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Decision Support System for Environmental Impact Assessment Using Fuzzy Logic.

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ABSTRACT
Environmental impact assessment is becoming a very important study before commissioning of any project plan or development in our country. This paper presents a decision support system for environmental impact assessment, using fuzzy sets techniques. In brief considering the regulatory parameters or the membership functions MFs in EIA study as an input to the black box (Fuzzy engine) and getting the rated numerical output after setting up the governing rule in the prevailing condition. These numerical out put would setup the environmental impact statement. The dynamic nature of this system would help prioritizing the environment management plan EMP.

Keywords: Membership functions MF, Fuzzy inference system FIS, Environment management plan EMP, Fuzzification, Defuzzification, Fuzzy variables FV.

1. INTRODUCTION

The status of fuzzy sets theory previously was limited to electronic data manipulation and processing, electrical switchgear control system. But these day as scientist and engineers have identified its potential in other field like artificial intelligence AI, development of expert system ES etc. further to some down to earth problem of simple decision making.
Our EIA methodology falls in this simple decision making category. Scoring the regulatory parameter rightly remains the challenge in it.
An EIA study is always a multidisciplinary teamwork. Expert from the different areas like land, air, water and socio economic field constitute a balanced team. A Varity of activities like field visit, documentation, public hearing and presentation is done. An important step in EIA study is to define its scope and note the key constraint. The precise EIA methodology depends on the nature of project but the objective of EIA study float around these key aspects.

- Base line studies
- Prediction of impacts
- Evaluation of impacts (EI)
- Environmental management plan (EMP)

Impact evaluation method available for EIA are Matrix method, overlay method using GIS and remote sensing, Adhoc method, simple check list method, network analysis, and

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combination of above mentioned. These methods are more or less time consuming and subjective because of repeatability, which is lacking in them. The reason may be the different sets of people perceive different thing differently. EIA studies also vary accordingly*[3] although this subjectivity would be there as we implement Fuzzy sets technique in the study but precision and repeatability would increase to some extent.

Environmental Impact Assessment (EIA) is a tool used to identify the environmental, social and economic impacts of a project prior to decision-making. It aims to predict magnitude of environmental impacts at an early stage in project planning and design, find ways and means to reduce adverse impacts, shape projects to suit the local environment and present the predictions and options to decision-makers. By using EIA both environmental and economic benefits can be achieved, such as reduced cost and time of project implementation and design, avoided treatment/clean-up costs and impacts of laws and regulations. The key elements of an EIA are (a) Scoping: identify key issues and concerns of interested parties; (b) Screening: decide whether an EIA is required based on information collected; (c) Identifying and evaluating alternatives: list alternative sites and techniques and the impacts of each; (d) Mitigating measures dealing with uncertainty: review proposed action to prevent or minimize the potential adverse effects of the project; and (e) Issuing environmental statements: report the findings of the EIA. (Source UNEP-DTIE)

Fuzzy logic is all about the relative importance of precision: How important is it to be exactly right when a rough answer will do? All books on fuzzy logic begin with a few good quotes on this very topic, and this is no exception. Here is what some clever people have said in the past.

“As complexity rises, precise statements lose meaning and meaningful statements lose precision.” —**Lotfi Zadeh, father of fuzzy sets theory.**

“I believe that nothing is unconditionally true, and hence I am opposed to every statement of positive truth and every man who makes it”. —**H. L. Mencken**

Figure 1.A provides the basic concept of how the fuzzy logic works. It depicts an input space, where the fuzzy variable sets are identified like for example air, water, land, noise and ecology etc. and fuzzification is done after populating the set by member ship functions for example BOD, DO, SPM, land traffic noise, employment and ground water etc. Then governing rule in the prevailing condition are set by applying simple experience and logic like, “if [ecology is poor] or [water is notacceptable] or [air is notacceptable] or [socioeconomic is bad] or [noise is severe] than [impact is severeimpact]” etc. Now fuzzy engine process these two input “input space” and “governing rule” to shape the output, which falls in output space. MATLAB create a dynamic system in which, slight change in one input would immediately affect the output in output space in the proportion of its importance, and there by given us the chance to analyze and prioritize the environment management plan EMP.

