Original Articles

Consensus in prioritizing river rehabilitation projects through the integration of social, economic and landscape indicators

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ABSTRACT

Selecting a river rehabilitation project is a complex decision which should address social, economic and landscape indicators. The rehabilitation project becomes even more complicated if the city qualifies for inscription on the UNESCO World Heritage List. Tangible and intangible factors must be assessed to take into account cultural and natural heritage, water flow, river naturalization, interaction of water stream, construction costs and operational and maintenance costs. The proposed method is a hybrid model combining Delphi, Analytical Hierarchy Process and VIKOR technique. This hybrid model has been applied to the historic walled town of Cuenca and the Huecar river. The objective of the selected rehabilitation project must be the optimal integration of the river in the townscape. The indicators most valued by the panelists have been cultural heritage and river naturalization with 28% and 25% respectively. As a result, the trapezoidal cross section has achieved an acceptable advantage and stability over the modified triangular cross section, valued as second.

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1. Introduction

In the United Nations World Water Development Report 2015, the Director-General of UNESCO Irina Bokova stated that water is inextricably linked to the development of all societies and cultures and therefore placing considerable pressure on water resources (UN-Water, 2015). Within this context, restoration of rivers has become a key policy objective in many countries around the world (Becker et al., 2014). River rehabilitation evaluation should be based not only on criteria of economic efficiency but also on broader landscape, cultural and social indicators. Decision making processes in river rehabilitation projects are complex due to the uncertainty about the benefits and conflicting goals. Therefore, river rehabilitation decisions should be undertaken based on a systematic and comprehensive procedure with sufficient consensus and transparency to avoid lack of acceptance. This gets even more complicated if the city qualifies for inscription on the UNESCO World Heritage List (WHL). UNESCO World Heritage Convention qualifies

for inscription on the WHL on the basis of six cultural and four natural criteria (UNESCO, 2006). To be included on the WHL, sites must be of outstanding universal value and meet at least one of ten selection criteria. In our case, the historic walled town of Cuenca and the Huecar river were qualified for inscription on the WHL on the basis of criteria iii, iv and v. These criteria focus on: bearing a unique or at least exceptional testimony to a cultural traditional; being an outstanding example of building, architectural or landscape which illustrates a significant stage in human history; and being an outstanding example of traditional human settlement, land-use which is representative of a culture or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change (UNESCO, 1995). A key factor to accomplish these criteria has been the integration between the upper town medieval fortress and the Huecar river and its surrounding landscape. In addition, the river rehabilitation receives nowadays more attention due to the public increasing awareness on its environmental degradation (European Union, 2000; Tanago et al., 2012). Therefore, the indicators involved in the development of this project must include environmental, architectural, social, cultural and landscape factors (Canto-Perello and Curiel-Esparza, 2006; Akiner and Akiner, 2010; Matthews et al., 2015). The reha-

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bilitation project is complex and requires a multidisciplinary panel of experts.

Hybrid models combining the Analytical Hierarchy Process (AHP) with other techniques using panels of experts have been successfully applied in environmental engineering. Hu et al. (2012) propose an evaluation framework of sustainable performance applying Fuzzy and AHP to implement product service systems. Liaghat et al. (2013) have integrated Weighted Linear Combination (WLC) as maps overlay of relevant indicators with AHP to analyze coastal tourism sites in Port Dickson district of Malaysia. Turskis et al. (2013) have studied the condition of the built and human environment through efficient decision making using AHP and ARAS-G techniques in renovation supported by multiple attribute evaluation. Wey and Hsu (2014) promote stakeholder engagement applying Delphi and AHP procedures to community development planning in the City of Irvine in the United States. Song et al. (2015) have proposed a hybrid method combining Delphi survey with GIS and Monte Carlo simulation to evaluate ecological vulnerability. Shang et al. (2015) have proposed an evaluation index system for Green Mine performance of China combining Fuzzy and AHP. Mousavi et al. (2015) have combined WLC and AHP for the identification and the prioritization of the most preferred areas for the establishment of corals artificial reefs. Canto-Perello et al. (2016) have developed an A'WOT hybrid method combining SWOT technique and AHP to promote the sustainable use of the urban underground space. Jiang et al. (2016) have studied healthy urban streams of the Suzhou creek corridor in Shanghai applying AHP with GIS data analysis and GIS space technology. Kamaruzzaman et al. (2016) have confirmed the Delphi method as the most applicable technique to develop comprehensive building environmental assessments.

