THE ALTERNATIVE STRATEGY SELECTION FOR SUSTAINABLE DEVELOPMENT USING FUZZY LOGIC

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Abstract. The concept of sustainable development is a direction towards which any multinational company operating in the European Union area and beyond must move. From this point of view, integrating of a national policy or of a strong national program of sustainable development in the company's strategy, that must be suitable for the community around in which it is operating, it has to be the main purpose for this paper. This process of the alternative strategy selection for sustainable development is challenging because it involves some issues such as fuzzy decision making under conditions of ambiguity and uncertainty, by certain decision makers who often comprise a group of several peoples, whose opinion or perception in most cases is being expressed in vague, ambiguous, even fuzzy language i could tell, through linguistic terms. The applied study in this article refers to design a methodology for choosing or joining to the most appropriate national plan or program of alternative strategy for sustainable development by a mining company for the benefit of the rural community in which it operates, taking into account certain preliminary performance criteria set. Thus, the weights of the importance of the strategic selection criteria are evaluated by the management team through the Fuzzy-Delphi method and the performance of each plan likely to be chosen for implementation with respect to these criteria is evaluated by the specialist on sustainable development issues whithin the mining company which exploit the mineral resources, using also the fuzzy sets theory. The results provided through the processes of fuzzification, operation with fuzzy numbers and defuzzification, which are part from the fuzzy method of multicriteria decision making, are promising, so that choosing the method of decision making in fuzzy environments is probably one of the most powerful tools for modeling uncertainty and ambiguity of human factor decision reasoning.

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1. Introduction

For nearly two decades, the United Nations imposed to its member states to manage strategic actions for sustainable development by creating a regulatory and legislative framework for the adoption of national strategies for sustainable development by various large companies which operates within its boundaries (UN DSD, 2011). The sustainable development is a current topic for many public and private initiatives in the European Union in general and in Romania in particular. The challenges that these initiatives seeks to respond are refering mainly to the fact of generating incomes for local communities, through the rational use of local resources, in a mutually beneficial relationship between the economic, social, cultural and natural factors.

According to the Principles of the ICCM (International Council on Mining and Metals), any mining company "should cooperate with governments, industry and the others stakeholders to achieve appropriate and effective public policy, laws, regulations and procedures that facilitate the mining sector's contribution towards sustainable development, in the context of certain national sustainable development strategies".
If the concept of sustainable development proved so far to be a primary strategic direction within many policies and programs of different public or private institutions, especially at corporate-level decision, its manifestation in concrete action plan proved to not be a very easy task (La?erty, 2004), due mainly because of the uncertainty of decision-making situations and of subjective reasoning of the human factor decision. Thus, the choosing problem of a plan or program of action well grounded for meeting the performance conditions in terms of implementing an effective and efficient sustainable development policy, can be solved by the method of fuzzy multicriteria decision making (FMCDM).

This paper proposes the evaluation and selection for the subsequent implementation of a national strategic plan for sustainable development which is the subject of numerous policies and programs of action at local, national or european level and which takes into account several criteria and strategic objectives wich must to be meet for a better future performance and further effectiveness.

The methods of fuzzy multicriteria decision-making have been developed due to the imprecision in assessing the relative importance of selection criteria and in estimating the performance of alternative strategies with respect to these criteria. The imprecision may derive from several respects: unquantifiable informations, incomplete informations, impossible obtainable informations and partly from ignorance. To overcome this obstacle, the fuzzy sets theory was developed to improve the reliability of decision making process under uncertainty (Bellman and Zadeh, 1970).
For fuzzy multicriteria decision making problem, the decision makers use linguistic values associated to their related linguistic variables to assess the importance of selection criteria and also to estimate the performance of each action plan of sustainable development with respect to these criteria for subsequent selection in the future implementation. This study will address as a practical example the problem of selection or joining to a national strategic plan of sustainable development within the mining project Roşia Montană Gold Corporation (RMGC), project which consists in exploring the mineral resources of gold and silver situated in the deposits located along the perimeter of Roşia Montană village, in central area of Romania.

