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Prioritizing alternatives in strategic environmental assessment (SEA) using VIKOR method with random sampling for data gaps

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ABSTRACT

This study suggests a framework to prioritize the plans in strategic environmental assessment (SEA) with incomplete information. The Monte Carlo method for the data gaps in SEA and the VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method, which is a multicriteria decision analysis (MCDA) method, are used. The VIKOR method is used to prioritize the plans based on a number of decision criteria because its decision philosophies, considering both the utility and regret of performance measures in MCDA, support the main objective of SEA, which is to minimize potential negative impacts and maximize potential positive impacts of plans. In this study, the proposed framework is applied to the SEA that is part of the long-term plan for dam construction in Korea. This study quantifies the environmental feasibility scores of ten alternative dam construction sites based on multiple criteria, including landscape and geology, ecological value, water quality, and environmental toxicity, and generates sets of random numbers to fill the gaps resulting from the incomplete data. By varying the importance between the regret and utility of performance measures, the rankings of feasible sites are quantified with the uncertainty bounds from the randomly generated numbers. We find that the resulting ranks among the sites can vary significantly according to the decision philosophy of stakeholders. Our results imply that the proposed framework can be utilized to provide quantitative information for decision making in SEA, considering various decision criteria pertaining to environmental aspects, uncertainty of incomplete data, and decision flexibility according to decision-makers' tendency.

1. Introduction

Strategic environmental assessment (SEA) is the formalized, systematic, and comprehensive process to evaluate the environmental impacts of policies, plans or programs (PPPs) and their alternatives (Therivel, Wilson, & Thompson, 1992). SEA provides a sound basis for informed decision making concerning sustainability (Geneletti, 2013; Rega and Bonifazi, 2014; Partidario, 2015; White & Nobel, 2013). It provides a framework to support decision making for sustainability, setting sustainability targets, ensuring the consideration of sustainable alternatives, and integrating sustainability criteria in PPP development, and it also promotes sustainability outcomes through tiering and institutional learning (White & Nobel, 2013). Furthermore, SEA frameworks foster public participation in environmental decision making and increase the openness of the decision-making processes.

In comparison to the environment impact assessment (EIA) process, in which alternatives are often limited to issues of technical designs, a broad range of alternatives can be considered in SEA, as it is performed in the early stage of PPP development (Bao, Shang, & Lu, 2001; Du, Yang, Xu, Zhang, & Yang, 2012). Therefore, developing and quantifying alternatives has become the core issue in recent SEA studies. To identify alternatives, various quantitative tools can be utilized, such as the scenario analysis method, life cycle assessment, cost–benefit analysis, and multicriteria decision analysis (MCDA).

MCDA is one of the most flexible techniques that can be used to consider different kinds of impacts of a PPP. MCDA is particularly useful because it can be used to quantify environmental as well as socio-economic impacts; thus, it has been widely used for decision making related to environmental problems. However, only a limited number of studies have applied MCDA to SEA (e.g., Du et al., 2012; Garfì, Ferrer-Martí, Bonoli, & ND Tondelli, 2011; Rocchi, 2012). Garfì et al. (2011) applied MCDA to SEA for selecting the most appropriate program for safe water availability in a semi-arid region of Brazil. To devise a management plan for a park in Italy, Rocchi (2012) used an MCDA approach—stochastic multicriteria acceptability analysis—that

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allows the use of cardinal data and does not require information on decision-makers' preferences.

In Korea, SEA was introduced in 2006 and has been applied to different types of plans such as the long-term plan for dam construction (LPDC). SEA provides decision-makers with different types of qualitative and quantitative information about the technical, economic, and environmental feasibility of dam construction sites. However, the existing steps employed in Korea for SEA do not utilize any quantitative assessment tools such as MCDA to integrate the different criteria and opinions of decision making. Here, we argue that one of the limiting factors hindering such quantitative approaches from being used within SEA might be the incomplete information about different decision criteria with multiple alternative options as SEA involves only preliminary data collections. Therefore, there is a need to develop an MCDA-based support tool for SEA using data collected for various criteria but with incomplete information.

This study suggests a framework to prioritize the plans in SEA with incomplete information. The VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) method is used in this study along with the Monte Carlo method. The VIKOR method, which is an MCDA method, is used to support the main objective of SEA, which is to minimize the potential negative impacts and maximize potential positive impacts of alternative options. Furthermore, the VIKOR method could benefit the SEA process by incorporating the various decision-makers' tendencies into the MCDA framework. The VIKOR method allows us to find a compromise solution between the two decision strategies of maximizing group utility and minimizing individual regret in MCDA problems. We also use the Monte Carlo method to fill the gaps resulting from incomplete information. Ensembles of randomly generated numbers are used for the data gaps in MCDA, and the resulting ensembles of the final performance scores of MCDA are aggregated to derive the expected performance score for each alternative. The proposed framework was applied to an existing SEA for the LPDC in Korea. In this study, we focused on providing quantitative measures to assess the environmental feasibility of dam constructions in ten alternative sites based on information collected as part of SEA.

