Modeling Heterogeneous Experts' Preference Ratings for Environmental Impact Assessment through a Fuzzy Decision Making System

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Abstract. Currently, there is an increasing demand for more efficient and practical environmental impact assessment (EIA) tools due to the emerging climate change challenges and need to better evaluate and control impacts of industrial technologies and activities. However, due to the inherent uncertainties, vagueness's of assessment data, traditional EIA methods are unable to handle efficiently and properly such decision making process, and consequently more efficient method resorts to the opinions of group of relevant experts in order to enhance the reliability of the assessment decision. However, experts' assessments are usually in heterogeneous forms, multi-metric or multi-criterion and usually conflicting. This article presents a fuzzy decision making systems (FDMS) that enables heterogeneous experts' preference ratings assessment and provides for aggregation of those opinions over multi-metric scales. Experts can provide their opinion in form of crisp, linguistic or fuzzy values.

Key words: Environmental Impact Assessment (EIA), Fuzzy Logics, Heterogeneous Experts Preferences, Multi-metric Evaluation

1 Introduction

Recently major climate changes occurred in the environment have led to a greater government's awareness of environmental problems and their prevention, on both local and global levels. Consequently, there has therefore been a proliferation of environmental impact assessment (EIA) tools which enable this impact on the environment to be measured.

The environmental impact assessment (EIA) of industrial technologies and 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 EIAs [1]. All industrial and development projects affect their surroundings. If they produce a benefit like less pollution and more wildlife, then they are said to have 'a positive environmental impact'. If their affect on the environment is harmful, then they are said to have 'a negative environmental impact'. An EIA is an assessment of the likely positive and/or negative influence a project may have on the environment. The purpose of the assessment is to ensure that decision-makers consider environmental impacts before deciding whether to proceed with new or existing projects. The problem typically involves: huge quantities of data to manipulate, low quality of data (uncertainty, measurement errors, missing data), different spatial and temporal scales (from seconds to years, from local to global), dynamic and stochastic behavior, and being at the crossroad among many disciplines/domains, and so many qualitative or subjective factors [2].

The processes of environmental impact assessment (EIA) are 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 main purpose of EIA is to predict and as far as possible minimize the negative impacts suffered by the environment as a result of sustaining all human activity. The main problem which appears in EIA models is that they are unable to handle information of a qualitative nature. In order to avoid this problem, qualitative information has traditionally been converted to a numerical scale. We believe that there are now techniques and developments with promising results, which allow us to handle, add and compare linguistic information, which is a reason to continue working in this direction. On account of this, the application of fuzzy techniques to traditional environmental impact assessment models avoids the previously mentioned problem [3].

Rodrigues et al. in 2003 [4] presented definition of the scale, delimitation of the scope, establishment of the objective, and outline of the norm for the formulation of an EIA system for agricultural technology innovations in the institutional context of R&D:

1. Scale – the adoption of an agricultural technology innovation may affect the immediate environment where the activity modified by the technology is carried-out (the near environment), the neighboring area (proximate environment), and the surrounding environment, mainly due to residue emissions. These are, thus, the scales to be addressed by the assessment system.
2. Scope – although the social, economic and ecological dimensions are equally essential for sustainability, the EIA system proposed here is restricted to the ecological aspects.
3. Objective – to promote rural sustainable development by the adoption of technological innovations that contribute to improve environmental quality as well as ecosystem conservation and restoration.
4. Norm – recommendation of agricultural technology is conditioned to improvement of the environmental performance of the activity to which technology is applied, as measured by designed environmental impact indicators.