To assess the importance of the strategic selection criteria, Fuzzy-Delphi method must be used, to have regard to the decision making opinions from different positions of the management hierarchy, just to give a character of homogeneity and subsequent performance to the decision making process. The fuzzy concept was incorporated into the Delphi method by calculating the weighted average of the importance given to the criteria after its evaluation by the members of the management committee, based on their experience and knowledge (Chang, Huang and Lin, 2000). Knowing that within the strategic criteria are more tactical subcriteria, which practicaly compose the first ones, the estimation of performance of the possible plans for sustainable development with respect to these subcriteria is assessed by the mining company specialist in the area of sustainable development issues, respectively by the Vicepresident of Heritage and Sustainable Development, also, by means of fuzzy sets.

2. Literature review

According to Moreno-Jimenez et al. (2005), the selection process consists in three main stages, namely modeling, evaluation and synthesis. Thus, the first step consists in the construction of a hierarchy, the second incorporates the judgments that reflect the preferences of actors involved in the selection process and finally the third step provides the priorities after comparing the alternatives.

The Delphi method was designed as a group technique whose purpose was to obtain the most reliable consensus of an experts group opinions, by applying a series of intensive questionnaires with a control feedback of opinions (Jon Landeta, 2006). The evaluation of selection criteria is a problem of fuzzy decision-making within the fuzzy assessments and the opinions of several experts may be taken into account. The makers decisions judgments are often divergent due to some reasons that most often arise in fuzzy environments.

Over the time, there were published a series of articles and papers in the topic of decision making problem under uncertainty. Thus, starting with the bedside article of fuzzy logic, namely "Fuzzy sets", published by Zadeh in 1965, so far there is a wide range of publications in the method domain of fuzzy multicriteria decision making (FMCDM), of which I will mention only the most current in their order of appearance: Yang and Chou (2005), Chang, Wang, and Wang (2006), Xu and Chen (2007), Yang et al. (2007), Yang and Hung (2007), Chou, Chang, and Shen (2008), Wang (2008), Yeh and Chang (2009), Hossein Alipour et al. (2010), Awasthi et al. (2010), Ye (2011) and Kaya and Kahraman (2011). The recent findings have extended the concept of FMCDM towards a fuzzy decision making-problem within a group, as it is mentioned by Chang et al. (2000), Cheng and Lin (2002), Chang and Wang (2006), Liu and Chen (2007), Yeh, Cheng, and Chi (2007), Chang, Wu, and Chen (2008), Ekel et al. (2009), Yeh and Chang (2009), Boroushakin and Malczewski (2010), Chen et al. (2011).

Cheng and Lin (2002) used the Delphi method to adjust the fuzzy assessments of each member of the decision group, assessments based on linguistic terms which are then converted into trapezoidal fuzzy numbers. These trapezoidal fuzzy numbers were used by Zeng et al. (2007) for capturing and converting the subjective judgments of decision-maker members. The next step was then the operation with fuzzy numbers via fuzzy inference rules and operators of addition, subtraction, multiplication and division, so that finally to take place the defuzzification process through various methods such as max, average, centroid, singleton, and others.

A classical fuzzy system is described in figure 1 below:

