision model. ANP introduces the concept of supermatrix. Further, the basic ANP structure with only one network is extended to BOCR structure, and thus ANP consists of four subnetworks, one for each of the four BOCR merits ([7]). BOCR factors of each decision are synthesized due to different formulas. A sensitivity analysis is also performed.

AHP/ANP derives a priority vector from a pairwise comparison matrix. How to gain a priority vector, has been an important research topic in the AHP/ANP and quite a number of alternative approaches have been proposed. The eigenvalue vector method and the data envelopment analysis (DEA) are discussed in this paper. Eigenvalue vector method was proposed already by Saaty ([5]). The use of DEA in AHP/ANP has been recently accomplished by Ramanathan, ([4]), and is known as CCR method. It is based on Charnes, Cooper and Rhodes results, [1], and adapted for calculating the priority vectors in the AHP. Newly, CCR method was modified by Wang and Chin, [6], and applied in AHP. Both methods, the eigenvalue vector method and DEA/CCR method, are in this paper also compared on the numerical example.

Further, the idea of fuzzy analytic hierarchy process is introduced within a discrete dynamic programming process. The analysis involves estimating the cumulative impacts of attributes (BOCR merits) that are calculated as a sum over all products of attribute's membership function f(x) (in the paper, we use a linear function of a trapezoidal form) and its relative importance (weight), obtained from AHP/ANP.

As soon as we determine for the treated environmental system the time periods, in each time period the possible states, for each state the possible decisions, the state transition function and assess the objectives, we are able to show all these elements in a form of network. In the network the states are designated by nodes, the transitions from state to the state in the next time period under the decision are designated by the connection of two nodes, while the supposed goal state is presented as the final node. Ultimately, the optimal sequence of decisions for multi-objective problem regards the generated network is found recursively using the theory of discrete dynamic programming based on Bellman's principle of optimality.

To illustrate the problem and the developed multicriteria decision support model we present some computational experiences from a case study in Slovenia, [8].

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