ADVANTAGES OF NEW ECOLOGICAL IMPACT AND RISK ASSESSMENT MODELS

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Evaluarile de impact/risc devin de importanţă crescută în realitatea vietii noastre. Majoritatea metodologiilor folosite pana acum au fost total subiective ceea ce facea ca evaluarile sa ramana dependente de datele initial colectate si de pregatirea si expertiza evaluatorilor initiali, un dezavantaj major fiind imposibilitatea actualizarii informatiei si imposibilitatea unei reconsiderarii a evaluarii initiale. Articolul prezinta noi metode care depasesc acest dezavantaj major, fiind capabile sa cuantifice, prin structura in rezultatele lor, incertitudinea inerenta a datelor folosite si a subiectivitatii evaluatorilor.

Ecological impact and risk assessments have become of increasing importance in our daily life. The majority of used methodologies until now have been totally subjectiv. That is why the assessments remained dependent the on initial collected data and on the evaluators background and expertise, a major disadvantage being the impossibility to update the information and to submit the initial evaluation to a further scrutiny. The paper presents new methods that overcome this major disadvantage being capable to quantify in their results the inherent uncertainty linked to the used data and evaluators subjectivity.

Key words: ecological risk, ecological risk assessment, ecological risk management

1. Introduction

The ecological impact and risk assessments are of increasing importance, being required by international, European, and national environmental laws to evaluate the consequences of intended or unintended pollution on a determined time horizon in order to finally assess the total environmental damage usually expressed in money or affected people.

In Romania, in the last years, the ecological risk assessment is required as a following-up step after Environmental Impact Balance Study - Phase II when a

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significant environmental impact is found. The significant environmental impact is defined as the impact that exceeds the intervention limits according to the existing regulations for the existing pollution. That means the process of environmental risk assessment should be carried out with the purpose of assessing the possible environmental risk occurring after the development of present or future projects activities. This process is always applied prior to major decisions that should be taken in relation with those projects. It should be mentioned that social, cultural and health effects are considered as an integrated part of Environmental Impact/Risk Assessments.

The assessments aim to offer information for the decision-making process on environmental consequences of the proposed activities and actions, and to promote environmental protection actions in order to achieve the sustainable development, by identifying the appropriate attenuation measures or planned enhancement actions plans [1].

This roll of Environmental Impact/Risk Assessments is formally recognized by the 17th principle of Rio Declaration for Environment and Development as being national instruments, to be used to assess the proposed activities that probably have a significant effect on the environment, *inter alia* being the subject of the decision of competent authorities. These are also planning instruments to promote a sustainable development policy through the integration of environmental considerations, in a proposed action plan.

Environmental impact can vary in:

- type (biophysical, social, health or economical)
- nature (direct or indirect, cumulative),
- magnitude (high, moderate, low),
- severity (high, moderate, low),
- geographic extent (local, regional, transboundary, global),
- timing (immediate/long term),
- duration (temporary/permanent),
- reversibility (reversible/irreversible)
- significance (unimportant/important),
- uncertainty (low/high).

The EIA (Environmental Impact Assessment) was introduced in 1969 through the US National Environmental Policy Act (NEPA) as a consequence of public concerns on the quality of the environment and increased effects of new technologies. It followed in USA an EIA early development stage during the period of 1970-1975, and in Australia, Canada and New Zeeland during the period of 1970-1980 [2]. Starting with ’80 the risk assessments become an important topic as a follow-up phase of EIA in order to determine the associated risk of the found environmental impacts.

In Romania, the environmental impact and risk assessment practice has been developed after 1995 (see Governmental Order 184/1997, and its modifications and other current applicable environmental laws related to the subject).

Until now, the used methods have been mainly subjective in nature. Used criteria in multiple criteria decision analysis have been subjectively chosen and also experts opinions elicitation did not take into account the relative importance of criteria using mainly linear aggregation methods. The final obtained assessments were not able to express quantitatively the uncertainty or to update information and data.

The literature associated to the topic is vast. The model and the associated algorithm used in this paper have origin in other disciplines, such as artificial intelligence, expert systems ([1], [4], [6], [5]).

