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Coping with uncertainty in environmental impact assessments: Open techniques

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ABSTRACT

Uncertainty is virtually unavoidable in environmental impact assessments (EIAs). From the literature related to treating and managing uncertainty, we have identified specific techniques for coping with uncertainty in EIAs. Here, we have focused on basic steps in the decision-making process that take place within an EIA setting. More specifically, we have identified uncertainties involved in each decision-making step and discussed the extent to which these can be treated and managed in the context of an activity or project that may have environmental impacts. To further demonstrate the relevance of the techniques identified, we have examined the extent to which the EIA guidelines currently used in Colombia consider and provide guidance on managing the uncertainty involved in these assessments. Some points that should be considered in order to provide greater robustness in impact assessments in Colombia have been identified. These include the management of stakeholder values, the systematic generation of project options, and their associated impacts as well as the associated management actions, and the evaluation of uncertainties and assumptions. We believe that the relevant and specific techniques reported here can be a reference for future evaluations of other EIA guidelines in different countries.

1. Introduction

Environmental impact assessments (EIAs) provide information on the changes that may occur in the environment as the consequence of a specific proposed activity. That is, EIAs help predict the likely impacts of a proposed activity (Norwegian Ministry of the Environment, 2003; Wathern, 1990). Further, EIAs can be considered as governance instruments since they introduce rules and assign specific roles and responsibilities to actors. EIAs aim to develop a greater environmental awareness among actors and, accordingly, lead to the incorporation of each actor's environmental values in decisions related to the proposed activities and plans (Arts et al., 2012).

Uncertainty is almost unavoidable in EIAs (Tennøy et al., 2006). Such assessments typically involve situations in which the full range of possible options and their impacts for a particular project cannot be known (e.g. Ozdemir and Saaty, 2006) or there is no consensus as to which option to choose or which impact to consider (e.g. Bojórquez-Tapia et al., 2005). Uncertainty also occurs in EIAs when there is a lack of certainty about the magnitude of impacts (e.g. Attanayake and Waterman, 2006; Gangolells et al., 2011), or the possible interactions among the impacts (e.g. Tullos, 2009), or when the assumptions made are not easily verifiable (e.g. Attanayake and Waterman, 2006; Walke et al., 2015). Uncertainty is also present when: (i) there is no agreement as to the criteria to use to evaluate the importance of the impacts (e.g. Bojórquez-Tapia et al., 2002); (ii) the effectiveness of measures to manage impacts is uncertain (e.g. Wiegleb et al., 2013; Bailey et al., 2014); or (iii) when it is extremely difficult to detect early changes in the environment in order to minimize them over time (e.g. Attanayake and Waterman, 2006; Nasen et al., 2011). These uncertainties pose tremendous challenges in successfully managing the impacts produced by, for instance, a development project. This is especially challenging since the uncertainties in EIAs, such as those referred to above, are usually obscured in the EIA report (Leung et al., 2016). Gustavsson (2011) claimed that such uncertainties are often hidden because of either a desire for rapid approval of the EIA or to avoid controversy among practitioners, the public, and project developers that could compromise project realization.

Thissen and Agusdinata (2008) have shown that insufficient attention is given to exhaustively identifying and assessing uncertainties in environmental studies. In line with this, Maier et al. (2008) concluded that there is a need to consider uncertainty during all stages of an environmental decision-making process. Wood et al. (2000), Tennøy et al. (2006), and Jay et al. (2007) have reported evidence of the intrinsic uncertainty attached to EIA predictions from a number of case studies worldwide. The gathered evidence consisted of comparisons between predictions in EIAs and the impacts measured during, or following, project implementation. In outlining EIA shortcomings, Tennøy et al. (2006)

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highlighted the major causes such as project changes, modeling errors, inaccurate data, unjustified assumptions, and bias introduced by specific actors involved in the project.

In this paper, we aim to identify some techniques in the literature that can help when dealing with uncertainty in projects. Further, the techniques identified are used as references to examine the extent to which the EIA guidelines in Colombia consider and provide advice on managing the uncertainties involved in these assessments. This analysis will show the relevance of the techniques identified as a means to examine the capability of a given EIA guideline in providing support in coping with uncertainty in such an assessment. The analysis is focused on specific steps in the decision-making process of an EIA. In doing so, we identity specific uncertainties involved in each decision-making step and discuss the extent to which these can be treated and managed in the context of an activity or project that may have environmental impacts. Some areas for improvement that ought to be considered to increase the robustness of impact assessments in Colombia are identified.