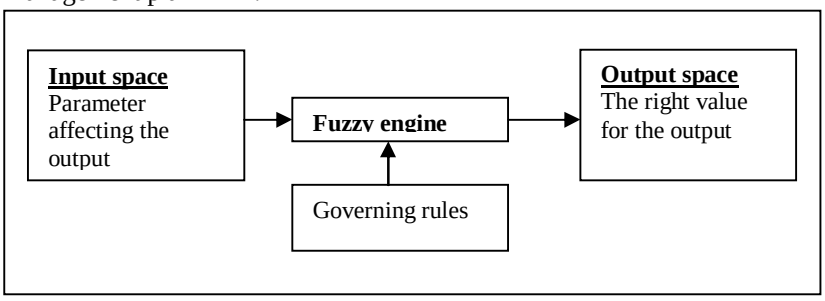

Figure 1.A. Mapping of fuzzy input to out put.

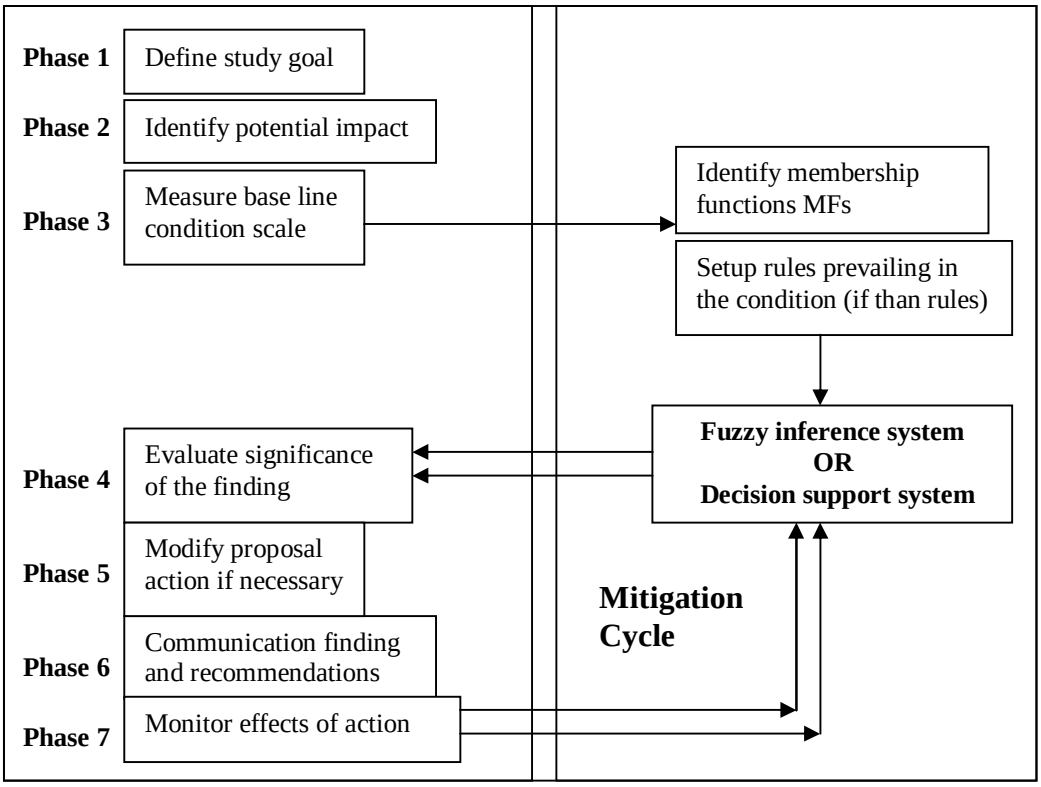

Figure 2.A. Incorporation Fuzzy sets theory in EIA.

2.0 METHODOLOGY

We will be using Ebrahim Mamdani's*[6] inference system for its ease in usage in environmental problems. Our objective is to design a general system, which would behave in a realistic way. Before starting let us consider a case, impact from sound to certain set of people would be less than that of some other set of people. Now expert of the field does this differentiation. Here, in our system we can easily differentiate between these two distinct situations by setting and prioritizing the rules. In fact it is very difficult to mathematically define such a situation.