2. Theoretical Basis

This paper presents a relevant comparison between new and old methods for ecological impact/risk assessments. The issue in ecological impact/risk assessments is essentially related to the topic of identifying robust methods, able to withstand the process of updating data and representing the subjective judgments taking into account all spectrum of opinions within an ecological risk assessment. The European and national environmental laws require, for the purpose of environmental impact assessments of certain projects, a large democratic consultation mentioning that the public should be consulted in the earliest phases of the project development.

UNEP (United Nations Environmental Program) is mentioning that public involvement is "a key for achieving both other procedural principles and the substantive objectives of the assessment process. A requirement to make information available to the concerned public and seek their views and comments helps ensure that assessment procedures are implemented in an open, transparent and accountable manner. Public scrutiny also encourages the preparation of robust and defensible assessment studies and reports. The inclusion of public views and comments in the decision-making process promotes equitable and informed choice, leading toward better and more acceptable social and environmental outcomes."[2].

Based essentially on a set of criteria put into a more or less complex decision matrix, the methods used so far lack to offer a transparent assessment approach because what is offered to the public are conclusions of an experts' panel, difficult enough to be understood. Those methods have been conceived on a totally subjective assessment framework thus it is difficult if not impossible to update the information in the light of new data both during the assessment process and after the assessment in the case of a new scrutiny process. Being solely based on experts opinion elicitation, people have no access to the experts used criteria. This makes them feel sometimes suspicious and overwhelmed by the high expertise information exhibited

in relation to the topic, even if the practice of non–technical report is meant to attenuate a little bit this impact.

The public needs to be part of the decision process so people should be allowed to access the used criteria in an easy to use easy to understand manner. However, this is not an easy task to be accomplished. Public is giving practical possibility to assess the ecological effects judging the information based on a summary of collected data. The elicited opinions are taken into account in the decision-making process. This endeavour requires a lot of work especially work to put together data, to summarize them and finally to offer relevant information for corresponding interested parties (e.g. stakeholders).

Technically speaking, that means a quality work. There is a need to bring science to the public, making people understand the aspects behind the ecological risk assessments, taking the public as part of working team, not ignoring its opinion even if it is not an expert one, and offering finally a sound scientific assessment. Science, by definition, is an organized body of knowledge about a particular subject. Ecology is a science that requires knowledge from a lot of fields of activities. In this approach, the work of the experts panel, especially of those who make the information user friendly, is more difficult, more complex, requiring good knowledge of how to apply the method.

The method is not just a simple algorithm; it requires extensive experience in the environmental and associated analytical fields, good communication skills in order to offer a relevant balance between technical aspects, and the easiness of expressing and releasing the relevant information needed for constructing a sound decision process. This is essential for a balanced assessment of its essential aspects. By their opinion, evaluators, experts, public or all other interested parties have the chance to elicit their opinions that will be finally used in the conclusion outlines.

The newly developed methods in the Operation Research field, especially Evidential Reasoning based on Dempster - Shafer theory, are meant to specifically support this type of decisions, involving large democratic consultation towards reaching a consensus. Our research work of the last few years, have been targeting these methods that have been developed also during a doctoral programme. The multi-criteria methods based on an extended probability theory framework offer decision support modelling for handling the inherent uncertainty related to the collected data and assessment judgments.

These new methods are able to mould uncertainty in a quantitative manner using a non linear aggregation method. Our research has been oriented toward a method using a conjunctive aggregation rule for modelling the conflict among provided information, emphasizing the common agreements among various stakeholders. Depending on the reliability of used data, different kinds of aggregation rules might be involved.

3. The advantages and benefits of new methodologies

According to UNEP (United Nations Environmental Programme) the assessment methodologies involving public consultation should be based on the following principles:

Responsibility – meaning to be appropriate and to offer timely opportunities for the public to be informed and heard

Efficiency – meaning to be realized with minimum time and cost burdens on proponents and participants, consistent with meeting accepted requirements and objectives of the assessments

Equitability – meaning to offer fair treatment of all participants, without bias toward or against any party

Transparency –meaning to be an open and accessible process, with clear, easily understood requirements

Certainty – meaning to offer guidelines and timelines sustained by official authorization

Pragmatism – meaning flexible application of the process, adapting it to the proposal, potential impacts and the purpose of decision-making

Credibility – The process is implemented objectively and administrated impartially. (adapted from [2]).