This paper will focus on the selection of a rehabilitation project using a decision support system which will be a hybrid model combining the AHP with the Delphi method and the VIKOR technique (Curiel-Esparza et al., 2014; Martin-Utrillas et al., 2015a; Mardani et al., 2016). It is expected from the hybrid model to achieve consensus on a complex decision among all the relevant stakeholders, with different points of views, sometimes opposed to each other. The hypothesis is whether this consensus may be achieved by a structured procedure integrating social, economic and landscape indicators. In addition, the compromise solution must also verify the conditions of acceptable advantage and stability to guarantee the maximum group utility and the minimum of disapproval The main strength is the ability to deal with tangible and intangible indicators. The proposed hybrid model develops pairwise comparison judgments from a panel of experts that are used to implement overall priorities for ranking the indicators and projects. The Delphi technique is well suited as a method for consensus-building by using a series of questionnaires to collect data from panelists (Gracht, 2012). The Delphi method has facilitated an efficient panel survey. Secondly, the AHP method has been capable of dealing with incommensurable criteria based on paired comparison from experts' judgment (Saaty, 2012a; Li et al., 2014; Wang and Xu, 2015). And finally, the VIKOR method has found a compromise solution for this decision problem that is the closest to the ideal (Opricovic and Tzeng, 2007; Liou et al., 2011). The present study sought to address existing literature gaps by: selecting a river rehabilitation project taking into account social, economic and landscape indicators; assessing tangible and intangible factors; reaching consensus among the different stakeholders; and ensuring the optimal integration of the river in the townscape. The rehabilitation projects have been evaluated according to all established indicators. And the achieved compromise solution has provided a maximum utility of the majority, and a minimum individual regret of the opponent in overall.

2. Methodology

The proposed method is a hybrid model combining Delphi, AHP, and VIKOR techniques. The Delphi method is an anonymously experts' foresight procedure. It is suitable for achieving consensus applying a series of questionnaires (Roubelat, 2011). This procedure gathers the point of views from the panelists. The panel consists of ten experts with recognized competence in urban planning and environmental engineering. An anonymous open-ended survey is sent to the panelists, who answer it including new strategies or indicators they think are pertinent to the analysis (Norouzian-Maleki et al., 2015). Afterwards, there is a feedback to reach consensus resending these data to the panelists in order to reconsider their answers. This feedback procedure with the aim of building consensus defines the three levels hierarchy shown in Fig. 1. AHP uses this hierarchy structure to analyze the indicators and the river rehabilitation projects relations among them and the objective, facilitating the comparisons by the panelists. The upper level shows the goal to be achieved. The indicators to be studied are depicted in the second level. And, the lower level of the hierarchy structure consists of the river rehabilitation projects to be analyzed among the panelists. The AHP technique uses paired comparison judgments from the panelists (Saaty, 2012b). These paired comparisons are used to evaluate the relative priority of the indicators. In addition, the consistency of the panelists' judgments has been analyzed to avoid random answers. Finally, the VIKOR procedure achieves the consensus rehabilitation project in complex problems involving different indicators. Two parameters will be evaluated for each of the rehabilitation projects: utility of the majority and individual reject (Opricovic, 2011). These parameters will be gathered in a consensus strategy to reach the optimal solution. The compromise river rehabilitation project is the one which achieves the maximum utility and the minimum regret. In addition, the compromise river rehabilitation project must satisfy the conditions of acceptable advantage and acceptable stability.

2.1. Hierarchy structure for selecting a river rehabilitation project

According to the Delphi method, the first questionnaire sent to the panelists has been used to choose main indicators and a set of projects. The interaction among the experts has been achieved with anonymous feedback. Afterwards, the AHP has been used to reduce the overall decision into smaller decision problems. The indicators and solutions agreed by the panelists as being of low importance have been removed (Curiel-Esparza et al., 2015). The adequate selection of indicators has been a key factor to lead to transparency in this procedure as discussed later on. From the first survey, the following indicators have been proposed:

- Cultural Heritage (CUH): This indicator has taken into account all aspects relative to ancient constructions as medieval walls, old bridges and traditional buildings, even the townscape and singular views integrating historical aspects and landscaping (Nagy, 2012; Brida et al., 2013; Zhang et al., 2015).
- Natural Heritage (NAH): This indicator has evaluated the historical environment and natural values. For example, using local materials, developing autochthonous vegetation, creation of water mirrors and rupture of linearity have been analyzed (Luderitz et al., 2011; Hale et al., 2014; Lee and Hsieh, 2016).
- Water Flow (WAF): This indicator has focused on the different regimes of water movement mainly based on the slope, wet section, rugosity and natural flow (Valiani and Caleffi, 2009; Mejia and Reed, 2011).
- River Naturalization (RIN): This indicator has evaluated the actions needed for enhancing the riparian and aquatic vegetation, the river ecosystem and the physicochemical characteristics of