The seven-phase/step model in planning and management of EIA proposed by UNEP can be modified in the way shown in figure 2.A. Now according to seven-phase model, identification input fuzzy variables FVs need to be done, refer to Figure 2.A. we take a general case assuming these parameter are in any way affecting the impact by some magnitude. We can incorporate many more FVs if needed. Now we have constituted fuzzy sets. Problem is broken in to eight inference systems due to the inability of current computers to process 34 inputs, single out put and about 20 rules simultaneously. In figure 2.B we tried to map eight-inference systems. All the eight-inference system are developed and solved separately. Output from first to seventh inferences system would go as an input to eight inference systems and output of eight would be the final result.

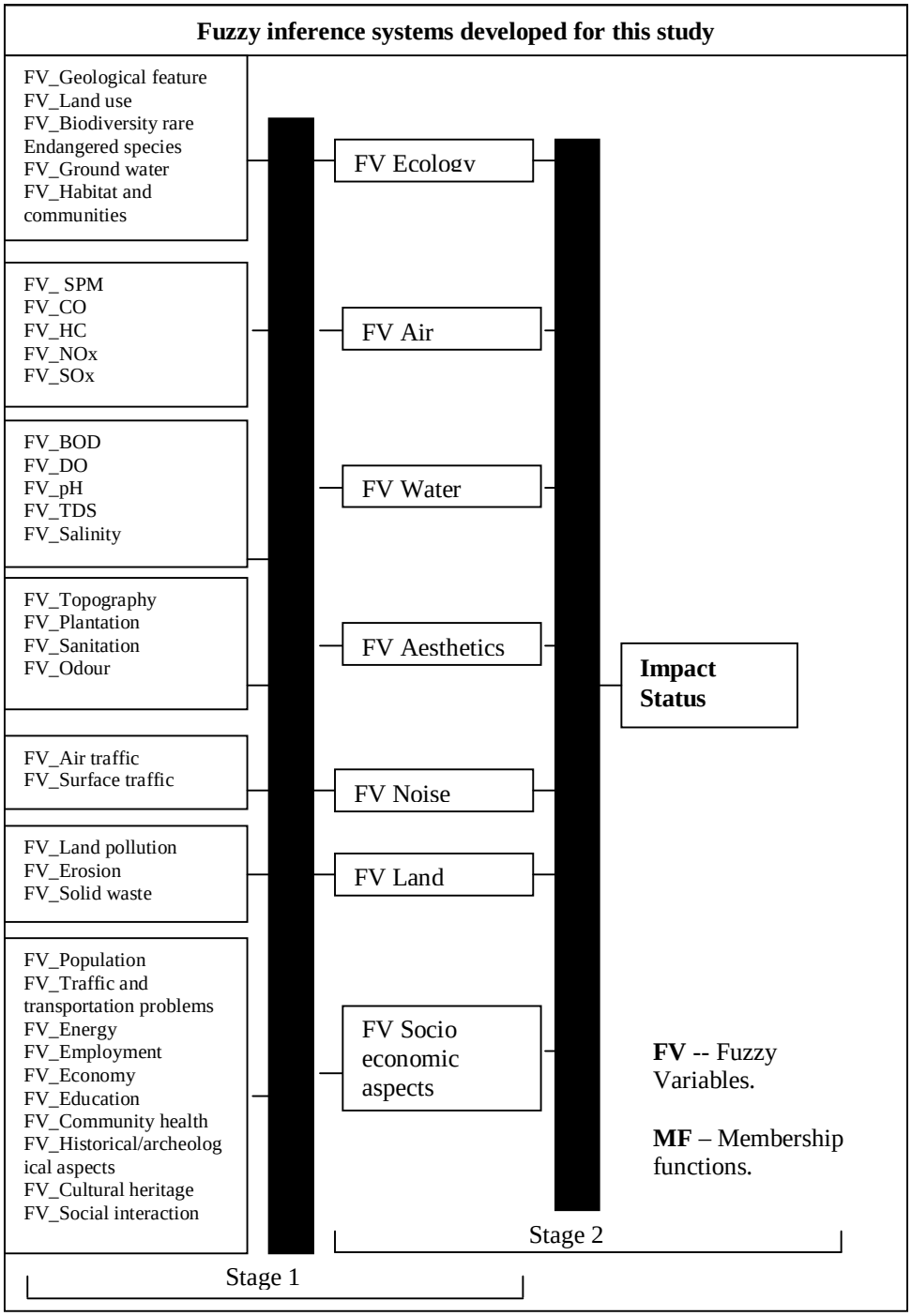

Figure 2.A. Fuzzy variables *[6]

2.1 Development of Inference-Systems.
We will be discussing the development of only eight inference IS named FIS_Impact all the rest of the seven will be developed on same methodology. There are 7 input variables FV_Air, FV_Water, FV_Ecology etc refer to figure 2.A stage 2. Now mathematically we can define fuzzy sets.