The evolution of these methods has been laying over a period of almost fifty years. Developed in the United States during ’60, they evolved as an essential tool in environmental and risk assessment used by governments, to offer implementation of their strategies and policies related to the environmental protection. The sustainable development approach is stimulating the development of new assessment methodologies able to face the challenge of knowledge representation.

One important approach in discovering dependencies is for instance *rough set theory* supporting the process of collecting relevant data and discovering new patterns to be used in such assessments. Used frequently in data mining, image processing, artificial intelligence and machine learning we find it a good support to use for new methodologies in risk assessment along with probabilistic or fuzzy approach algorithm [4].

Another method, recently used in the field of environmental impact/risk assessments is the Evidential Reasoning based on Dempster-Shafer theory of evidence [3]. The conjunctive combination rule or modified versions of it are able to obtain a distributed evaluation *degree of belief*. Belief function concept, to model uncertainty, is an useful instrument that allows us to update information in a hierarchical assessment structure proposed by the evidential reasoning method and associated computational algorithm. The method is knowledge sensitive; that is precisely why it is dedicated for experts use. Different new techniques are being used

in ecological assessments in order to respond to the above-mentioned requirements mentioned by UNEP [2]. The advantages offered by the new methodologies, using these approaches are as follows:

- Offer measurement and epistemic uncertainty models
- Allow to update information and reassessments of the initial assessment
- Offer a good sensitivity /robustness concerning changes in certain limits of the used data/information

Our value judgments are based on concepts expressed in terms of natural language. Natural language is known to be pervaded with vagueness, and consequently this is triggering sometimes a great deal of uncertainty and imprecision. Uncertainty is a characteristic that comes from randomness of considered phenomena, and also from our limited knowledge related to the object of judgment.

To make a meaningful comparison between old and new methods, we should look especially to the way that subjective judgments are sustained by rational arguments. This way we will find differences showing that the new methods are trying to improve the quality of impact/risk assessments by improving the accuracy of the subjective judgments. The new used methods are able to improve the transparency of arguments. Despite the fact that address the challenge of a good analysis of changes and effects, old methods are lacking transparency in the assessment and the reproducibility of the results. In the projects where data are not readily available and when it may takes a number of years to release the results from the assessments, new re-assessments might be necessary in order to update the initial one with new information that became available. As we already mentioned, this is not possible with old methods that use a totally subjective frame for their assessment results.

Pastakia [5], the author of a method called RIAM (Rapid Impact Assessment Matrix) comments about these assessments that the competent planning and regulatory authorities "should be able to evaluate the environmental impact statements and to be satisfied that the technical conclusions are sound". According to the international, European and Romanian laws this statement is a non-technical description of the project, used methods, conclusions and supporting evidences and data. It is a summary that should assists decision-makers in the decision-making process.

However, this statement is usually a voluminous document with information and supporting data "with no real account for the process of argument by which judgments were arrived lacking a transparent records in this idea" as Pastakia remarked [5]. When it comes to submit the project to a new scrutiny or when it comes to re-assess some points to decide about some possible inadequately understood

topics, the old methods are stacked into evaluators experts value judgments, each evaluator having his/her own criteria for his/her specific field of expertise.

From these reasons, the necessity to find an assessment method able to account for recording the arguments that lead to a conclusion in a subjective judgment is becoming of paramount importance for subjective judgments in order to become highly transparent. The method should be able to analyze how the judgment has been made, and also the criteria against which judgments have been made. There is a false sense of objectivity that if the assessment states the used criteria, the transparency of the judgments is assured. The issue is that choosing criteria is also a subjective process and only stating them is not assuring fulfilment of the objective of making the judgments transparent and reproducible in certain limits. An analysis of reliability of these value judgments should be carried out because the major issue involved in these assessments is related to the uncertainty triggered by judged phenomena, used data and used knowledge coming from experts theoretical background and experimental work.

Experts value judgments should be based on knowledge about the analyzed object which means the experts should be able to make verifiable statements. Pastakia comments the following about his method: "Rapid Impact Assessment Matrix, for example, describes a system of scoring within a matrix that has been designed to allow subjective judgments to be quantitatively recorded, thus providing both an impact evaluation and a record that can be re-assessed in the future. The system is ideally suited where a multi-disciplinary team approach is used as it allows for data from different environmental components to be analyzed against common important criteria within a common matrix, thus providing a rapid, clear assessment of major impacts. This method seeks to overcome the issue of recording subjective judgments by defining the criteria and scales against which these judgments are to be made; and by placing results in a simple matrix that allows for a permanent record of the arguments in the judgment" [5]. The method however cannot quantify the uncertainty which is related to this kind of assessment.