Analyzing the Colombian guidelines in relation to their limitations in treating and managing uncertainty is particularly relevant since studies conducted by Contraloría General de la República, the supreme audit institution in Colombia, have exposed the weakness and general ineffectiveness of the Colombian EIA system. Further, the currently used guidelines were released in 2002 and, since then, new developments in uncertainty management have been published that should ideally be incorporated. This situation further warrants attention given that current development policies in Colombia are increasing pressure on planning authorities to speed up the review and approval of EIAs. This pressure creates tensions because Colombia has one of the world's largest biological diversities and has set high priorities for environmental conservation (Toro et al., 2010). To the best of our knowledge, the proposed examination of the current guidelines is a unique approach. Although Toro et al. (2010) have examined the Colombian EIA system, they did not address the issue of the treatment and management of uncertainty in EIAs. Further encouragement for this study comes from international studies that have shown the relevance of, and the need to, exhaustively identify and assess uncertainties in environmental studies in order to provide input to make robust decisions and effectively manage impacts (i.e., Wood et al., 2000; Tennøy et al., 2006; Jay et al., 2007; Maier et al., 2008; Thissen and Agusdinata, 2008; Gustavsson, 2011).

The remainder of this paper is divided into four sections. The second section elaborates on options for coping with uncertainty in EIAs that are identified from reviewing the literature. In Section 3, we highlight the limitations that are inherent to the EIA guidelines when treating and managing uncertainty in Colombia. A discussion of the results follows in Section 4. Finally, Section 5 draws some conclusions from this study.

2. Uncertainty treatment and management for EIAs

By reviewing the literature related to treating and managing uncertainty in various fields, including EIAs, this section elaborates on the techniques open to EIAs in responding to their inherent uncertainties. From the relevant literature, we have selected specific papers that suggest significant and proven techniques for EIAs. The significance of each paper's contribution was largely assessed based on whether they reported successful case studies that demonstrated the practicality of the techniques shown or had a positive impact on the scientific community based on their citation history. These criteria resulted in a review that included 43 papers that addressed specific applications of methods to cope with uncertainty plus 8 review papers and 26 that developed frameworks for assessing and/or managing uncertainty. In addition, we included 11 papers that reviewed EIA current practices and their effectiveness as these suggested research options for improved EIA implementation. The papers selected had been published within the past twenty years and originated from many countries. However, most of the papers that demonstrate the practicality of new techniques for EIAs have been published since 2003. These characteristics reflect the scope and comprehensiveness of the review. More details of the bibliographic analysis carried out for this research can be found in the Appendix A to this paper.

To assist in understanding this paper, we first define and describe uncertainty and its relationship to decision-making. Many definitions of uncertainty are to be found in the literature. Lipshitz and Strauss (1997) and Samson et al. (2009) have provided reviews of this issue. Both sets of authors, and similarly Zimmermann (2000), concluded that each definition of uncertainty depends on the specific problem addressed and its context. For the research described in this paper, Zimmermann's definition of uncertainty will be adopted. This definition assumes that uncertainty implies a situation in which a person does not have the required information to precisely describe, prescribe, or predict an event or its characteristics (Zimmermann, 2000). As such, uncertainty includes situations where only a limited amount of information is missing and those with a complete lack of information. Following from this definition, decision-making is made under conditions of uncertainty when at least some of the targets (objectives or goals of the decision) or some of the estimated outcomes, courses of action, or their impacts or alternatives in the analysis involve uncertainty (Bellman and Zadeh, 1970). Note that the term decision-making is usually used to reflect the process to determine a course or courses of action after analyzing alternatives. Decision-making consists of comparing possible outcomes or alternatives (from this point onwards termed options) with targets, constraints or criteria (henceforth termed criteria). Both the options and the criteria can involve uncertainty. Furthermore, in the setting of EIAs, uncertainty can occur in any of the following basic interacting decision-making steps suggested by Canter et al. (1998), Liu et al. (2008), and Maier et al. (2008):

- identifying options and their impacts for a project,
- identifying criteria to assess options,
- choosing an option, or a set of options,
- identifying management actions to carry out the chosen option(s),
- enacting the selected management actions, and
- managerial review and judgment.

In the remainder of this section, we identify some of the uncertainties involved in each of the decision-making steps identified above, and discuss the extent to which these can be treated and managed in the context of an activity or project that may have environmental impacts.

2.1. Identifying options and impacts for a project

In this stage, it is important to ensure that relevant options and their associated impacts are not overlooked since, otherwise, stakeholders in a given project might miss an opportunity to optimize a project's outcomes and reduce its impacts (Hage et al., 2010). Thus, a crucial contribution to effective decision-making is the exhaustive generation and analysis of relevant options. This is particularly relevant since Pope et al. (2013) reported that the option identification process is a recurrent weakness in impact assessments. Moreover, Alshuwaikhat (2005) stressed that, when it comes to the project assessment stage, several options that have potentially different environmental impacts than the option chosen have often already been eliminated by decisions taken at earlier stages in the planning process, before a detailed environmental assessment has taken place.

Identifying options and impacts is addressed to some extent in environmental studies that use scenario analysis and planning. Reviews of the state-of-the-art of scenario analysis and planning for environmental decision-making and environmental impact assessments have been provided by Duinker and Greig (2007) and by Mahmoud et al. (2009). More recently, Tourki et al. (2013) have also reported applications of