On the other hand, attributed to its capability to handle inexactness and vague qualitative values, fuzzy set theory has been used extensively in manipulating the data and processing of the EIA decision problem. During the last years several approaches based on fuzzy logic have been developed to assess environmental impacts, indicating the potential of fuzzy logic in this field. Anile et al. [5] developed an approach based on fuzzy logic, which was applied to assess the impact of the use of a river on social and economic environmental factors. Parashar et al. [6] designed a fuzzy procedure of cross-impact simulation to carry out EIAs, which was applied to a textile industry. Silvert [7] proposed a method based on fuzzy logic to analyze ecological impacts in complex cases, in which there were conflicts between the results obtained by different indicators or when the information was non-quantitative. Enea and Salemi [8] developed an EIA procedure based on the extension principle by using parameters defined by means of fuzzy numbers, which was applied to assess the environmental impact of an incineration plant. De Siqueira and De Mello [9] developed a decision-making method to assess environmental impacts by means of fuzzy logic, which was applied to compare different options of a high-speed rail project in Santa Catalina (Brazil). Szczepaniak et al. [10] assessed the environmental impact of a phosphatic fertilizer plant by means of fuzzy logic. Liu and Lai [11] combined fuzzy logic and a fuzzy analytic network process to assess the environmental impact of the deposition of minerals in Punta Gorda (Cuba). Blanco et al. [3] developed an EIA computational application based on fuzzy logic, which takes into account either the quantitative or the qualitative assessments of each environmental impact.

In fact, the surveyed literature has indicated that little or even no researches have considered addressing the heterogeneity of EIA data for a multi-metric variables. As the EIA process involves huge amount of quantitative and qualitative factors that influence the outcomes of the assessment process, vagueness, uncertainty and heterogeneity makes the problem more complex, that demands an adequate solution approach to treat such complexity. Consequently one efficient method is to resort to the opinions of group of relevant experts in order to enhance the reliability of the intended assessment outcome decision. But, because these experts' assessments can usually be in heterogeneous forms, multi-metric or multi-criterion and usually conflicting, a new EIA approach is needed. This research is mainly intended to address the issue of heterogeneity of experts EIA data typically confronted in most EIA situations. This is through developing a fuzzy decision making system (FDMS) that make use of the fuzzy logics the main tool for handling inherent assessment vagueness, uncertainty and heterogeneity.

The paper is organized as follows. Section 2 describes how heterogeneous experts' data can be comfortably dealt with. Section 3 introduces the architecture of a proposed FDMS for EIA. Section 4 finally states the conclusion.

2 Handling Heterogeneous Experts EIA Data Using Fuzzy Numbers

Zadeh [12] pioneered the use of fuzzy set theory (FST) to address problems involving uncertainty, inexactness and vagueness. In a universe of discourse X, a fuzzy subset $\widetilde{A}$ of X is defined with a membership function $\mu_{\widetilde{A}}(x)$ that maps each element x in X to a real number in the interval *[0, 1]*. The function value of $\mu_{\widetilde{A}}(x)$ signifies the grade of membership of x in $\widetilde{A}$. When $\mu_{\widetilde{A}}(x)$ is large, its grade of membership of x in $\widetilde{A}$ is strong [13].

All elements in the judgment matrix and weight vectors can be represented by triangular fuzzy numbers (TFN). A fuzzy number $\widetilde{A}$ expresses the meaning 'about A'. For fuzzy numbers we use triangular fuzzy numbers (that is, fuzzy numbers with lower (l), modal (m), and upper (u) values), because they are simpler than trapezoidal fuzzy numbers. A fuzzy triangular number is defined as follows:

Definition 1. *A fuzzy number* $\boldsymbol{M}$ *on* $\boldsymbol{R}$ *is defined to be a fuzzy triangular number if its membership function* $\mu_m : R \rightarrow [0,1]$ *is equal to:*

$$\mu_m = \begin{cases} \frac{1}{m-l}x - \frac{l}{m-l} & x \in [l,m], \\ \frac{1}{m-u}x - \frac{l}{m-u} & x \in [m,u], \\ 0 & otherwise \end{cases} \tag{1}$$

Where $l \leq m \leq u$, and l and u stand for the lower and upper values of the support of the fuzzy number M, respectively, and m for the modal value. A fuzzy triangular number, as expressed by Equation (1), will be denoted by (l, m, u). Fuzzy membership function and the definition of a fuzzy number are shown in Figure 1.