The new methods such as Evidential Reasoning based on Dempster Shafer methodology, are able to face the challenge of offering a model for quantifying the uncertainty and also a method being able to respond to the necessity of large democratic consultation including the public, being transparent and offering a mathematically based support for decision making process that can be analyzed and submitted to further scrutiny if necessary.

The Evidential Reasoning method is based on belief structures, and uses an aggregation rule that is emphasizing common points. It basically assigns probability mass functions to sets without need to consider the probability of set elements which makes it especially suited for the fields where data are not single results but rather ranges of results. Initial Dempster-Shafer algorithm represented the basis for Evidential Reasoning (ER) computational algorithm that suffered also modifications

in order to make it proper to represent the uncertainty for rational decision analysis [6], [7]. Rational decisions can be made based on logic and motivations. The belief structures approach seems to be a very appropriate frame offering distributed assessments taking into account the relative importance of the considered attributes by assigning appropriate weights. It takes also into account the incompleteness of data and information unavoidable in a process such this related to an environmental impact/risk assessment. ER approach is applied as a method of choice in various areas such as engineering design evaluation, organizational self-assessment, safety and risk assessment.

In Figure 1, we present a schematic of the used belief structures of Dempster Shafer Theory, aimed to indicate the way that information is combined obtaining a distributed *belief structure*, quantifying the severity of consequences of pollution found as having a significant impact during Environmental Study Phase II. The method uses a hierarchical structure with a top level attribute characterized by a system of basic attributes at the lower level. Through rather extended survey, all interested parties are offering a summary of information and are asked to assess the presented pollution situations expressed by a quantitative data and qualitative data and information summary. Based on their own background and experience they have the possibility to express their opinions.

The European law mentions that, depending on the project, at the national level each country can choose the interested stakeholders groups, and submit to them (according to the European Directives) information about the concerned projects. The results from the public consultation in the new presented methods are computed and aggregated with the evaluators assessments on an equal or relevant weight basis. The method has very good robustness/sensitivity allowing the ranking process to be maintained when changes are operated within a data in certain limits. The algorithm allows data and information updates, quantification of uncertainty, and value judgements representation determining the assessment results reproducibility."

The short example illustrated in Figure 1 is the following. Consider a set "E" as being the set of all possible states expressed by three assertions made of the propositions containing concepts expressed by language as is presented next:

0 - there is no impact

N - there is an insignificant impact

S - there is a significant impact

The model uses the notion of assigned probability, representing the subjective probability assigned to each set from the power set of "E". This is denoted with "m", and represents a function defined on "2^E"(the power set) showing the subjective probability of a state of the world sustained by those assertions taking into account the evidences, and has a value from the range [0, 1]. For a certain set from "2^E"this functions is denoted "m (A)" and has the following characteristics.

The sum of all probability masses should be equal to 1 if the sets are different from the empty set:

$$\sum m(A) = 1 \text{ when } A > 0, \text{ and } \sum m(A) = 0 \text{ when } A = 0$$

