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A Review on Fuzzy - AHP technique in Environmental Impact Assessment of Construction Projects, India

Jaspal Singh[1], Vivek Kumar Tiwari[2*], Umesh Chand Sharma[3] and Swadesh Kumar[4]

[1] Department of Environmental Sciences, Bareilly College, Bareilly, U.P. 243001 INDIA
[2] 4/97, Paramarsh (Servicing Environment and Development) Viram Khand Gomti Nagar, Lucknow-226025
[3]88A, Manas Nagar, Near Sea TV office, Agra- U.P. 28200 INDIA
[4]Department of Environmental Science, Babasaheb Bhimrao Ambedkar (Central) University, Raibareli Raod, Lucknow, Uttar Pradesh, INDIA

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ABSTRACT

There are several countries today using procedures for Environmental impact assessment (EIA) is based on a series of mathematical techniques which attempt to localize, describe and assess the positive and negative effects that any human activity has on our environment, generally causing it to deteriorate. The environmental impact assessment (EIA) of projects requires the evaluation of the effects of very diverse actions on a number of different environmental factors, the uncertainty and inaccuracy being inherent in the process of allocating values to environmental impacts carried out by a panel of experts, stakeholders and affected population. The application of the fuzzy Logic and AHP technique can be helpful in identification of the risk associated with construction or developing project and improves the study of EIA. Fuzzy is one of the characteristics of human thoughts for which fuzzy sets theory is an effective tool for fuzziness. A fuzzy logic knowledge-based approach can be used for the environmental impact assessment study of the different construction projects. The review article highlights the role of Fuzzy AHP logic method in EIA of different construction projects, fuzzy logic modeling - software for fuzzy EIA, fuzzy numbers and steps of fuzzy methods as well as reveals that how fuzziness can be determined by applying fuzzy logic method in construction projects.

1) INTRODUCTION

Environmental impact assessment (EIA) is based on a series of mathematical techniques which attempt to localize, describe and assess the positive and negative effects of any human activity has on our environment, generally causing it to deteriorate. The main purpose of EIA is to predict and minimize the negative impacts suffered by the environment due to any construction projects or activity [32]. There are several risks factors affecting the life cycle of the construction projects which needs to be identified. The application of the fuzzy set theory [60] can be helpful in selection of site for construction [34] and identification of the risk associated with construction or developing project [39] as well as improve the study of EIA. Fuzzy is one of the characteristics of human thoughts for which fuzzy sets theory is an effective tool for fuzziness. [24]. A fuzzy logic knowledge-based approach can be used for the environmental impact assessment study of housing and construction projects. Fuzzy logic has been successfully applied in the environmental field. A number of representative examples of such applications can be quoted in the last two decades, such as surface water and ground water remediation [54, 33], soil amendments [6], air pollution management [17] and diverse air, water and terrestrial ecosystem environmental studies [2]. Remote sensing and Geographical information system help to collect the information related to land use, urban sprawl, integrating water quality sampling data, disaster related information and is also used to predict various types of non-point source (NPS) pollution. GIS was an excellent tool for this type of study as it facilitated the integration of many layers of information over a large area. The spatial database generated by this study is also helpful for architecture, researchers and planners to develop a favorable environment housing project and in housing project societies. Environmental Impact Assessment (EIA) is an efficient method for preserving natural resources and protecting the environment [37]. Therefore, most developed countries have introduced EIA into their regulations and for the consequent approval of all projects [11, 16]. The environmental impact assessment (EIA) of projects requires the evaluation of the effects of very diverse actions on a number of different environmental factors, the uncertainty and inaccuracy being inherent in the process of allocating values to environmental impacts carried out by a panel of experts, stakeholders and affected population and for these reasons fuzzy logic is a suitable and useful tool with which to carry out EIA [37]. The unique features of construction activities such as being long period projects including complicated processes, abominable environment, financial intensity and dynamic organization structures [48, 52].

