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Environmental impact assessment using a utility-based recursive evidential reasoning approach for structural flood mitigation measures in Metro Manila, Philippines

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ABSTRACT

In recent years, the practice of environmental impact assessment (EIA) has created significant awareness on the role of environmentally sound projects in sustainable development. In view of the recent studies on the effects of climate change, the Philippine government has given high priority to the construction of flood control structures to alleviate the destructive effects of unmitigated floods, especially in highly urbanized areas like Metro Manila. EIA thus, should be carefully and effectively carried out to maximize or optimize the potential benefits that can be derived from structural flood mitigation measures (SFMMs). A utility-based environmental assessment approach may significantly aid flood managers and decision-makers in planning for effective and environmentally sound SFMM projects. This study proposes a utility-based assessment approach using the rapid impact assessment matrix (RIAM) technique, coupled with the evidential reasoning approach, to rationally and systematically evaluate the ecological and socio-economic impacts of 4 planned SFMM projects (i.e. 2 river channel improvements and 2 new open channels) in Metro Manila. Results show that the overall environmental effects of each of the planned SFMM projects are positive, which indicate that the utility of the positive impacts would generally outweigh the negative impacts. The results also imply that the planned river channel improvements will yield higher environmental benefits over the planned open channels. This study was able to present a clear and rational approach in the examination of overall environmental effects of SFMMs, which provides valuable insights that can be used by decision-makers and policy makers to improve the EIA practice and evaluation of projects in the Philippines.

1. Introduction

For centuries, people have been undertaking hydraulic works in different parts of the world to alleviate flood damages (Poulard et al., 2010). In Southeast Asia, most of the key cities, including Jakarta (Indonesia), Bangkok (Thailand) and Metro Manila (Philippines), to name but a few, are highly vulnerable to destructive flash floods and inundations. Recent studies on climate change (The World Bank, 2010; Yusuf and Francisco, 2009) indicated that the Southeast Asian region will likely experience higher frequency of extreme flood events in the coming years, thus creating higher demand for flood mitigation projects, which often includes structural measures. Structural flood mitigation measures (SFMMs) are technological features that are often used (and considered valuable) in many highly urbanized flood prone areas. Poor implementation and management of these infrastructures however, may lead to geomorphological, ecological and social ramifications (Everard, 2004). For instance, in the past, several channelization works in Europe (for flood protection) have resulted in various adverse environmental consequences in various river ecosystems (Brookes and Gregory, 1983). The process of environmental impact assessment (EIA) must then be taken as a necessary step during the early planning stages of SFMM projects to obtain a clearer view of the costs and benefits, not only to promote social and economic development, but also to minimize the projects' impacts on the ecological environment.

In principle, EIA is a process undertaken to identify the beneficial and harmful effects of projects, plans, programs or policies on

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the physical, biological and socio-economic components of the environment (Petts, 1999; Wang et al., 2006). The use of appropriate EIA techniques can aid planners and decision-makers in formulating appropriate action plans based on informed decisions in light of project urgency and limited resources, which are common constraints in many developing countries (Shah et al., 2010).

In the Philippines, particularly in Metro Manila, the EIA methods used for SFMMs are generally descriptive and qualitative (e.g. Department of Public Works and Highways, 1998; City Office of Navotas, 2009), which are basically similar to the ad hoc and checklist methods described by Lohani et al. (1997). Numerous innovations already exist that can help address some of the weaknesses of these methods, among which are the multicriteria/multiattribute decision analysis approach (McDaniels, 1996; Hokkanen and Salminen, 1997; Kim et al., 1998), weighting-scaling checklists (Canter and Sadler, 1997), input–output analysis method (Lenzen, 2003), life cycle assessment (Tukker, 2000; Brentrup et al., 2004), analytic hierarchical process (Ramanathan, 2001; Goyal and Deshpande, 2001), fuzzy sets approaches (Munda et al., 1994; Parashar et al., 1997), and the Rapid Impact Assessment Matrix (RIAM) technique (Pastakia, 1998; Mondal, 2010; El-Naqa, 2005; Al Malek and Mohamed, 2005).

For SFMM projects, the authors proposed the use of a modified RIAM technique (Gilbuena et al., 2013a) that reduces the subjectivity, as well as improve the transparency, of the EIA process in the Philippines. This method, however, does not provide the means to measure the overall impacts of each project alternative (Gilbuena et al., 2013a). If the overall impact of a SFMM project can be quantitatively and realistically estimated, planners and decision-makers may be able to maximize the potential benefits of each project alternative.

