

Multi-criteria decision-making (MCDM) for the sustainable management of water withdrawals in Alpine watercourses

Erica Vassoney

Alpine watercourses are subject to conflicting interests, related to the increasing number of water withdrawals and the need for protecting aquatic ecosystems and natural sceneries. Moreover, the impacts of climate change on water resources availability will further intensify conflicts among different water users. To face these complex water management problems, new approaches, based on a participatory framework, are required to support decision-makers in achieving more sustainable solutions. Multi-attribute decision-making (MADM) methods can be used for this purpose.

The aim of this thesis is to refine the innovative methodological framework adopted in Aosta Valley (northwest Italy) for the overall assessment of water withdrawal sustainability. The region is located in the middle of the Alps and most of its watercourses are significantly impacted by water withdrawals, mainly for hydropower generation and agricultural irrigation. Therefore, an experimental approach, based on the application of MADM and actively involving key stakeholders, has been developed to identify the optimal scenario of ecological flows to be released downstream of a withdrawal dam. The aim is to achieve a decision that represents the best mediation among river environment and landscape protection and the other water users' interests.

The main improvements presented in this thesis were aimed at increasing the representativeness of the different stakes involved in each decision-making process. The revised MADM decision tree usually includes four criteria (Energy, Environment & fishing, Landscape, and Economy), each quantified by one or more indicators. All the revised indicators are directly related to the watercourse discharge. Moreover, they are reactive, representative, and based on the normative framework.

In particular, the thesis focuses on two indicators. The Index of river Habitat integrity (IH), derived from the MesoHABSIM (Mesohabitat Simulation Model) methodology, quantifies the effects of water withdrawals on river ecosystems and

fish communities. This index has especially allowed overcoming the limitations of the previous indicators derived from the European Water Framework Directive, which were scarcely reactive to hydrological alterations. On the contrary, the new indicator Landscape Protection Level (LPL) has been developed to assess the effects of water withdrawals on the river landscape. The reactivity and representativeness of both indicators are demonstrated by presenting the results of some real case studies, involving existing hydropower plants.

Furthermore, the effectiveness of the MADM technique used in Aosta Valley is evaluated by comparing the results and the methodological approach of different MADM methods, applied to the same real case study. The implemented analyses (including correlation tests and sensitivity analyses) and the feedback of some involved stakeholders show the robustness and feasibility of the method adopted in the region.

In the last part of the thesis, an overview of the decision-making processes concluded and ongoing in Aosta Valley is presented, highlighting the general satisfaction with the revised methodological approach. Indeed, decision-makers and stakeholders have noticed an improvement in the decision-making quality. Therefore, the methodology has been formally adopted in the institutional water withdrawal licensing procedure for the definition of ecological flows. It is thus currently applied to several real case studies over the regional territory, both *ex-ante* and *ex-post*, involving different types of water withdrawals.