A fuzzy multiple criteria decision-making (FMCDM) tool has also been used to measure hazard for a urban building projects. In this case, Kuo and Luo (2012) used consistent fuzzy preference relations (CFPR), to analyze the comparative

* Corresponding Author: **Vivek Kumar Tiwari**
Email address: vivekanand17nov@gmail.com

impacts of 20 recognized risk issues on the project concert. The likelihood of each risk factor occurring is analyzed with the fuzzy multiple attributes direct rating (FMADR). This risk assessment method was found to be very reliable and effective in evaluating the overall project risks that can be encountered when executing a metropolitan construction project.

The fuzzy AHP is used to provide the weights of selected criteria. It can deal with the fuzzy inputs and consider the contingency of the outcome by using fuzzy numbers and the hierarchy structure of AHP. In the literature the fuzzy AHP is one of the most these criteria at the same time for finding a final solution, popular MADM methods [25, 34].

The fuzzy AHP is one of the effective approaches used to address the uncertainty and vagueness from the subjective perception and the experience of human's indecision-making process. By using the fuzzy AHP, the decision makers are allowed to provide the comparing results by the interval judgment instead of crisp value judgment which makes the decision makers feel more convenient and confident. The effects of uncertainty on the pair wise comparison are qualitatively estimated by the decision maker at a given level regarding their parent in the next higher level, based on the requirement of the comparative judgment principle. The fuzzy AHP integrates these individual effects of uncertainty on the pair wise comparison by combining the calculated ratio score local priorities according to the requirement of the synthesis of priorities.

In this study, the fuzzy AHP is applied to evaluate the weight factor by using five linguistic terms: equally significant, moderately significant, strongly significant, very strongly significant and extremely significant of which the numerical ratings are 1, 3, 5, 7 and 9, respectively [41].

In any country, infrastructure development will increase the growth of countries economy and generates the large amount of job opportunities. Hence those projects involve a large amount of investment to carry out. In view of that, if any sort of wastage (either time, resources etc) occurs that would lead to the huge monetary losses. These losses occur due to various risks associated with such mega projects. Consequently, these risks play a crucial role for the completion of project within the time schedule and planned budget.AHP model is more effective, because of its systematic approach to structuring risk assessment problems by providing hierarchical approach [39].

Tam *et al.,* [51] conducted a survey to examine the elements of poor construction safety management. Patrick *et al.,* [36] presented eighty-eight risk factors associated with construction project objectives in terms of cost, time, quality, environment and safety. Tah and Carr [50] proposed the application of fuzzy logic for risk assessment of construction projects. Similarly, fuzzy inference system is a very useful technique in tackling the complex problems of construction risk assessment. On the other hand, Kuchta [27] applied fuzzy numbers in risk evaluation of construction projects. Zeng *et al.,* [62] applied fuzzy set theory to evaluate the performance of cost and time in management of construction projects, risk management and utilization.

2) LITERATURE REVIEW

2.1 Determining weights of factors using the Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision making (MCDM) method [28] that assists the decision maker in solving a complex problem with multiple conflicting and subjective criteria (e.g. location or investment selection, project ranking, etc.) [21]. A popular twin comparison method called AHP, proposed by Saaty [42] and Saaty *et al.,* [44] has been widely used for this purpose. Twin comparisons enable us to increase the compatibility of evaluations. The advantage of the AHP method over other multipurpose decision-making methods is its flexibility, convenience for decision makers, and the possibility to verify compatibilities [38]. The AHP method can assess both qualitative (subjective) and quantitative (objective) attributes of alternatives. The twin comparison methodology reduces partiality and bias in decision making. The AHP method uses relative values and is, hence, a suitable tool to deal with attributes of various dimensions. Traditional multi-criteria decision-making methods evaluate all alternatives at a single level, which inadvertently restricts the simultaneous comparison of numerically heterogeneous alternatives [44]. The decision maker can specify preferences about the importance of each performance criteria in form of either natural language or numerical value [52]. In the real world, It is very difficult to extract accurate data pertaining to measurement factors since all human preferences are susceptible to a degree of uncertainty. Decision-makers are also inclined to favors natural language expressions over exact numbers when assessing criteria and alternatives [20]. The AHP method makes it possible to identify the weight (importance) of indicators at one level of hierarchy against a higher level, or the hierarchically non-structured weights of indicators. The essence of the method lies in the matrix of twin comparison [47].

