Assessment of Environmental Impacts Using Fuzzy Logic Inference Model (Case study: Kamal Saleh Dam)

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Expanded Abstract

Introduction

Determination of the importance of environmental impacts is one of the main issues and concerns in the process of Environmental Impact Assessment (EIA) of projects. Ecological impacts assessment is very complicated and requires estimates and anticipation of all environmental impacts and always associated with uncertainty. A major problem in assessment of ecological impacts is that they cannot be formulated in one algorithm, because the vital elements and their interactions cannot be completely identified (Crisp). On the other hand, the spatial heterogeneity of ecological systems and the complexity of decision making have made the impact assessment more difficult. Therefore, the concept of environmental impacts is often ambiguous. The main problem is that EIA models are incapable of managing qualitative data. Fuzzy inference will avoid these difficulties. Fuzzy logic brings a method for a broad range of objective data, quantitative data, opinions and subjective judgments to a natural language to describe the environmental impacts. Fuzzy logic is an especial, powerful technique for classifying and describing the environmental conditions, with both natural and human origins. Fuzzy logic has the ability to quantify and classify the environmental impacts with subjective nature. The main objective of fuzzy inference method for EIA is to calculate the significance of the effects based on fuzzy logic. In this study, fuzzy logic is used to determine and rank the significance of impacts, as a method to assess qualitative data. Therefore, the performance of fuzzy logic inference method in comparison with mathematical matrix method is discussed.

Materials and Methods

Kamal Saleh Dam basin is located in 49˚ 4′ 2″ to 49˚ 27′ 11″ east longitude and 33˚ 33′ 13″ to 33˚ 55′ 55″ North latitude, with an area of 655 square kilometers. It is located in south west part of Markazi province and North East part of Lorestan province in western Iran. This dam has been constructed at a distance of 74 km from the Arak city and 46 km to Shazand city on the Tireh River.

In this research, fuzzy logic (Kamal Saleh DAM) is applied in case study to assess the environmental impacts as a novel method for the environmental impact assessment. Therefore, an evaluation was done by two methods: mathematical matrix and fuzzy logic. The mathematical matrix method was used after indigenization, so that the matrix is composed of two parts: a complementary index and a basic index, each index includes three criteria containing six subordinate criteria overall (magnitude (M_{ij}), duration (D_{ij}) and occurrence Time (T_{ij}) *as* basic index parameters, and synergy effects (S_{ij}), cumulative effects (A_{ij}) & Probability of occurrence (P_{ij}) as complementary index parameters) along with the nature of impact (N_{ij}) showed by + and – symbols which indicate the desirable and undesirable effects of the impact (I_{ij}), respectively. Finally, using the mentioned mathematical relation, we achieved the importance of impact of each actionon the environment.

$$MDT_{ij} = \frac{M_{ij} + D_{ij} + T_{ij}}{15} \quad (1)$$

$$SAP_{ij} = \frac{S_{ij} + A_{ij} + P_{ij}}{15} \quad (2)$$

$$I_{ij} = MDT_{ij}^{1-SAP_{ij}} \quad (3)$$

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Then, the importance of the effects was classified as very low (VL: 0.2≤X<0.36), low (L: 0. 36≤X<0.52), medium (M: 0.52≤X<0.68), high (H: 0.68≤X<0.84) and very high (VH: 0.84≤X<1).

Fuzzy logic

In the fuzzy logic method, above mentioned mathematical matrix indices were considered as fuzzy inference system input. The criteria got fuzzificationed. After determination of membership functions similar to the groups of mathematical matrix classification, and forming rule base center in the importance of impact, the criteria were calculated by the center of gravity method as defuzzzification approach. The output of the fuzzy logic inference is actually measurement about the effect of each activity on the environment. Ultimately, the efficiency of two mentioned methods was compared with one another for assessment of the importance of the effects. These two methods have quite similar inputs. To do this, in mathematical matrix method and fuzzy logic, 6 criteria for 2 indices (complementary index & basic index) were used (magnitude (M_{ij}), duration (D_{ij}) and occurrence Time (T_{ij}) *as* basic index parameters, and synergy effects (S_{ij}), cumulative effects (A_{ij}) and probability of occurrence (P_{ij}) as complementary index parameters).

In the method of fuzzy inference system, Matlab Ver R2012a software and Mamadani execution method were used. The same mathematical matrix indices as system input was implemented.

Results and Discussion

According to the below chart review (Fig.1), the difference in the number of linguistic variables in mathematical matrix and fuzzy methods is quite obvious. These differences are arised from the decision making method in Aristotelian logic and fuzzy logic. The importance of the impact calculated based on a mathematical matrix class can create uncertainty, which is more important in borders of classification (where X is increasing along with the value of impact from very low to very high), i.e. as we move towards increasing the variable X, the value of linguistic variable will increase. This can be seen as several classes in output matrix. For example, if the variable is X=0.53, it belongs to medium-class and if variable is X=0.67, it still belongs to the same class, even though there has been a major numerical increase; on the other hand, with the increase of 0.01 at 0.67 point, the importance of impact will change from medium to high.

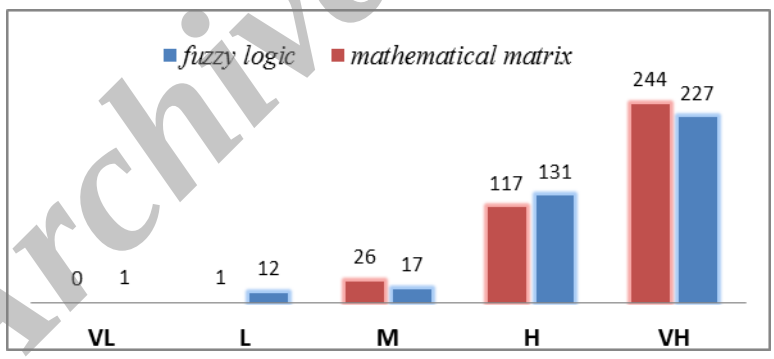

Fig. 1. Comparison of the numeric summation of whole impacts importance (positive and negative) in the two methods of mathematical matrix and fuzzy logic

However, fuzzy logic approach solved this problem and its output is defined based on membership grade. For example, if the output of fuzzy logic is $\bar{Y}$ =0.67, then the fuzzy logic determines a degree of membership for two membership functions, and thus the uncertainty in the mathematical matrix classification. Impact importance of $\bar{Y}$=0.67 in fuzzy logic belongs to two membership functions with different membership levels, moderate linguistic variable with μ_M = 0.06 degree of membership and high linguistic variable with μ_H = 0.94 membership degree.

Conclusion

The concept of environmental impact Assessment is unambiguous and ecological effects cannot be explicitly defined. For this reason, the fuzzy logic has a very high performance in formulating the importance of each impact in an appropriate manner. Fuzzy logic is capable of using qualitative criteria or linguistic variables for assessment and solving of the problem of the variables formulation. It is simultaneously capable of using and synthesis of both qualitative and quantitative data derived from environmental assessors. As a result, the fuzzy logic method leads to modification of uncertainty which is always a problem in unambiguous and complicated

matters such as EIA. Since one of the main issues in environmental impact assessment (with project approval and determination of appropriate corrective solutions) is to define the impact significance correctly; the fuzzy logic with its spectacular capabilities is an appropriate method. Determination of the importance of environmental impacts is one of the main issues in the process of environmental impact assessment (EIA). Ecological impact assessments is very complicated and always associated with uncertainty because the assessment data are often qualitative. The common EIA methods are incapable of managing these kinds of data.

Keywords: environmental impact assessment, fuzzy logic interference, impact importance, mathematical matrix.