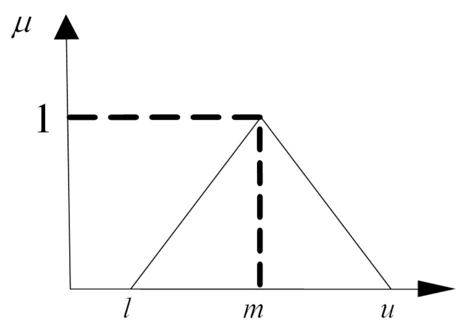

Fig. 1. The membership of a fuzzy triangular number

Some basic relevant operations on fuzzy triangular numbers which were developed and used in [14] are defined as follows. For any two fuzzy triangular numbers $\widetilde{A} = (a_1, a_2, a_3)$, $\widetilde{B} = (b_1, b_2, b_3)$:

$\widetilde{A} \oplus \widetilde{B} = (a_1 + b_1, a_2 + b_2, a_3 + b_3)$ *for addition*
$\widetilde{A} \otimes \widetilde{B} = (a_1 \cdot b_1, a_2 \cdot b_2, a_3 \cdot b_3)$ *for multiplication*
$\widetilde{A}/\widetilde{B} = (a_1/b_1, a_2/b_2, a_3/b_3)$ *for division*
$\frac{1}{\widetilde{A}} = (\frac{1}{a_1}, \frac{1}{a_2}, \frac{1}{a_3})$ *for reciprocal*
$\widetilde{A}^n = (a_1^n, a_2^n, a_3^n)$ *for power*

Therefore, using fuzzy triangular numbers, the decision-maker when faces a complex, uncertain problem, he can conveniently express his/her judgments as a range of values around a fuzzy value instead of exact number, and can as well express it using linguistic values (i.e., "High", "Low", etc.) corresponding to some fuzzy numbers.

This article is concerned about considering fuzzy numbers as a tool to enable treating heterogeneous experts' opinions in assessing environmental impacts. Before explaining how, let us first state the basic variables of EIA, upon which the underlying EIA will be explained later in this article. Figure 2 below depicts the hierarchical nature of the EIA problem.

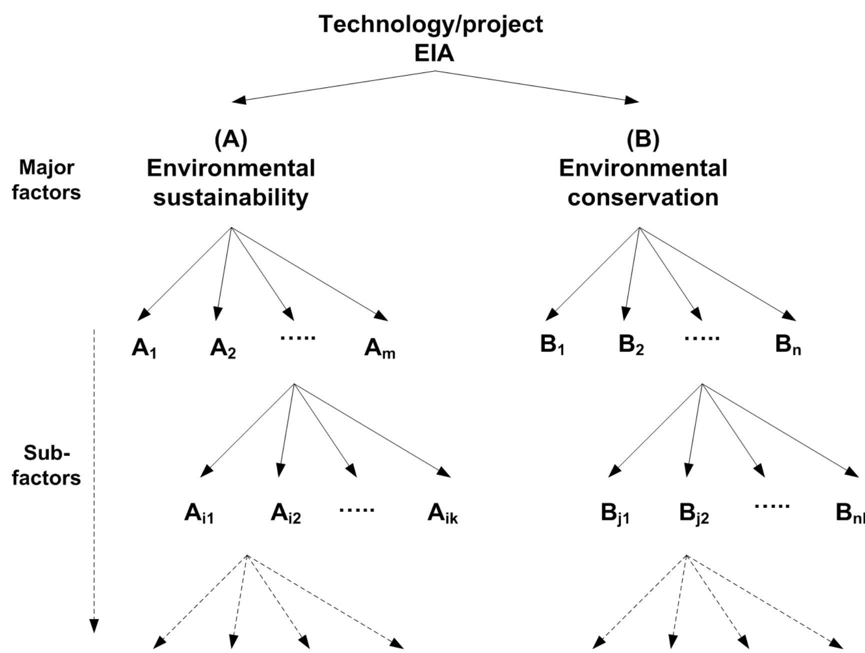

Fig. 2. The EIA hierarchy

In figure 2, the impact of an industrial technology or a project activity is usually assessed hierarchically based on a number of quantitative and qualitative environmental factors. Two major factors are most often and generally considered: environmental conservation and environmental sustainability. These two factors collect the majority of other sub-factors that are always affected by any industrial project or activity.

