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Integrating multicriteria evaluation and stakeholders analysis for assessing hydropower projects

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HIGHLIGHTS

- The paper concerns a multi-level decision-making tool able to support energy planning.
- The evaluation framework is based on the use of AHP and Stakeholders Analysis.
- Hydropower projects in the Sesia Valley (Italy) are evaluated and ranked in the study.
- Environmental, economic, technical and sociopolitical criteria have been considered.
- 42 stakeholder groups have been included in the evaluation.

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ABSTRACT

The use of hydroelectric potential and the protection of the river ecosystem are two contrasting aspects that arise in the management of the same resource, generating conflicts between different stakeholders. The purpose of the paper is to develop a multi-level decision-making tool, able to support energy planning, with specific reference to the construction of hydropower plants in mountain areas. Starting from a real-world problem concerning the basin of the Sesia Valley (Italy), an evaluation framework based on the combined use of Multicriteria Evaluation and Stakeholders Analysis is proposed in the study. The results of the work show that the methodology is able to grant participated decisions through a multi-stakeholders traceable and transparent assessment process, to highlight the important elements of the decision problem and to support the definition of future design guidelines.

1. Introduction

The use of hydroelectric potential and the protection of the river ecosystem are two contrasting aspects that arise in the management of the same resource, generating conflicts between different stakeholders. In order to achieve a balance between increasing the production of hydropower and environmental protection, a clear comparative evaluation of different interests at stake on the basis of sustainability criteria will be necessary. Mention has to be made to the fact that the issues related to public participation and transparency in decision processes concerning river basins and water resources are recognized as crucial by the European Union (EU) Water Framework Directive (2000/60/EC) where stakeholder analysis is recommended as a method to support river basin management.

In decision problems in the context of energy planning, a very important role is played by Multicriteria Analysis (Supriyasilp et al., 2009; Nixon et al., 2010; San Cristobal, 2011; Mourmouris and Potolias, 2013). Generally speaking, Multicriteria Analysis (MCA) is used to make a comparative assessment of alternative projects or heterogeneous measures (Roy and Bouyssou, 1993; Figueira et al., 2005). These methods allow several criteria to be taken into account simultaneously in a complex situation and they are designed to help Decision Makers (DMs) to integrate the different options, which reflect the opinions of the involved actors, in a prospective or retrospective framework. Participation of the decision-makers in the process is a central part of the approach.

The present study concerns a methodological approach based on the combined use of MCA and stakeholders analysis for reconciling ecosystem conservation and hydropower exploitation of a river basin. The purpose of the paper is to develop a multi-level decision-making tool, able to support energy planning, with specific reference to the construction of hydropower plants in mountain areas.

In particular, the research addresses the decision problem under investigation through the integration between the Analytic Hierarchy Process (AHP, Saaty, 1980), on the side of the MCA evaluation, and the stakeholders mapping, together with the

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power/interest matrix, on the side of the stakeholders analysis. It has to be noticed that the integrated use of AHP and stakeholders theory has been considered in the scientific literature, especially in the field of waste management (Contreras et al., 2008; Geneletti, 2010; Shen et al., 2012) while the applications in the domain of energy planning are less consolidated.

Starting from a real case related to the Sesia river basin (Italy), the study describes the experimentation of the integrated use of MCA and stakeholders analysis with the final aim of reducing potential conflicts among the users of the water resources, of supporting the collaboration, the dialog and the exchange among users, scientific researchers, Municipal Authorities and private companies. Many actors with conflicting interests are present on the area. The overall objective of the proposed evaluation tool is to ensure ecologically sustainable flows of the rivers and to consider the economic and productive development of the territory, ensuring the life of the local communities (Rosso et al., 2012).

The study is part of the activities developed within the European project "Alp Water Scarce (AWS) – Against Water Management Water scarcity in the Alps" (www.alpwaterscarce.eu).

2. Methodological background

2.1. Multicriteria evaluation

Among the different multicriteria methods, a very important role is played by the theory of the Analytic Hierarchy Process (AHP, Saaty, 1980). AHP offers a general framework to deal with complex decisions which provides a comparison of the different options. The method is based on a multi-criteria measurement theory that is used to derive relative priority scales on absolute scales (invariant under the identity transformation) from both discrete and continuous paired comparisons in multilevel hierarchy structure. These comparisons may be taken from actual measurements or from a fundamental scale that reflects the relative strength of preferences and feelings (Saaty, 2005). The method allows tangible and intangible elements to be incorporated simultaneously in the evaluation, through the use of both real data and experts′ subjective decisions.