2.2 Fuzzy AHP techniques in EIA (Environmental Impact Assessment)

It is a simple and practical multi-criteria evaluation method applied [24] in many fields. During the decision-making process, it will express the joint conclusion of multiple experts as to the optimal solution [49]. Fuzzy AHP [15, 63] is an organic mix of analytic hierarchy process and fuzzy comprehensive evaluation [23, 24] technique which was developed by Saaty [41] and also a modelling technique based on multi-criteria decision-making method. It is used to assess the project's impact on alone-the-line or surrounding areas [15, 63]. The application of the fuzzy set theory can improve the study of EIA. A fuzzy logic knowledge-based approach can be used for the environmental impact assessment study of the different construction projects. The table 1 showing about the Evolution and history of EIA and figure 1 showing about the Fuzzy logic for EIA. [29, 30] of construction projects.

The method is specially used where different criteria sets are used in project evaluation and the criterion is found to be incapable of dealing with the problems of uncertainty in decision-making situation. Buckley [5] applied the fuzzy set theory to depict the fuzziness of the decision-makers. This process comprises of both group decisions and fuzziness. Examples for the proper application of the fuzzy AHP are: decisions in new product development [7]; flexible manufacturing systems [10]; safety management in production [12]; selection of enterprise resource planning systems [8]; evaluation of success factors in e-commerce [26]; personnel selection [19]; affordable housing [4] and weapon selection [13]. In a similar study, land capability of Shandiz urban region, northeast of Iran, was assessed for spatial development

using multi-criteria evaluation framework [1]. AHP is a mathematical method for the determination of the priority of the process and criteria in the evaluation process and decision making. The main reason of applying AHP is that it helps decision makers to solve the complex problem into a hierarchical structure. The AHP analysis creates better and clear rationale for selecting the various options in a complex decision environment such as impact assessment for housing projects [4]. Fuzzy models have many interesting features that make them ideal for such conceptual models [58] in addition:

- Fuzzy models are represented as a set of fuzzy sets to describe outputs and a set of rules.
- Fuzzy models can easily be understood by experts.
- Fuzzy models can easily express complicated nonlinear relations.

2.3 AIEIA: Software for fuzzy Environmental Impact Assessment

AIEIA [31, 32] is a software program for the comprehensive management of environmental projects which was developed using the fuzzy set theory [60], object-oriented programming techniques and information management with databases. These techniques are used to determine the best execution alternative for a project, taking into consideration not only the environmental impact produced in each alternative, but also other variables such as those of an economic, political, social or cultural nature. This software has a number of functions for the study of EIA of a project. These are project management, Information management and Calculation of the fuzzy environmental impact study (FEIS). The use of AIEIA software can improve the EIA model and EIA mechanism.

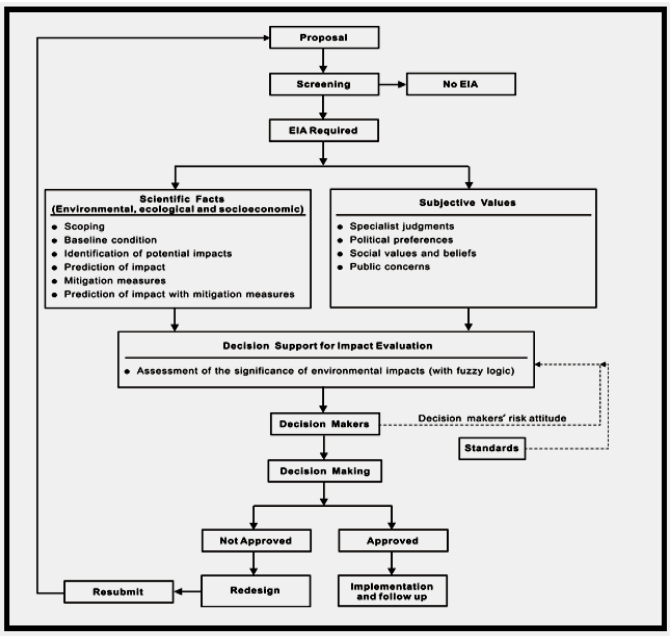

Fig. 1: Fuzzy logic for EIA. [29, 30] of construction projects.