It is important to state how impact characteristics and magnitudes of various environmental factors can be computed. In fact this article is partially inspired, but in some slightly different form, on the EIA method based on fuzzy logic proposed by the authors in [1]. The impact has three properties: (1) intensity, (2) extent, (3) persistence. They used respective assessment functions to define the relationship between these impact characteristics and their contribution, which has proven a vague issue. The values of the three impact properties were estimated for each of them by means of triangular fuzzy numbers. Then, the impact contribution are combined into either negative or positive impact values. The authors in [1] estimated other properties for impact like confidence intervals on impacts.

However, in this article, we propose simpler and more logical approach that enables reliance on experts' judgments in estimating directly the contribution of impacts for various environmental factors. In addition, experts participate in judging the importance's (called pondering coefficients [1]) of each one of the three impact properties, and the significance of each environmental factor within the EIA hierarchy. In fact, the word "significance" is closely similar to the word "importance". It is also related to role of sub-component to its superior component. But, we here just linguistically distinguish significance of sub-factors to major factors, from importance of impact properties to the resultant impact.

Triangular fuzzy number (TFN) are commonly used to quantify the values of importance's and significance of impacts and the values of impact contributions as well, as illustratively shown in tables 1 and 2 respectively.

Table 1. The linguistic values and fuzzy numbers for importance and significance of the impact contributions and environmental factors.

Importance ($\widetilde{I}_{tijk}$)		**Significance ($\widetilde{S}_{tijk}$)**	
Linguistic value	**Fuzzy number**	**Linguistic value**	**Fuzzy number**
VL	(0,2,4)	IS	(0,3,4)
L	(2,4,6)	MI	(2,4,6)
M	(4,6,8)	N	(4,6,8)
H	(6,7,10)	MS	(6,8,10)
VH	(8,10,10)	HS	(8,10,10)

Table 2. The linguistic values and fuzzy numbers of the impact contribution components of the environmental factors.

Impact contribution					
Impact component contribution ($\widetilde{v}_{tijk}$)					
Linguistic value	VL	VL–L	L	L–M	M
Fuzzy number	(0,10,20)	(10,20,30)	(20,30,40)	(30,40,50)	(40,50,60)
Linguistic Value	M–H	H	H–VH	VH	
Fuzzy number	(50,60,70)	(60,70,80)	(70,80,90)	(80,90,100)	

In table 1, the linguistic labels VL, L, M, H, VH stand for "very low", "low", "medium", "high", "very high" options, respectively and are used as pondering coefficient for the values of the three impact contributions corresponding to three impact properties mentioned above. Also, the linguistic labels IS, MI, N, MS, and HS stands for "insignificant", "moderately insignificant", "neutral", "moderately significant", "highly significance" options. Both the two psychometric scales range from 0 up to 10.

In table 2, nine linguistic labels can be used to quantify the magnitude of the environmental impact contribution of the environmental factors. These are: VL, VL-L, L, L-M, M, M-H, H, H-VH, VH stand for "very low", "between very low and low", "low", "between low and medium", "medium", "between medium and high", "high", "between high and very high", "very high" decision options, respectively. These linguistic values of impact contribution range from 0 up to 100 (the range is arbitrarily chosen, and may be: 0 to 10 or even 0 to 1000, or any other convenient range) as a psychometric, dimensionless, unified quantification of the impact contribution of any environmental factors regardless of its physical scale. So, every contribution of each component is assessed from 0 to 100. Naturally, if the intensity component reaches 100, then this means maximum intensity and 0 value means lowest level of intensity, and the same applies for other impact components. Each impact contribution can be either negative or positive, applying the same scale.

It should be noted that the adoption of the above psychometric numerical scales could be arbitrary altered by the decision making analysts based on their views of how usefully and adequately the assessment decision making can be controlled.

Here, based on the above adopted judgment scales, the heterogeneity of assessment data are efficiently treated through giving experts three options for evaluation, or in other meaning, enabling manipulating these three assessment choices of data format. These data formats are as follows:

- Linguistic judgments (e.g., VL, IS, etc.)
- Crisp judgments (i.e., crisp 2 is taken as (2,2,2))
- Fuzzy judgments (e.g., FTN : (2,4,6), (8,10,10))

In fact, the above options cover almost all possible cases or situations of EAI assessment data, and this constitutes the major concern of this article, besides being able to logically handle these values through a well-defined decision making procedure.

