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Decision-support for environmental impact assessment: A hybrid approach using fuzzy logic and fuzzy analytic network process

Kevin F.R. Liu *, Jia-Hong Lai

Department of Environmental Engineering, Da-Yeh University, No. 112, Shanjiao Road, Dacun, Changhua 51591, Taiwan, ROC

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ABSTRACT

The decision-making on approval of environmental impact assessment (EIA) is an intrinsically complex multi-dimensional process because it does not only consider the scientific facts but also reflect subjective values. The use of decision-support methods to balance facts and values can be beneficial for decision makers. This paper attempts to propose an integrated decision-support framework that employs fuzzy logic (FL) to manipulate the subjectivity as decision makers do in appraising the facts and values, significance-acceptability transformation (SAT) to incorporate standards and decision makers' risk attitude into decision-making process, and fuzzy analytic network process (FANP) to manage the dependences among environmental factors and suggest an overall acceptability of the proposal. Finally, the proposed approach will be applied to the EIAs of construction projects, exemplified in a case study of the Taiwan High-Speed Rail project.

1. Introduction

Environmental impact assessment (EIA) can be defined as the systematic identification and evaluation of the potential impacts (effects) of proposed projects, plans, programs, or legislative actions relative to the physical–chemical, biological, cultural, and socioeconomic components of the total environment (Canter, 1996). The EIA process essentially involves scoping, studying baseline conditions, identifying potential impacts, predicting significant impacts, and evaluating them (Shepard, 2005). Scoping determines which components are to be included in the EIA and alternatives to be considered. A baseline condition, namely the existing environment, is recognized as a benchmark by which the future conditions of project alternatives are compared. Historically, several methodologies have been developed for the identification of impacts on the baseline condition, including the ad hoc, overlay, checklist, matrix, and networks methods. The purpose of impact prediction is to forecast the effects of an identified impact through methods such as subjective judgment, case studies, quantitative mathematical models, statistical models, pilot models and experiments. Once an impact has been forecasted, it is necessary to evaluate it's significance on environmental effects. Eventually, decision makers (EIA review committee) have to decide whether to accept the proposal or not.

The decision-making on approval of EIA reports is an intrinsically complex multi-dimensional process because it does not only consider the scientific facts (environmental, ecological and socio-economic impacts) but also reflect subjective values (judgment, preference, value and concern). Fig. 1 delineates a flowchart of EIA process; wherein, the use of decision-support methods to balance facts and values can be beneficial for decision makers. Several decision-support methods have been proposed in literature. Among them, two categories are noteworthy. The utilization of analytic hierarchy process (AHP) (Saaty, 1990) and its variants have become the first remarkable category due to their capability for facilitating multi-criteria decision-making. For example, Tsamboulas and Mikroudis (2000) devoted themselves to the combination of the AHP with cost-benefit analysis methods to develop an overall assessment of the impacts of transport initiatives over different geographical regions and time periods. Ong, Koh, and Nee (2001) used the AHP method to assess the environmental impact of materials process techniques by deriving a single environmental score based on process emissions for each of the products or alternatives evaluated. In order to compare three large industrial development alternatives in an orderly manner, Sólnes (2003) applied the AHP to calculate the environmental quality index of each. Readers are referred to Ramanathan's (2001) discussion on the advantages and shortcomings of using the AHP for environmental impact assessment. Tesfamariam and Sadiq (2006) applied fuzzy AHP to deal with the selection of drilling fluid/mud for offshore oil and gas operations, which incorporated decision maker's risk attitude and associated confidence on the estimates of pairwise comparisons. Srdjevic (2007) proposed a methodology for combining multi-criteria decision-making and social choice theory in a group decision-making process and used it to select the most

* Corresponding author. Tel.: +886 4 8511888x2367; fax: +886 4 8511336.
E-mail address: kevinliu@mail.dyu.edu.tw (K.F.R. Liu).