Table 1: Evolution and history of EIA

Pre-1970	Project review based on the technical/engineering and economic analysis. Limited consideration given to environmental consequences. EIA introduced by NEPA in 1969 in US.
Early/mid-1970s	Basic principle: Guidelines, procedures including public participation requirement instituted and formalized. Standard methodologies for impact analysis developed (e.g. matrix, checklist and network). Canada, Australia and New Zealand became the first among countries to follow NEPA in 1973-1974. Unlike Australia, which legislated EIA, Canada and New Zealand established administrative procedures. Major public inquires helped in process's development and subsequent follow up actions.
Late 1970 and early 1980s	More formalised guidance was developed. Other industrial and developing countries introduced formal EIA requirements (France, 1976; Philippines, 1977), began to use the process informally or experimentally (Netherlands, 1978) or adopted elements, such as impact statements or reports, as part of development applications for planning permission (Germany and Ireland). Use of EA by developing countries (Brazil, Philippines, China, Indonesia) Strategic Environment Assessment (SEA), risk analysis included in EA processes. Greater emphasis on ecological modelling, prediction and evaluation methods. Provision for public involvement. Coordination of EA with land use planning processes.
Mid 1980s to end of decade	In Europe, EC Directive on EIA established basic principle and procedural requirements for all member states. Increasing efforts to address cumulative effects. World Bank and other leading international aid agencies established EA requirements. Spread of EIA process in Asia.
1990s	Requirement to consider trans-boundary effects under Espoo convention. Increased use of GIS and other information technologies. Sustainability principal and global issues receive increased attention. India also adopted the EIA formally in 1994. Formulation of EA legislation by many developing countries. Rapid growth in EA training.

Source: International Study of the Effectiveness of Environmental Assessment, final report, Environmental assessment in a changing world, Prepared by Sadler, (1996).

2.4 *Fuzzy AHP method and Fuzzy Number*

Fuzzy AHP method was applied to create favourable weights for fuzzy linguistic variable of construction project risk assessment. Fuzzy AHP method is a systematic method to the alternative choice and justification of problem by using the approach of fuzzy set theory and hierarchical structure study [55, 57]. In FAHP method, the pair-wise distinctions in the judgment matrix are taken as fuzzy numbers. It uses fuzzy arithmetic and fuzzy summing operators. Then the procedure calculates a series of weight vectors which is used to choose the main attributes [19].

In construction projects overall risk assessment is a multi criteria decision making (MCDM) approaches which in complication in reference of decision making, each factors are given suitable attributed values and relative weights are typically toned by fuzzy numbers [53]. A fuzzy number is a convex fuzzy set, characterized by a given interval of real numbers, each with a grade of membership between 0 and 1. The most familiar used fuzzy numbers are triangular and trapezoidal fuzzy numbers. The membership or non-membership to a fuzzy set is plane and gradual. The membership degree of a set is characterized by membership functions that give fuzzy sets flexibility in modelling with normally used linguistic expressions, such as 'the project threat is high' or 'the time extent of project is short,' and 'the quality of construction project is poor' or 'the cost of project is high etc. As it is presented in Table 3. fuzzy linguistic values are frequently presented by specific terms in the real life, but they can also be represented by fuzzy numbers. It is typically suitable to characterize the degree of subjective judgment in qualitative side than in crisp value [9]. The word risk is a qualitative and vague concept that can be defined by fuzzy linguistic terms.