Following the AHP methodology, a complex problem can be divided into several sub-problems that are organized according to hierarchical levels, where each level denotes a set of criteria or attributes related to each sub-problem. The top level of the hierarchy denotes the goal of the problem and the intermediate levels denote the factors of the respective upper levels. Meanwhile, the bottom level contains the alternatives or actions considered when achieving the goal. AHP permits factors to be compared, with the importance of individual factors being relative to their effects on the problem solution, and the priority list of the considered alternatives to be reached (Saaty, 2005).

The analysis is based on three fundamental principles: breaking down the problem; pairwise comparison of the various alternatives; and synthesis of the preferences.

The first step of the analysis consists in subdividing the decision-making problem into several levels in such a way that they form a hierarchy with unidirectional hierarchical relationships between levels. The decomposition is carried out from the top to the bottom, starting from the objective, and going on to the criteria and sub-criteria, and then to the final alternatives.

Once the hierarchy is constructed, the decision elements are compared pairwise in terms of their importance for their control criterion. Particularly, Decision Makers are asked to respond to a series of pairwise comparisons in which two elements at a time are compared in terms of their contribution to their specific upper-level criteria. The relative importance values are determined on a 9-points scale, the so-called "Saaty′s Fundamental Scale". The numerical judgments established at each level of the hierarchy make up pair matrixes.

After comparison matrixes are created, relative weights of the elements of each level with respect to an element in the adjacent upper level are computed as the components of the normalized eigenvector associated to the largest eigenvalue of their comparison matrix. Mention has to be made to the fact that the eigenvector method yields a natural measure of consistency. Saaty (1980) defined the consistency index (CI) as represented in the following equation:

$$CI = (\lambda_{\max} - n)/(n-1) \quad (1)$$

where $\lambda_{\max}$ is the maximum eigenvalue and n is the number of factors in the judgment matrix. Accordingly, Saaty (1980) defined the consistency ratio (CR) as in the following equation:

$$CR = CI/RI \quad (2)$$

where RI is the consistency index of a randomly generated reciprocal matrix from the 9-point scale, with forced reciprocals. Saaty (1980) has provided average consistencies (RI values) of randomly generated matrixes (up to 11×11 size) for a sample size of 500.

The consistency ratio CR is a measure of how a given matrix compares to a purely random matrix in terms of the consistency index. A value of the consistency ratio $CR \leq 0.1$ is considered acceptable. Larger values of CR require the Decision Maker to revise his judgments.

Composite weights are then determined by aggregating the weights throughout the hierarchy. This is done by following a path from the top of the hierarchy down to each alternative at the lowest level, and multiplying the weights along each segment of the path. The outcome of this aggregation is a normalized eigenvector of the overall weights of the options (Saaty, 1980).

In case of multi-stakeholders evaluation, two methods can be employed in AHP for aggregating the preferences: the geometric mean method and the weighted arithmetic mean method. In the first method, the geometric means of individual evaluations are used as elements in pair-wise comparison matrices and then prioritized and computed. In the second method, priorities are computed and then combined using a weighted arithmetic mean method (Ramanathan and Ganesh, 1994). It has to be noticed that in case the group members act as individuals, both the methods can be used to estimate the resulting priorities (Contreras et al., 2008).

The AHP methodology has been accepted by the international scientific community as a robust and flexible multi-criteria decision making tool to deal with complex decision problems. An overview of the applications involving AHP can be found in Subramanian and Ramanathan (2012), Sipahi and Timor (2010), Ho (2008), and Vaidya and Kumar (2006).

With specific reference to the field of hydropower system, different applications of AHP exist considering impact evaluation and risk analysis (Yu et al., 2011; Zhao and Chen, 2011; Wen et al., 2008), financial evaluation (Wang and Wang, 2012; Zhao and Jia, 2011) and assessment of alternative projects (Zhang et al., 2009; Luo et al., 2004; Bhattarai, 2003; Cowan et al., 2010).

2.2. Stakeholders analysis

The stakeholder analysis theory was born in the ‘60s as a tool for supporting management processes. It constitutes an approach for understanding a system by identifying the key actors, and assessing their respective interest in that system.

Generally speaking, the theory is based on the identification and classification of the stakeholder groups, which can be defined