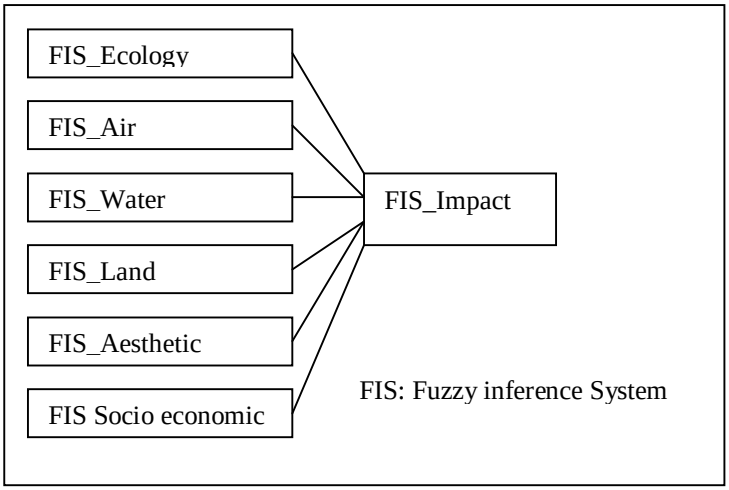

Figure 2.B. Mapping of eight inference systems

In genral:
FV=[MF_1 μ=x, MF_2 μ=x, MF_3 μ=x, MF_4 μ=x ……. ,MF_n μ=x] - 1

FV_Air=[MF_NotAcceptable μ=x, MF_Acceptable μ=x,
MF_BarelyAcceptable μ=x, MF_Good μ=x]
Where 1≥ x ≥0
FV_Water=[MF_NotAcceptable μ=x, MF_Acceptable μ=x,
MF_BarelyAcceptable μ=x, MF_Good μ=x]
Where 1≥ x ≥0
FV_Land=[MF_Poor μ=x, MF_Moderate μ=x, MF_Good μ=x]
Where 1≥ x ≥0
FV_Ecology=[MF_Poor μ=x, MF_Average μ=x, MF_Good μ=x,
MF_Excellent μ=x]
Where 1≥ x ≥0
FV_Aesthatic=[MF_Good μ=x, MF_Bad μ=x]
Where 1≥ x ≥0
FV_Socioeconomic=[MF_Bad μ=x, MF_Moderate μ=x, MF_Good μ=x]
Where 1≥ x ≥0
FV_Noise=[MF_Severe μ=x, MF_BarelyAcceptable μ=x,
MF_Acceptable μ=x] ;Where 1≥ x ≥0

2.2 Assignment of Fuzzy Membership Functions*[4]

There are several ways to generate a fuzzy membership function. For environmental applications, there are two different but complementary approaches to grouping individuals into fuzzy sets or classes. The first is the Similarity Relation model (SR), and the second is based on the Semantic Import model (SI). We have used SR model which is comparatively simple to use, because it utilizes an a priority membership function (MF) for individual variables under consideration the attribute values considered are converted to common membership grades (from 0 to 1.0), according to the class limits specified by the analysts based on experience or conventionally imposed definitions. We have incorporated triangular, Trapezoidal, generalized bell, Gaussian, Sigmoidal and Polynomial membership variation[a]. For the case of Air it is shown in figure 2.C.