Next section, the architecture of the proposed FDMS is presented.

3 FDMS for EIA

This section presents the proposed FDMS (see Fig. 3) for carrying out EIA. Actually, the proposed system is specially intended to be utilized in one of two possibly different cases. The intended case is the need to conduct the EIA of an individual industrial technology or activity, without having to compare it with other offered technology or project alternative. The other case involves the comparison of several alternatives against group of impact assessment criteria. The first case is not common and very few or even scarce approaches exist for handling single alternative (Yes-or-No). Usually most of the existing approaches apply multi-criterion decision making, for which there exist wide spectra of solution methodologies. This represents the novelty of the proposed approach, the capability to solely conduct judge a single offered technological alternative.

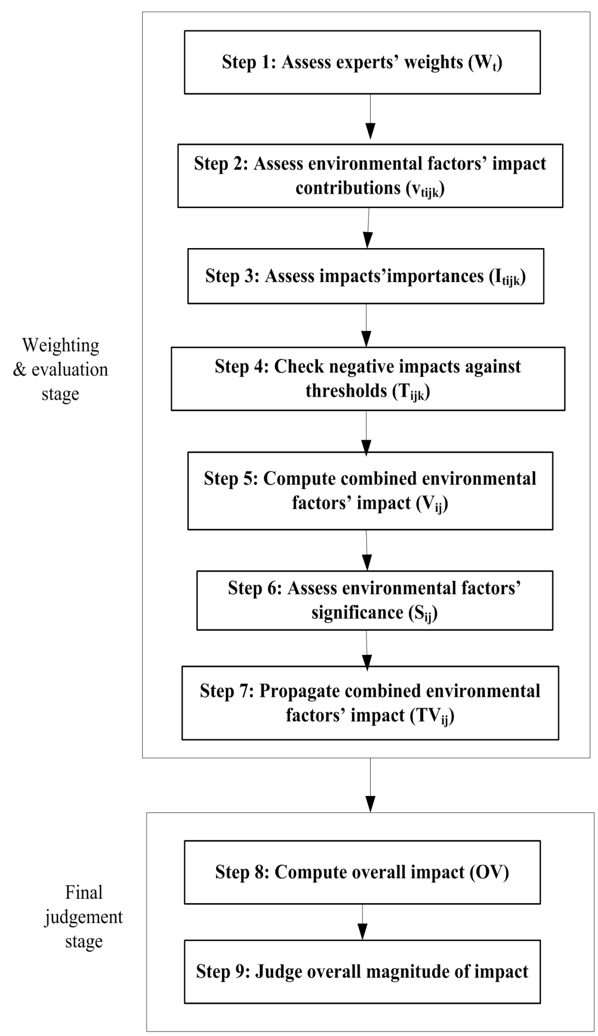

Fig. 3. The proposed FDMS for EIA.

In fact, the proposed procedure suites for the both cases; multiple and single alternatives. It can be used to score individual technological alternative, with the ability to judge its acceptance or rejection, based on either some preliminary benchmarking information or through using estimation and rules of thumbs. It transparently tackles the hierarchical nature of the EIA, its uncertainty, vagueness, subjectivity in a simple procedure.

The proposed systems mathematics are typically and collectively synthesized from the work previously conducted in [1] and [15], where triangular fuzzy numbers and fuzzy numbers arithmetic are used to simply combine and aggregate preference ratings guided by levels of importance and significance of impact contributions and environmental factors, respectively. A summary of the logical sequence of computations for the proposed FDMS for EIA is as follows.

1. Weighting & evaluation stage

Step 1: Assess experts' weights (Wt):

A team of relevant experts to the EIA process at each assessment sub-area are formed by the decision making analysts responsible for managing the decision support. Then, triangular fuzzy numbers for importance of each tth expert are judged by the decision analysts or other stakeholder, based on their relevance, experience, and knowledge. These importances guide the influence of each experts on the whole assessment process. This can be also done alternatively using Fuzzy-AHP [16]. Expert importances are then defuzzified for simpler use thereafter. Then, expert weights are defuzzified as explained in [15]. Defuzzification of expert weights could be accomplished through utilizing the Best Non-fuzzy Performance (BNP) values defuzzification method [17]. The COA method's BNP value for triangular fuzzy performance score can be calculated as follows:

$$BNP = l + \frac{(u-l)+(m-l)}{3} \tag{2}$$

Then, the defuzzified weight $d(\widetilde{W_t}) = BNP(\widetilde{W_t})$. Expert weights are then normalized using the following formula:

$$W_t = \frac{d(\widetilde{W_t})}{\sum_{t=1}^{T} d(\widetilde{W_t})} \tag{3}$$

Step 2: Assess environmental factors' impact contributions ($\widetilde{v}_{tijk}$):