Yang and Singh (1994) developed a recursive evidential reasoning approach that uses a belief structure to model qualitative assessments in multiple attribute decision making problems (with uncertainties) on the basis of the decision theory and the Dempster–Shafer theory of evidence. Luo and Caselton (1997) pointed out that the Dempster–Shafer theory provides a natural and readily grasped basis for the expression of uncertainties, which offers more flexibility than the traditional statistical methods and Bayesian approach (Beynon et al., 2000) when quantifying weak or subjective information (Luo and Caselton, 1997). The evidential reasoning approach in general addresses the uncertainties and lack of knowledge in subjective decisions that are inherent in qualitative assessment processes (Yang, 2001). This approach has been used to deal with multiple attribute decision analysis problems in engineering and management, for example, in vehicle assessment (Yang and Sen, 1994), cargo ship design (Sen and Yang, 1995), system safety analysis and synthesis (Wang et al., 1995), car performance assessment (Yang, 2001) and environmental impact assessment (Wang et al., 2006). Further, a utility-based information transformation technique has been developed in the evidential reasoning approach to provide a systematic procedure to transform various types of information into a unified format, so that both quantitative and qualitative information with uncertainties can be handled in a consistent manner (Yang, 2001). This approach has been coupled with the RIAM technique to obtain a unified EIA result in the form of utility values (Wang et al., 2006) that provides a systematic and effective way to compare and rank project alternatives. The potential of this approach however, has not been fully explored, especially the benefits of its utility-based assessment and its applications in the EIA of planned SFMM projects.

This study explores the application of a utility-based recursive evidential reasoning approach (as an extension in the RIAM technique) in the EIA of planned SFMM projects. As a novel approach, the modified RIAM technique (Gilbuena et al., 2013a) was coupled with the utility-based evidential reasoning approach to evaluate the environmental impacts of SFMMs. A new utility function based on the mean environmental score of each range bands in the modified RIAM technique (Gilbuena et al., 2013a), standardized to a range [−1 to 1], was proposed to estimate the overall utility values of the SFMMs in terms of the negative and positive utility ranges. The concept of “gains” and “losses” (Kahneman and Tversky, 1979) was used to interpret the results to create a distinction between the effects of different decision preferences on the aggregated positive and negative impacts. As far as the authors know, no other similar approach that utilizes the RIAM technique and takes into account decision preferences in the environmental assessment of SFMMs, is available in the literature. In addition, the algorithm of the utility-based assessment is presented in a simple “step-by-step” approach to provide a clear and comprehensive procedure for the EIA of SFMM projects.

The proposed modifications in the utility-based evidential reasoning approach are intended to advance the EIA process for SFMM projects in the Philippines, but may also find application in other forms of EIA studies. The succeeding sections describe the EIA of the 4 SFMMs using the modified RIAM technique and the analysis previously carried out by the authors (Gilbuena et al., 2013a); elaborate the recursive evidential reasoning approach, including the development of a new utility function that is compatible with the modified RIAM technique; analyze and discuss the results of the impact assessment; and offer some recommendations and conclusions with the aim of improving the practice of EIA for SFMMs in the Philippines.

2. EIA by RIAM technique

The authors carried out a study that investigated the use of a modified RIAM technique to assess the environmental impacts of 4 planned SFMM projects in Metro Manila consisting of 2 river improvement works (dikes) and 2 new open channels (Gilbuena et al., 2013a). The following sub-sections describe the environmental conditions of the study area and the EIA method used.

2.1. Environmental and socio-economic conditions of the study area

Fig. 1 shows the geographic location of Metro Manila (right figure) and its administrative boundary (center figure). Metro Manila is a megacity situated in a semi-alluvial fan that opens to Manila Bay on the west and Laguna de Bay Lake on the southeast. It is composed of 17 highly urbanized municipalities that collectively have a total population of around 11.76 million (National Statistics Office, 2007). Its total land area is about 638 km^2, which makes it the most densely populated administrative region in the country. Metro Manila is also the focal point for major political and economic activities in the Philippines. A study by the National Statistical Coordination Board (2009) revealed that around 30% of the country’s gross domestic product comes from Metro Manila. Despite the high economic activities in this region, economic growth and urban development is persistently slow, which, according to Page (2000), is largely due to the frequently occurring floods during the monsoon and storm periods (from May to October).

Large floods have been documented in Metro Manila as early as 1898 (Fano, 2000). The first comprehensive flood study and flood control plan were carried out in 1943, but was only completed in 1952 (Bureau of Public Works, 1952). The flood control plan consisted mainly of drainage improvement works covering most parts of the present day Metro Manila. In 2009, Recent flood events are increasingly devastating, which often results in the loss of many lives and widespread damages to agriculture and properties. Based