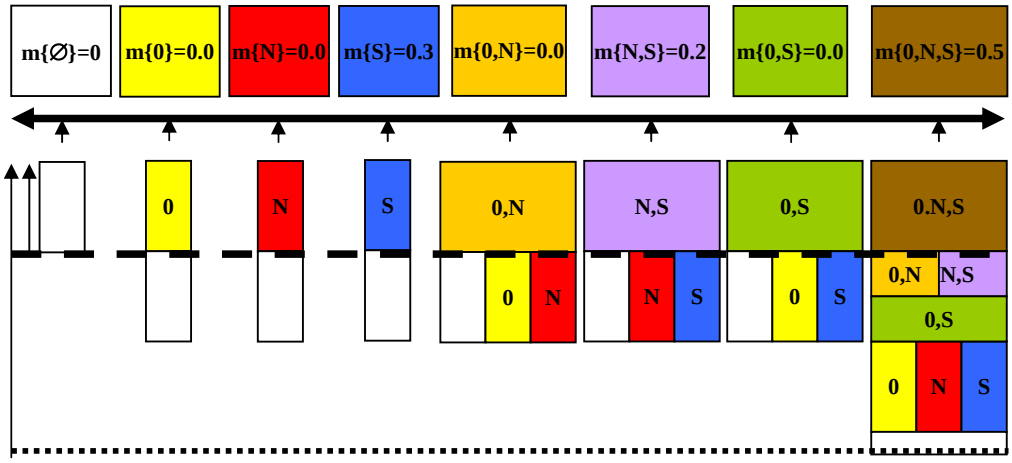

Fig 1 Subjective probability for realizing each represented hypothesis- Schematic representation of power set 2^E

The probability mass is assigned only to considered sets from "2^E"($A \subseteq E$) not to their subsets.

The theory defines more important functions on the set "2^E"with values in [0,1] from which we mention:

- Bel (A) shows the belief degree in the set A from "2^E", and implicitly to "E" but also to each subset to A. This is the difference between m (A)- expressing only the A probability and Bel(A)
- Plausibility is defined as Pl(A) =1-Bel ($\overline{A}$)

Knowing: Bel{0}=0.0 ; Bel{N}=0.0; Bel{S}=0.3, we can compute Bel.

$$Bel(A) = \sum m(B) \text{ for any } B \text{ equal or included in } A$$

$$Bel\{0,N\} = m\{0,N\} + m\{0\} + m\{N\} = 0.0 + 0.0 + 0.0 = 0.0$$

$$Bel\{N,S\} = m\{N,S\} + m\{N\} + m\{S\} = 0.2 + 0.0 + 0.3 = 0.5$$

$$Bel\{0,S\} = m\{0,S\} + m\{0\} + m\{S\} = 0.0 + 0.0 + 0.3 = 0.3$$

$$Bel\{0,N.S\} = m\{0,N,S\} + m\{0,N\} + m\{N,S\} + m\{0,S\} + m\{0\} + m\{N\} + m\{S\} =$$
$$= 0.5 + 0.0 + 0.2 + 0.0 + 0.0 + 0.0 + 0.3 = 1$$

Knowing : Bel{0}=0.0 ; Bel{N}=0.0; Bel{S}=0.3, we can compute Pl A.

Pl (A) =∑ m(B) for any A that intersects B and is different for the empty set(everything that is not belonging to A doesn't mean that cannot be assigned to non A (i.e. to contradict as truth value on A) Plausibility is a function that take advantages for everything can support the set A from the power set.

$$\mathrm{Pl}\{0\} = 1 - \mathrm{Bel}\{\bar{0}\} = 1,\ \mathrm{Pl}\{\mathrm{N}\} = 1 - \mathrm{Bel}\{\bar{\mathrm{N}}\} = 1,\ \mathrm{Pl}\{\mathrm{S}\} = 1 - \mathrm{Bel}\{\bar{\mathrm{S}}\} = 1$$

$$\mathrm{Pl}\{0,\mathrm{N}\} = 1 - \mathrm{Bel}\{\overline{0\mathrm{N}}\} = 1 - \mathrm{Bel}\{\mathrm{S}\} = 1 - 0.3 = 0.7$$

$$\mathrm{Pl}\{\mathrm{N},\mathrm{S}\} = 1 - \mathrm{Bel}\{\overline{\mathrm{NS}}\} = 1 - \mathrm{Bel}\{0\} = 1 - 0.0 = 1$$

$$\mathrm{Pl}\{0,\mathrm{S}\} = 1 - \mathrm{Bel}\{\overline{\mathrm{S}0}\} = 1 - \mathrm{Bel}\{\mathrm{N}\} = 1 - 0.0 = 1$$

$$\mathrm{Pl}\{0,\mathrm{N},\mathrm{S}\} = 1 - \mathrm{Bel}\{\overline{0\mathrm{NS}}\} = 1 - 0.0 = 1$$

4. Conclusions

The new method outlined in this paper has a powerful net advantage over other methods. It considers an approach and an associated algorithm able to face uncertainty challenges, and able to combine on a conjunctive rule AND basis the independent evidences in order to emphasize the common points of consensus. The modified ER algorithm is, at this stage, the most appropriate algorithmic solution to support the decision on rational basis in environmental impact/risk assessments.

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