Table.3. Fuzzy linguistic variables and their term

Fuzzy linguistic variables	**Linguistic terms**
Time	Short, average, long, very long
Cost	Low, average, high, very high
Quality	Poor, average, high, very high
Safety	Unsafe, average, safe, very safe
Environmental sustainability	Unsustainable, little-sustainable, sustainable, highly-sustainable

Source:-Taylan, *et al.,* 2014 [52]

2.5 Fuzzy Logic Method

Zadeh [61] set forth fuzzy logic theory as an approach for dealing with conditions where classes were not transparently defined. Zadeh noted that imprecisely defined classes describe much of human thoughts. In classic set theory, an item is either a member of the set (1) or not a member of the set (0), Fuzzy logic grants for gradations between full membership and full non-membership [18]. Fuzzy logic, though, can model the conclusion of gradients or variables between high and low as well as the analogous significance of diverse environmental issues [35]. Fuzzy logic also allows the use of expert idea and experience in the modeling process. One big benefit of the fuzzy logic approach is that it provides a composite fuzzy score, a value between 1 (high) and 0 (low). The composite fuzzy score is easy to decode and understand the significance of cases [35]. Fuzzy logic analysis is well flourish to data poor environments. Unknown data points can be handled within the fuzzy membership function. Extra variables can be added to produce a complex system of modeling to point out the association between management agenda and environmental parameters [18]. The analytic hierarchy process (AHP) is frequently interrelated to the fuzzy logic method. Bascetin [3] noted that AHP and fuzzy logic have been systematically used as tools to deal with "inherent imprecision" in a wide range of problems. Saaty [41, 45] developed the AHP method which aids the decision makers to take suitable decisions at finer level, working throughout the goal, objectives, sub-objectives and another parts of action. During the decision-making process, it will express the conclusion of multiple experts as to the optimal solution [49]. Decision makers continue through a series of simple pair-wise distinct judgments throughout the hierarchy to produce overall priorities. Siddiqui *et al.,* [46] showed how AHP could be used to find the most useful site for a solid waste land filling. Fuzzy logic study results in a combined fuzzy score, which is a continuous range between zero and one. This continuous range gives improved spatial variability found in natural systems as well as appropriateness of any projects. Table: 2. Population of study area.

2.6 *Fuzzy Logic Modelling*

Fuzzy logic is significant at modeling uncertainty or gradations [18]. In fuzzy set theory, an item is either part of a set (1) or not parts of the set (0) are given marks or numbers. Though, most environmental variables cannot be described effectively in a binary mode. Fuzzy logic takes into consideration of old areas [40]). Fuzzy comprehensive evaluation method can mostly reflect the nature of subjective assessment without limitation of scale [59], but its weight is usually given by the experts based on experience cannot help with subjectivity. Another advantage of fuzzy logic study is that it incorporates opinion of expert and stakeholder values [18, 40]. The weights and fuzzy membership functions were finding in discussion with Dr. D. Phillip Guertin of the University of Arizona and experts from ADEQ. Fuzzy logic analysis is particularly well suitable for data poor environments management [18, 40]. Inability of AHP to deal with the imprecision and subjectiveness in the pairwise comparison process have been improved in Fuzzy AHP.

Instead of single crisp value, in Fuzzy AHP use a range of value to incorporate decision maker's uncertainty. From this range decision maker can select the values that reflect his confidence and also he can specify his attitude like optimistic, pessimistic or moderate [22]. Optimistic attitude is represented by the highest value of range, moderate attitude is represented by the middle value of the range and pessimistic attitude is represented by the lowest value of the range.

2.7 *Fuzzy Logic steps*

In Fuzzy AHP triangular or trapezoidal fuzzy number are used to represent the decision maker's assessments on alternatives with respect to each criterion. The concept of fuzzy extent analysis is applied to solve the fuzzy reciprocal matrix for determining the criteria importance and alternative performance. The alpha-cut analysis is used to transform the fuzzy performance matrix representing the overall performance of all alternatives with respect to each criterion into an interval performance matrix, to avoid the complex and unreliable process of comparing fuzzy utilities. An overall performance index is obtained for each alternative across all

criteria by applying the concept of the degree of similarity to the ideal solution using the vector matching function [14]. The steps required for Fuzzy AHP developed by Hepu Deng [14] and then modified by Jeganathan [22] for the assessment is as follows:

- Acquisition of Normal (crisp) Pairwise Comparison Matrices (PCM)
- Fuzzifying the crisp PCM to Fuzzy PCM
- Fuzzy Extent Analysis for Calculation of Performance ratings
- Weightage Multiplication from Hierarchy
- Alpha cut analysis for embedding uncertainty of Decision Maker confidence
- Lambda function for embedding Attitude of the Decision Maker
- Normalizing the Effect table
- Positive and Negative Similarity Vector Identification
- Similarity measurement using Vector Matching Function
- Final Performance Index Measurement.