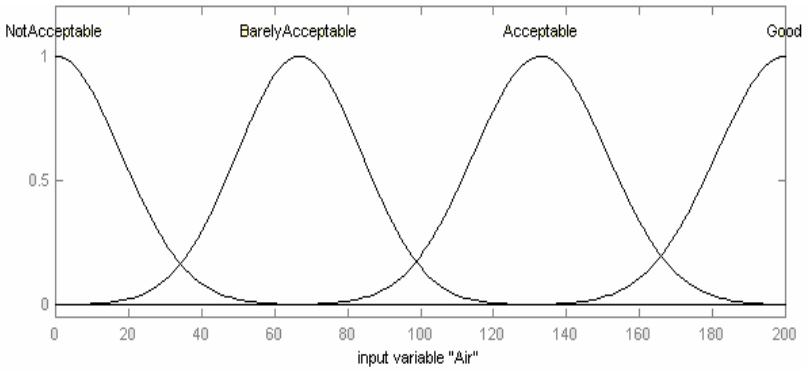

Figure 2.C. Membership function for input fuzzy variable Air

2.3 Translating The Prevailing Condition, Rule Setting.

Now at this stage we are left with defining the rules[b]. These rules are very important in terms of representation of the actual prevailing perception and need[c] about the environment. These rules will directly affect the output. For example, say that if air quality is poor and water quality is also poor so definitely the environmental quality will also be poor. Now these statements have to be described mathematically.

In general we can define.

If [FV **is** MF $_{\mu=x}$] **and /or/not** [FV **is** MF $_{\mu=x}$] **and /or/not** [FV **is** MF $_{\mu=x}$] **Than** [FV **is** MF $_{\mu=x}$] -2

Following above expression, we defined four rules prevailing in the condition.

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If [Ecology is poor] or [Aesthetic is bad] or [SocioEconomic
is bad] or [air is notacceptable] or [water is
notacceptable] or [land is poor] or [noise is severe] then
[impact is severeimpact ](1)

If [Ecology is Excellent] or [Aesthetic is Good] or
(Socioeconomic is Good) or [Air is Good] or [Water is Good]
or [Land is Good] or [Noise is Acceptable] then  [Impact is
NoImpact] (1)
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(a)-Choosing different functionalities like gauss, sigmoid etc. is authers[1] own perception of the situation and is carrying a scope of improvement, (b)-Rules still need refinement and improvement cannot be ruled out, (c)-the need to be biased to certain fact is controlled while rules setting.

If [Ecology is Average] or [Air is BarelyAcceptable] or [Water is BarelyAcceptable] [Noise is BarelyAcceptable] then [Impact is ConsiderableImpact] (1)

If [Ecology is Good] or [Aesthetic is Acceptable] or [SocioEconomic is Moderate] or [Air is Acceptable] or [Water is Acceptable] or [Land is Moderate] then [Impact is ModerateImpact](1)

3.0 RESULT OF THE ANALYSIS.

We have considered the three aspect of an environmental evaluation system, (a) Baseline condition, (b) Condition after project implemented and (c) Condition with environmental management plan. The outputs from the inference system are shown in figure.3.A, figure.3.B and fugure.3.C.These are 637, 500 and 713. The conclusion drawn from these results is that the project after EMP is well and good, because the value has gone to 713 which is overall a positive impact.

The figure.3.D is showing the dependency of air and ecology with the impact. It is depicting that the impact is less when you go to higher values of ecology and air and vice versa. The shape of the curve is very complex here where the fuzzy logic did the work. Obtaining such a dependency with ordinary mean would definitely be a very complex work.

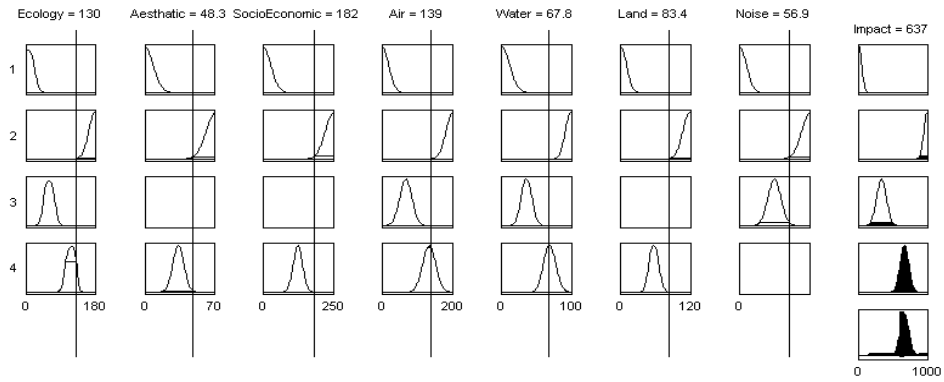

Figure 3.A. Impact status at Baseline condition.