Let t: the index of t^{th} expert, t= *1,2,... T.*

i: the i^{th} level in the EIA hierarchy, i = *1,2,...n.*

j: the j^{th} environmental factor in the EIA hierarchy, j = *1,2,...m.*

k: the k^{th} impact contribution component in the EIA hierarchy (i.e., intensity, extent and persistance), k = *1,2,3.*

$\widetilde{v}_{tijk}$: the k^{th} contribution component of the j^{th} environmental factors's at i^{th} level in the EIA hierarchy, and assigned by the t^{th} expert.

Now, using the linguistic scale (table 2), and for the j^{th} environmental factor within the i^{th} level, each relevant t^{th} expert assigns a value for each k^{th} impact contribution.

Positive and negative impacts are identified.

Step 3: Assess impacts' importances ($\widetilde{I}_{tijk}$):

Now, the importance I_{tijk} for each k^{th} impact component of the j^{th} environmental factor at the i^{th} level is assigned by the t^{th} expert, utilizing the linguistic values and the corresponding fuzzy number of the table 1.

Step 4: Check critically negative impacts against thresholds (H_{ijk}):

It is common that for each environmental factor, expert scientists usually agree on the values of threshold for each component of critical impact. This means that, before hand, the values of thresholds corresponding to the: H_{ij1}, H_{ij2}, H_{ij3}. Any negative impact contribution is assessed against a pre-established threshold values defined by the stakeholder experts. Generally, the technology should be discarded when the threshold for negative impact is exceeded. Practically, the upper value of the fuzzy number impact component assigned by the experts is compared to the crisp value of the impact threshold. For instance, the technology should be discarded, as long as 75% agreement or 75% sum of weights (arbitrarily can be chosen utilizing common western democracy majority) exists on that the experts' assigned values of impact contribution exceeds thresholds. Otherwise, weighted average of experts' assignment decides for acceptance, in comparing impact values with their corresponding thresholds.

Example: suppose that we have four experts ($t = 4$) assessing the values of a negative impact contributions of a given j^{th} environmental factor on a i^{th} level of the EIA hierarchy. Their assignments (v_{tijk}) and their computed defuzzified weights (W_t) are as follows:

Expert 1: $W_1 = 0.35$, $\widetilde{v}_{1ij1}$= (10,20,30), $\widetilde{v}_{1ij2}$= (40,50,60), $\widetilde{v}_{1ij3}$= (80,90,90)

Expert 2: W_2= 0.15, $\widetilde{v}_{2ij1}$= (0,10,20), $\widetilde{v}_{2ij2}$= (60,70,80), $\widetilde{v}_{2ij3}$= (50,60,70)

Expert 3: W_3= 0.25, $\widetilde{v}_{3ij1}$= (10,20,30), $\widetilde{v}_{3ij2}$= (80,90,90), $\widetilde{v}_{3ij3}$= (40,50,60)

Expert 4: W_4= 0.25, $\widetilde{v}_{4ij1}$= (10,20,30), $\widetilde{v}_{4ij2}$= (40,50,60), $\widetilde{v}_{4ij3}$= (20,30,40)

Now, applying the above decision making principle to the following case of impacts thresholds: $H_{ij1} = 40$, $H_{ij2} = 80$, $H_{ij3} = 60$.