3. The proposed methodology for selecting the best strategy for sustainable development

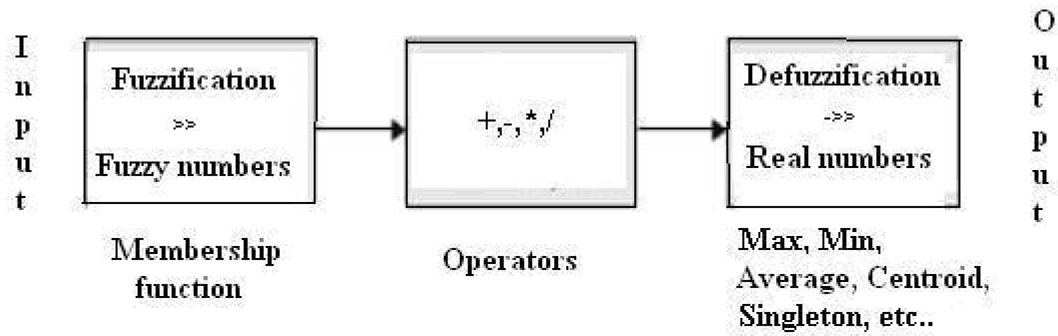

Figure 1. A classical fuzzy system

The implementation of the proposed methodology involves going through five main stages, as described in figure 2. As it can be seen within the algorithm below, the first step in the selection of sustainable development plan refers to the actual proposal of alternatives which often may have more elements in common (their number is noted by n). It follows then to establish the strategic criteria and tactical subcriteria selection, after then we note the number of strategic criteria by m. Stage 3 consists of determining the importance of the selection strategic criteria at the high management level by using Fuzzy-Delphi method. In stage 4 takes place the estimation of the performance of each strategic plans of sustainable development with respect to each tactical subcriteriu by a single expert in this case, using fuzzy sets. In the phase 5 takes place the defuzzification process of the aggregate scores obtained by multiplying operation of the results from steps 3 and 4 within the fuzzy method of multicriteria decision making. In the last stage, takes place the final ranking of alternatives in terms of choosing the best plan for sustainable development so finally to be chosen for implementing the plan with the highest obtained score.

3.1 Brief introduction on fuzzy sets theory

In the following we will enter in the area of fuzzy logic, so that we refer to what is mean fuzzy sets, fuzzy numbers and operations between them. Let X a collection of objects and x a generic element of the set X. A set A in the

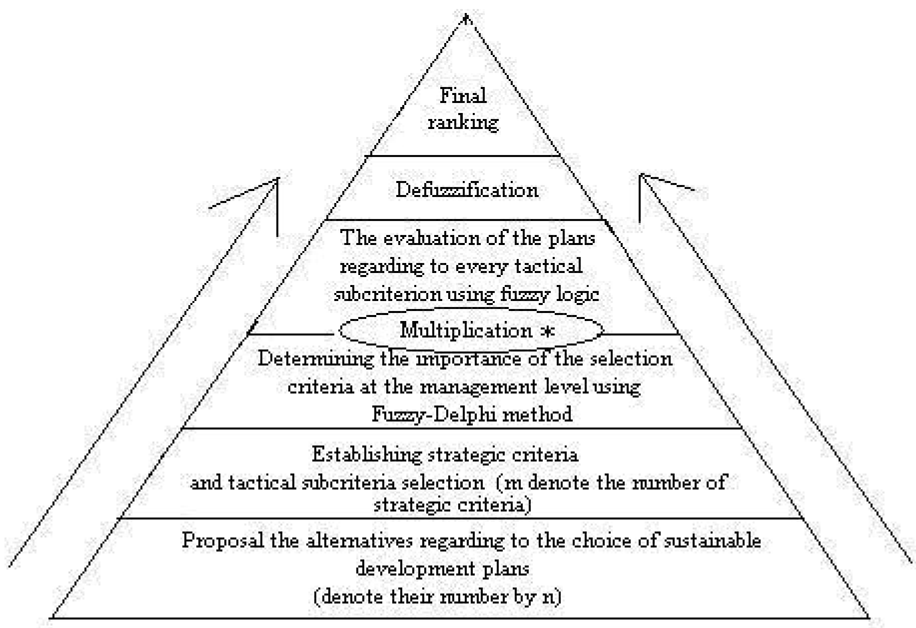

Figure 2 The algorithm of methodology implementation for selecting sustainable development strategy

classical sense, included in $X(A \subset X)$, is defined as a collection of elements $x \in X$, so that each element x can either belong, either do not belong to set A. Defining a characteristic function for each element of X, function that can have only the values 0 and 1, then the set A can be represented by a series of ordered pairs such as $(x, 1)$ and $(x, 0)$, indicating that $x \in A$ or, respectively, $x \notin A$. In contrast to the set in the classical sense, a fuzzy set expresses the degree of which an element belongs to a certain collection of objects. Thus, the characteristic function attached to the elements of a fuzzy set can have values in the entire interval $[0, 1]$, indicating the degree of membership of each element to that collection. Let X a collection of objects denoted generically by x. A fuzzy set A over set the X is defined by a set of ordered pairs in the form:

$$A = \{(x, \mu_A(x))/x \in X\} \quad (1)$$

where $\mu_A(x)$ is called the membership function of x in the fuzzy set A. Its value shows the degree of membership of x to A (Yang, Chen, and Hung, 2007; Zadeh, 1965).