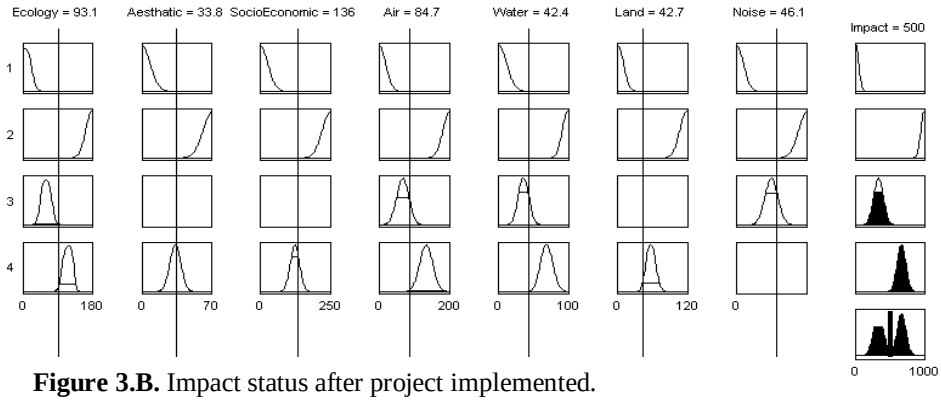

Figure 3.B. Impact status after project implemented.

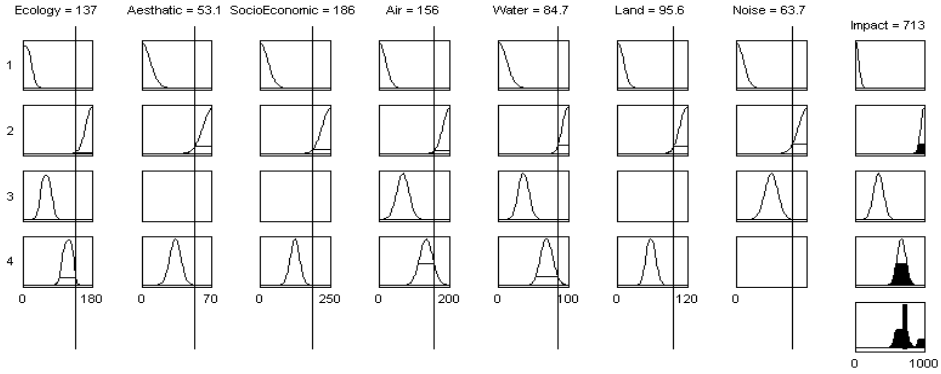

Figure 3.C. Impact status after implementation of environmental management plan.

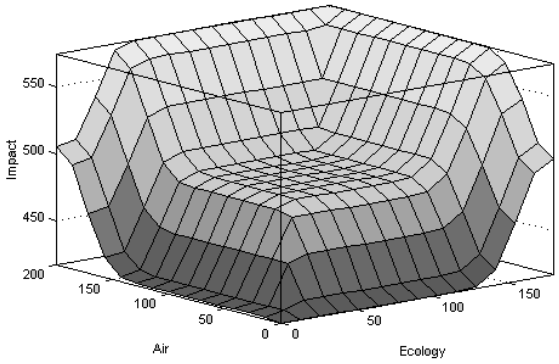

Figure 3.D. Dependency of Air and ecology with impact.

4.0 CONCLUSION AND SCOPE OF THIS WORK.

Identification of membership functions still remains the challenge in this area. This work can only maximize the repeatability characteristic, idealistic nature, and hence overall objectivity of the problem.

The membership function variation is also a point of importance, more real is the membership functional variation more ideal is the output. A lot of scope for improvement remains, Interference of expert is indeed required.

Rule governing or prevailing in the condition are to be set by the experts of the very field itself. Moreover good translation of the rules in logical form improve the idealistic nature of the solution and hence the result of analysis would behave in the way as a complete team of expert would behave to the problem, whom having the same approach of the rules in their mind.

Complete system can be develop that can help in prototyping and project or industrial simulation, trade off between productivity and impact can be set though it. Further more, mitigation measures can be priorities keeping in view the direct dependence from the system dynamically.

Development of embedded fuzzy control systems in analyzer and monitoring station cannot be ruled out at this point.

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