Comparing the three thresholds with the corresponding upper values of the impact contributions, the upper values of the first components (i.e., intensity) do not exceed 40 across all experts. Concerning the second component (i.e., extent), assessments of expert 1 and expert 2 exceed $H_{ij2} = 80$, but they constitute 50 % of the experts group, and their sum of weights makes only 40 < 75%, so we resort to the average value of upper values (60+80+90+60)/4 = 72 which is < H_{ij2} = 80. Regarding the third component (i.e., persistence), we find that three experts (1,2,3), constituting 75% of the four experts, agree on the exceed of impact values over the threshold. In this case, the technology or project must be rejected, and we must stop assessment of the corresponding j^{th} environmental factor if it was preliminarily designated as "critical". Other decision making schemes in dealing with threshold could be designed.

Step 5: Compute combined environmental factors' impact ($\widetilde{V}_{tij}$):

Now, given the experts' assigned values of the impact contributions, $\widetilde{v}_{tijk}$, together with their assessment of the corresponding importances, $\widetilde{I}_{tijk}$, then, the combined impact of the j^{th} environmental factor, $\widetilde{V}_{tij}$, for each t^{th} expert is computed using the following mathematical formula:

$$\widetilde{V}_{tij} = \sum_{k=1}^{3} \widetilde{v}_{tijk} \cdot \widetilde{I}_{tijk} \tag{4}$$

Then, the total combined environmental factors' impact for all experts are computed and defuzzified as follows:

$$\widetilde{TV}_{ij} = \sum_{t=1}^{T} W_t \cdot \widetilde{V}_{tij} \tag{5}$$

$$TV_{ij} = d(\widetilde{TV}_{ij}) = BNP(\widetilde{TV}_{ij}) \tag{6}$$

Now, the value of the combined environmental factors' impact, TV_{ij}, is assigned a positive or negative sign depending on the known characteristic of the j^{th} environmental factor.

Step 6: Assess environmental factors' significance ($\widetilde{S}_{tij}$):

Each i^{th} environmental factors at the i^{th} level of the EIA hierarchy is assessed by the relevant experts using the linguistic scale in table 1, expressing the environmental sub-factors influence the impact of their main factor up the hierarchy of EIA assessment. Then, the significance at each i^{th} level is defuzzified and normalized as follows:

$$S_{ij} = d(\widetilde{S}_{ij}) = BNP(\widetilde{S}_{ij}) \tag{7}$$

$$S_{ij} = \frac{d(\widetilde{S}_{ij})}{\sum_{j=1}^{m} d(\widetilde{S}_{ij})} \tag{8}$$

Sub-factors are related by their significance on their common main factors. This logical interpreted as the sum of significances of sub-factors at the i^{th} level is equal 1 ($\sum S_{ij} = 1$).

Step 7: Propagate combined environmental factors' impact (TV_{ij}):

The combined environmental impacts are transferred up the hierarchy toward first level (0^{th} level). Figure 4 below describes the idea of propagating impacts.

The formula (equation 9) used to compute the combined impact of the main $(i-1)^{th}$ environmental factor ($TV_{(i-1)j}$), using the impacts (TV_{ij}) weighted by the normalized sub-factors' significances at the i^{th} level (positive and negative signs are used), is as follows:

$$TV_{(i-1)j} = \sum_{j=1}^{m} TV_{ij} \cdot S_{ij} \tag{9}$$

2. Final judgement stage

Step 8: Compute overall impact (OV):

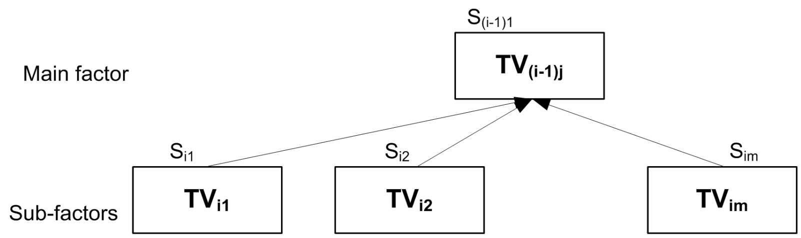

Fig. 4. Propagating impacts up to the main factors of the EIA hierarchy.

Now, at the top level of the hierarchy (0^{th} level), the positive and negative combined impacts, TV^+ and TV^-, respectively, are subtracted from each other to determine the signed resultant impact:

$$OV = TV^+ - TV^- \tag{10}$$

Step 9: Judge overall magnitude of impact:

The overall impact can be judged based on fuzzified dimensionless scale of impact levels, guided by transformed (parallel and dimensionless) benchmarking values, to either accept or refuse the proposed technology or the project. Figure 5 and table 3 illustrate how judgment could be made, which is explained below.