3) CONCLUSION

- AHP is an American scholar T.L.Saaty proposed in the 20th century 70 years, and based on a certain scale which changes subjective judgments into objective ones and solves qualitative problems with quantitative analysis. It is a simple and practical multi-criteria evaluation method applied in many fields. Fuzzy comprehensive evaluation is a branch of fuzzy mathematic which is created by a well-known electronic engineer and cybernetics expert L.A.Zadeh and dealed with the fuzzy phenomenon with mathematical method.
- Fuzzy is one of the characteristics of human thinking and fuzzy sets theory is an effective tool for fuzzy phenomenon treatment, while the evaluation is a general view of things that the nature of thinking determines its fuzziness. As a result, the fuzzy mathematic method has been widely used in the field of systematic evaluation.
- AHP is better at computing index weight and comparing index in the same row than at classifying level, while fuzzy comprehensive evaluation method can mostly reflect the nature of subjective assessment without limitation of scale, but its weight is usually given by the experts based on experience cannot help with subjectivity. The advantages of the two methods are coupling to form a new method:
- Fuzzy-AHP (FAHP), which combines the qualitative analysis with quantitative analysis to make subjective estimates more objective. FAHP has grown rapidly, due to be continuously refined and improved, which has advantage on dealing with complex issues of multi-level evaluation and problems of decision-making and has gradually expanded to apply on several fields in recent years. At the same time, the models increasingly enriched and became more and more different as a result of the complexity of various fields.
- AHP has its own superiority in computing index weight and comparing index in the same row than at classifying level. While fuzzy comprehensive evaluation method is good at classifying level.
- The fuzzy AHP is one of the effective approaches used to address the uncertainty and vagueness from the subjective perception and the experience of human's indecision-making process. By using the fuzzy AHP, the decision makers are allowed to provide the comparing results by the interval judgment instead of crisp value judgment which makes the decision makers feel more convenient and confident.
- The effects of uncertainty on the pair wise comparison are qualitatively estimated by the decision maker at a given level regarding their parent in the next higher level, based on the requirement of the comparative judgment principle. The fuzzy AHP integrates these individual effects of uncertainty on the pair wise comparison by combining the calculated ratio-score local priorities according to the requirement of the synthesis of priorities.
- EIA certainly has a vital role to play in addressing environmental issues surrounding project development. The integration of environment into development planning is the most important tool in achieving sustainable development. EIA process is necessary in providing an anticipatory and preventive mechanism for environmental management and protection in any development. Several developing countries are still at the infancy stage of operationalization of their EIA processes.
- EIA are the most popular among the EIM suite of tools. With its origins in the USA, EIA is considered the starting point in the process of implementing sustainable development agendas. In terms of benefits, it has identified EIAs as the most effective tool for integrating environmental concerns in development planning and implementation.
- EIA also provide a good example on how a combination of 'top down' and 'bottom-up' approaches could improve democracy and service delivery. Chief among the EIA challenges are the increasing level of subjectivity and the lack of universally scientific standards and methodologies.
- A fuzzy logic knowledge-based approach can be used for the environmental impact assessment study of the construction projects. Fuzzy logic has been successfully applied in the environmental field.
- Fuzzy logic method is useful in environmental impact assessment (EIA) of projects which requires the evaluation of the effects of very diverse actions on a number of different environmental factors, the uncertainty and inaccuracy being inherent in the process of allocating values to environmental impacts carried out by a panel of experts, stakeholders and affected population.
- AIEIA, Software are used to determine the best execution alternative for a project, taking into consideration not only the environmental impact produced in each alternative, but also other variables such as those of an economic, political, social or cultural nature. This software has a number of functions for the study of EIA of a project.

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