The membership function assigns for each element of the set X a certain degree of membership to the set A that has a value in the interval $[0, 1]$. If the membership function value is 0 or 1, then the fuzzy set A became a set in a classic sense, $\mu_A(x)$ being the characteristic function attached to the set A. The set X is called universe of discourse and it can be discrete (with ordered or unordered items) or continuous (isomorphic with the set of the real numbers).

The construction of a fuzzy set depends on establishing the universe of discourse and the membership functions. The choice of membership function is subjective, in the sense that different people can choose different membership functions to express the same concept. This bias arises from differences existing among individuals relative to how they perceive and express abstract concepts.

In practice, for a continuous universe of discourse (the set of real numbers or a range of it), usually are defining more fuzzy sets whose membership function covers the entire set X in a more or a less uniform way. These fuzzy sets, which usually are associated with the current language of the usual adjectives like "big", "medium", "small", are called linguistic values.

A fuzzy number is defined as a convex and normal fuzzy set defined on R whose membership function is continuous. The most widely used fuzzy numbers are the triangular and trapezoidal fuzzy numbers, mainly due to their simplicity and ease of application in modeling and interpretation (Petroni and Rizzi, 2002). A triangular fuzzy number (a_i, b_i, c_i) is a fuzzy number whose membership function $\mu_i(x)$ is defined by the following expressions (Karsak, 2001):

$$\mu_i(x) = \begin{cases} 0, \ if \ x < a_i \\ \frac{x-a_i}{b_i-a_i}, \ if \ a_i \leq x \leq b_i \\ \frac{x-b_i}{b_i-c_i}, \ if \ b_i \leq x \leq c_i \\ 0, \ if \ x > c_i \end{cases} \tag{2}$$

Let be (a_1, a_2, a_3) and (b_1, b_2, b_3) two fuzzy triangular numbers. Then, the basic operations between them are as follows:

$$(a + b) = (a_1 + b_1, a_2 + b_2, a_3 + b_3) \ \ for \ addition \tag{3}$$

and

$$(a \star b) = (a_1 \star b_1, a_2 \star b_2, a_3 \star b_3) \ \ for \ multiplication. \tag{4}$$

Similarly, a trapezoidal fuzzy number $a = (a_1, a_2, a_3, a_4), a_1 \leq a_2 \leq a_3 \leq a_4$, has the following membership function, illustrated also in figure 3:

$$\mu_a(x) = \begin{cases} 0, \quad x \leq a_1 \\ \frac{x-a_1}{a_2-a_1}, \quad a_1 \leq x \leq a_2 \\ \frac{x-a_4}{a_3-a_4}, \quad a_3 \leq x \leq a_4 \\ 0, \quad x \geq a_4 \end{cases} \tag{5}$$

Let consider another trapezoidal fuzzy number $b = (b_1, b_2, b_3, b_4)$. Then the basic operations with trapezoidal fuzzy numbers are described as follows:

$$(a + b) = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b + 4) \ \ for \ addition \tag{6}$$

and

$$(a \star b) = (a_1 \star b_1, a_2 \star b_2, a_3 \star b_3, a_4 \star b_4) \ \ for \ multiplication. \tag{7}$$

It is easy to see from the figure that if $a_2 = a_3$ it is resulting the transformation of trapezoidal fuzzy number into a fuzzy triangular number, thus $a = (a_1, a_2, a_3, a_4)$ becomes $a = (a_1, a_2, a_3)$ as it can be seen in figure 4.