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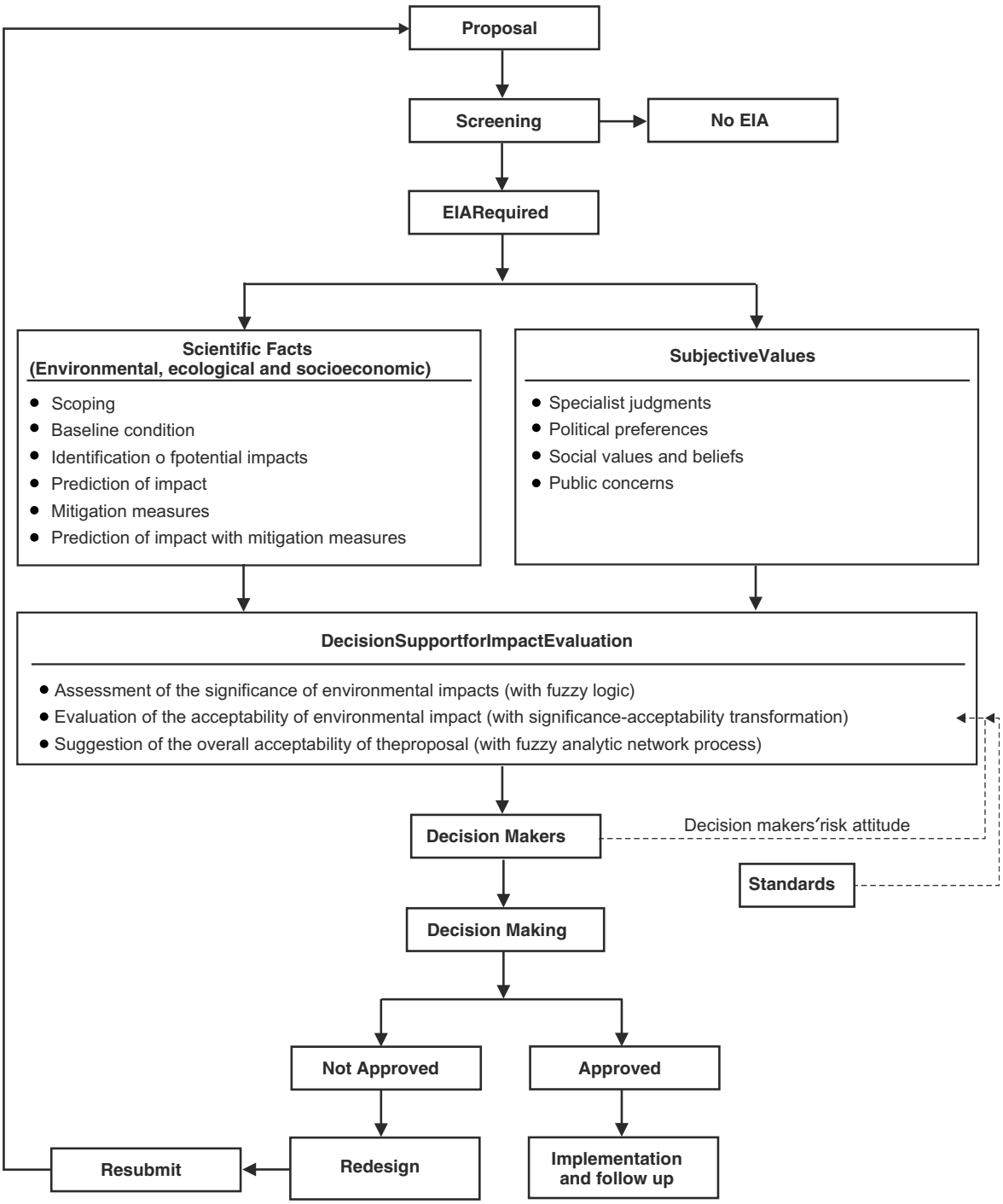

Fig. 1. A decision-making process for environmental impact assessment.

desired long-term water management plan. Brent, Rogers, Ramabitsa-Siimane, and Rohwer (2007) focused on the application of the AHP technique in the context of sustainable development to establish and optimise health care waste management systems in rural areas of developing countries. Liu (2007) outlines a new integration of fuzzy logic and fuzzy AHP to perform the evaluation of environmental sustainability in 146 countries. The analytic network process (ANP) (Saaty, 2001) relieves the independence limitation inherent in the AHP so that several researchers have been able to manipulate the dependence property of environmental factors. For example, according to data on the land cover, population, roads, streams, air pollution and topography of the Mid-Atlantic Region of the United States, Tran, Gregory, O'Neill, and Smith (2004) conducted an integrated environmental assessment by combining principal component analysis and the ANP. Cheng and Li (2005) introduced the use of the ANP to develop a decision model for evaluating potentially adverse environmental impacts of alternative construction plans. Although Mikhailov and Madan (2003) have proposed a fuzzy extension of the ANP called fuzzy analytic network process (FANP), which allows fuzzy weights for dealing with imprecise human comparison judgments, there is still no published literature reporting the use of the FANP to appraise environmental impacts.

The second category exploits the fuzzy logic method to inference the environmental impacts or significances. For instance, Borri, Concilio, and Conte (1998) introduced a fuzzy rule-based