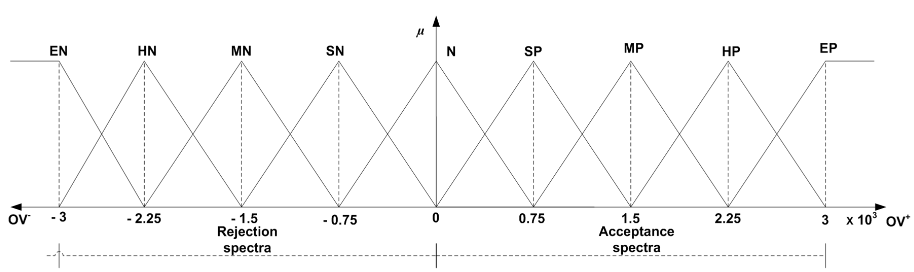

Fig. 5. The fuzzified judgmental scale for the overall impact (OV).

First of all, before fuzzifying the values of the overall impact (OV), it is important to identify its maximum and minimum possible values. According to equations 4 through 10, and given the selected linguistic scales, the maximum and minimum possible overall impact values that can be reached are 3000 and -3000, respectively. This is indicated in figure 6. Consequently, 9 fuzzy numbers can be defined on the OV scale. They are; EN, HN, MN, SN, N, SP, NP, HP, EP stand for "extremely negative", "highly negative", "moderately negative", "slightly negative", "negative", "slightly positive", "moderately positive", "highly

Table 3. The linguistic values and corresponding fuzzy numbers of the fuzzified environmental impacts.

Overall impact (OV)	
Linguistic value	**Fuzzy number**
EN	(-3,-3,-2.25)
HN	(-3,-2.25,-1.5)
MN	(-2.25,-1.5,-0.75)
SN	(-1.5,-0.75,0)
N	(-0.75,0,0.75)
SP	(0,0.75,1.5)
MP	(0.75,1.5,2.25)
HP	(1.5,2.25,3)
EP	(2.25,3,3)

positive", "extremely positive" overall impacts, respectively. These linguistic values and their corresponding fuzzy numbers are shown in table 3. Then, logically, and based on the experts and decision analysts involved and their decision control policy, an acceptance and rejection spectra or ranges could be located on the fuzzified scale. Based on the computation the resultant value of the OV are matched with this scale and using the maximum membership operator it is then assigned to some linguistic value on such scale, and the final judgment can be taken. Also, benchmarking values for previously assessed technologies can be helpful in tuning the established linguistic values and their corresponding fuzzy numbers.

4 Conclusion

EIA is a very complex decision making problem that besides its inherent ambiguity and uncertainty, usually involves heterogeneous assessment data associated with multi-metric parameters and assessment scales as a result of diverse or heterogeneous experts and decision maker's background and tools.

This article has outlined a method for how heterogeneous experts' opinions under fuzzy environment can be addressed, and presented a new approach for EIA that takes into account the natural properties of impacts besides their uncertainty and vagueness's, and makes extensive use of human expert efficient control. The proposed methodology is advantageous in that it can solely assess the EIA of an individually offered technological alternative, without a need to compare it or consider multiple several alternatives. It also can implicitly make use of benchmark assessment cases through adjusting the acceptance and rejection zones on the fuzzified scale of the overall impact.

Finally, it should be noted that the transformation of the various impact values of various quantitative environmental factor across the levels of EIA hierarchy obviously promote homogeneity and alleviate heterogeneity through the suggested judgmental scales, based on the utilized linguistic values and their corresponding fuzzy numbers. This also enables considering and blending together impacts of both quantitative and qualitative environmental factors. Still, there are several opportunities for further improving the proposed approach through fine-tuning the fuzzy number scales and impacts combination methods.

Acknowledgement

This work was supported by the Ministry of Education, Youth and Sports of the Czech Republic (Grant No. MSM 604070904 – Information and knowledge support of strategic management and 2C06004 – Intelligent instruments for assessment of relevance of content of data and knowledge resources.

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