3.2. The evaluation of importance of the selection strategic criteria and the estimation of the performance of each sustainable development plan with respect to each tactical subcriteriu

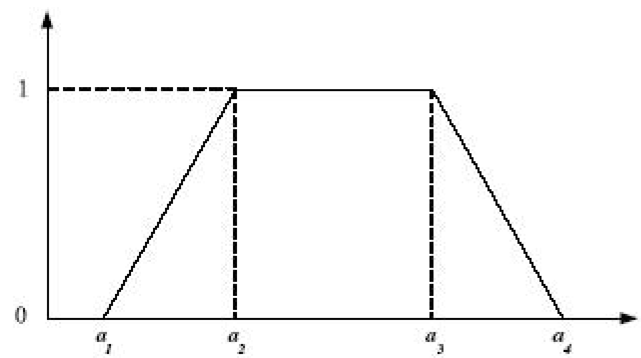

Figure 3 The membership function of trapezoidal fuzzy numbers

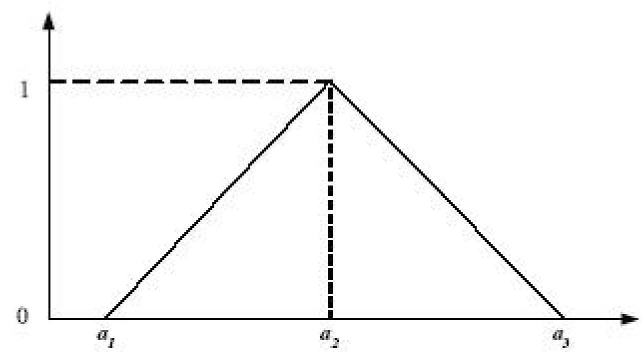

Figure 4 The membership function of triangular fuzzy numbers

For modeling and representation of decision-makers views in relation with the evaluation of importance of the selection strategic criteria and with the estimation of the performance of each sustainable development plan with respect to tactical subcriteria and also for the final selection of the plan, we shall take the following steps:
- establishing the strategic criteria and assessment of their their importance at the senior management level by using the Fuzzy-Delphi method;
- the estimation of the performance of each strategic alternative for sustainable development with respect to each tactical subcriteriu by an expert, respectively by the Vice President on Cultural Heritage and Sustainable Development;
- the final ranking of performance scores of the alternative plans for sustainable development for selecting the best one, after fuzzification and defuzzification processes.
The Fuzzy-Delphi method is a methodology in which the decision makers subjective judgments are transformed in easy manipulated data using fuzzy sets. To start, we will focus on identifying the alternative plans or strategies for sustainable development which by the opinion of the decision makers will be part from the selection process. Let noted their number by n where $j = 1, \ldots, n$.

The next step is to establish the strategic selection criteria and assess their importance which representing the directions that a good sustainable development plan needs to meet. Let us note by lc_i the importance of criterion i, where $i = 1, \ldots, m.$. It should be noted that each member of the management decision makers has a certain weight in decisional process (denote the weight by p), taking into account his position in the hierarchy and his experience. In our case, we consider that the sum of weights of each decider member is equal to 1. If the number of decision makers is k, then:

$$p_1 + p_2 + \cdots + p_k = 1 \tag{8}$$

The opinion makers on the importance of each criterion is expressed by a linguistic value which is then converted into a trapezoidal fuzzy number. Thus, let us note the assessment of the importance of criterion i evaluated by the decision maker k with lc_{ik}. Therefore, the final fuzzy value of the importance of criterion i, it will be weighted as follows, taking into account the opinion of each decision maker:

$$lc_i = lc_{i1} \star p_1 + lc_{i2} \star p_2 + \cdots + lc_{ik} \star p_k. \tag{9}$$

For estimation of the performance of each plan with respect to the established tactical subcriteria, we will call this time a single expert who is in our case the Vicepresident of Cultural Heritage and Sustainable Development of the company. Thus, for each subcriterion it will be given a subjective estimation expressed also this time by linguistic values which through the process of fuzzification it will be turn in trapezoidal fuzzy numbers. Suppose that the value of fuzzy numbers on the horizontal axis when we represent the membership functions of the trapezoidal fuzzy numbers not exceed the limit of 10, as can be seen in figure 5. As we can see, each linguistic value that summarizes the