2. Materials and methods

2.1. Dam construction plan and SEA in Korea

In Korea, the LPDC is established every 10 years, modified or changed every five years, and required to implement SEA (Song, Park, Shin, Kim, & Grigg, 2010, Fig. 1). The LPDC process considers various aspects of plans, such as social, environmental, technical, and economic aspects, and within the LPDC, the SEA process focuses on the assessment of various environmental aspects of dam construction. In this case, ten potential dam construction sites were considered (Fig. 2 and Table 1). All the sites were located in the upstream areas of major rivers in Korea: four sites on the Han River, four sites on the Nakdong River, and two sites on the Geum River. Legally protected species and abandoned mines were found in the potential sites.

In the SEA process, data concerning four environmental categories related to landscape and geology (LG), ecological value (EV), water quality (WQ), and environmental toxicity (ET) were collected to evaluate the environmental conditions of the dam site candidates, as listed in Tables 2–6. Table 2 shows recommended monitoring factors for the four categories of data considered in the SEA process. The data collected for each category (Tables 3–6) do not cover all of the factors recommended for consideration.

For LG (Table 3), seven indicators were used, and scores from 2 to 8 were assigned. A higher score for a site indicates a greater feasibility of dam construction, given a specific set of topological and geological considerations. Only four different scores (2, 4, 6 and 8) were assigned in the surveys, as it is difficult to have detailed grades

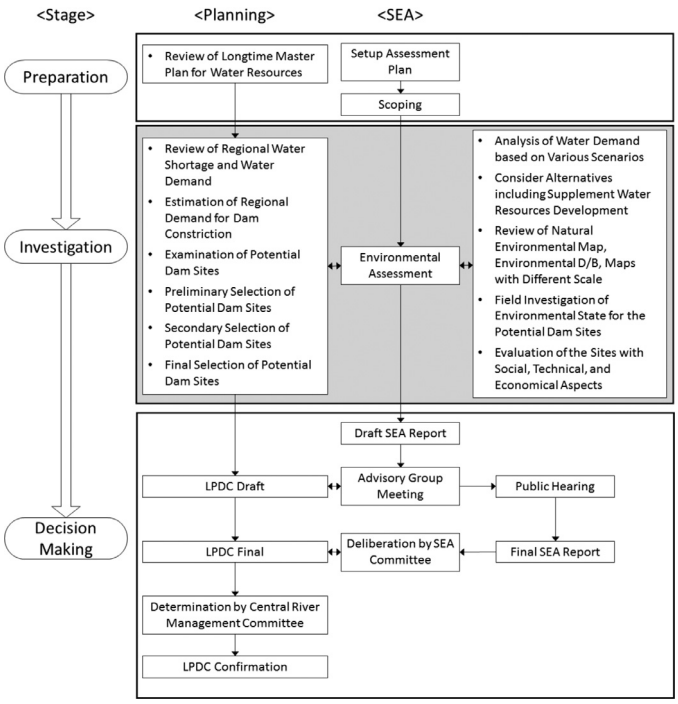

Fig. 1. SEA that is part of the long-term plan for dam construction (LPDC) in Korea (Song et al., 2010).

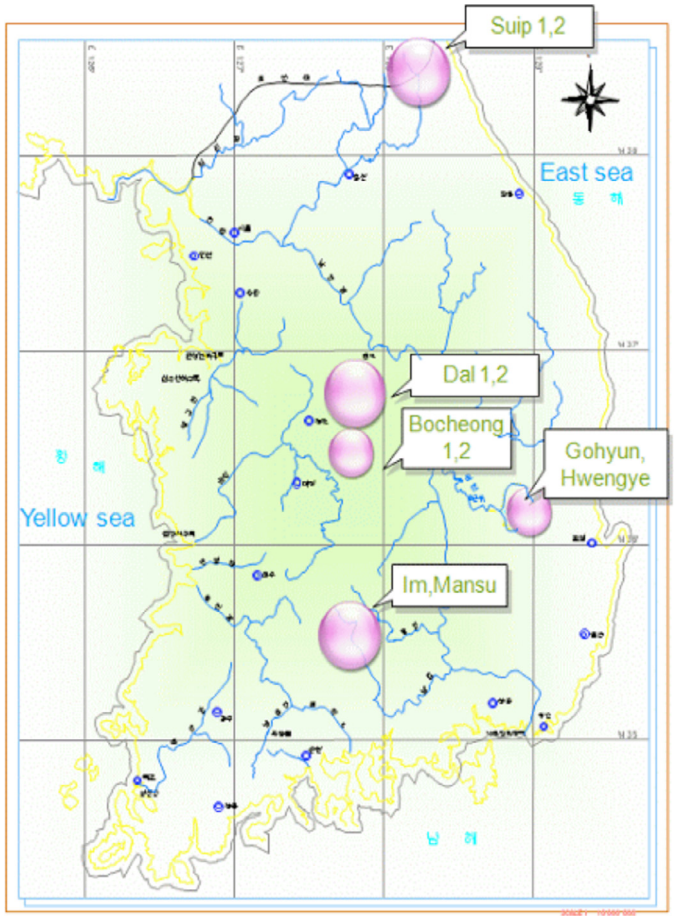

Fig. 2. Location of candidate sites for dam planning in SEA.