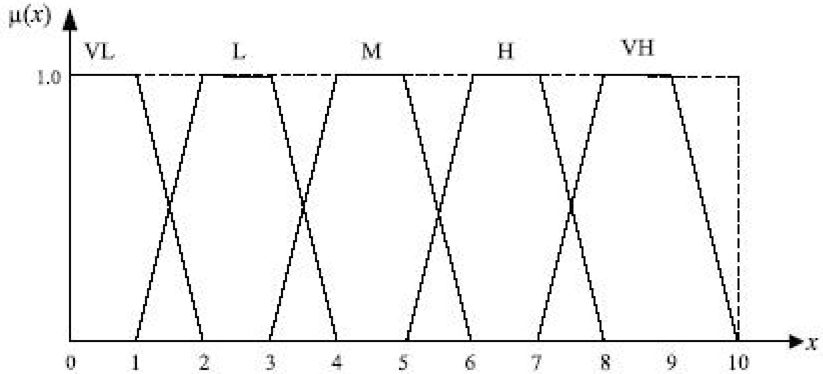

Figure 5 The membership function of trapezoidal fuzzy numbers

subjective assessment and estimation of the human factor decision maker can be converted into trapezoidal fuzzy numbers, as follows in table 1:

Tabel 1. The trapezoidal fuzzy numbers related to the assessment of the importance of the strategic criteria and to the estimation of the performance of sustainable development plans with respect to the tactical subcriteria

Linguistic values	Trapezoidal fuzzy numbers
Very low (VL)	$(0, 0, 1, 2)$
Low (L)	$(1, 2, 3, 4)$
Moderate (M)	$(3, 4, 5, 6)$
High (H)	$(5, 6, 7, 8)$
Very high (VH)	$(7, 8, 9, 10)$

Regarding to the performance estimation of each plan for sustainable development with respect to the tactical selection subcriteria and to the importance evaluation of the strategic selection criteria, the perceptions of decision makers are therefore converted from linguistic values as "Very low (VL)", "Low (L)", " Moderate (M)", " High (H)", or " Very high (VH)" into trapezoidal fuzzy numbers.

Following review by the Vicepresident of Cultural Heritage and Sustainable Development of each plan in hand with respect to each of the tactical subcriteria which in turn make up each strategic criterion initially established by the management team, we shall determine the average scores with respect to these subcriteria in order to calculate the strategic criterion score that encompasses these subcriteria. Thus, having 3 trapezoidal fuzzy numbers, for example, $a = (a_1, a_2, a_3, a_4), b = (b_1, b_2, b_3, b_4)$ and $c = (c_1, c_2, c_3, c_4)$, the average will be:

$$Average(a, b, c) = \left(\frac{a_1 + b_1 + c_1}{3}, \frac{a_2 + b_2 + c_2}{3}, \frac{a_3 + b_3 + c_3}{3}, \frac{a_4 + b_4 + c_4}{3} \right) \tag{10}$$

All values resulting from this operations, trapezoidal fuzzy numbers in this case, will be implemented into a matrix denoted by E_{ij} which represents the performance estimation of the plan j with respect to criterion i , where $j = 1, \ldots, n$ and $i = 1, \ldots, m$.

3.3 The final ranking and the selection of the best plan

The fuzzy weights describing the importance of each selection criteria will be implemented as a matrix with 1 row and m columns, as follows:

$$lc = (lc_1 \ lc_2 \ \ldots \ lc_m) \tag{11}$$

To establish the final performance of each alternative plan for sustainable development, the above matrix lc will be multiplied with each matrix consisting of $E_{ji}, j = 1, \ldots, n, i = 1, \ldots, m$, as follows (we note the performance of each plan by P_j):

$$P_j = lc \star E_{ji}. \tag{12}$$

The E_{ij} matrix corresponding to every plan P_j will be implemented as a matrix with m rows ($i = 1, \ldots, m$) and 1 column and it is representing the fuzzy estimation of the performance of plan j with respect to each criterion i, , results provided from the average between tactical subcriterion weights that compose the main strategic criteria originally established by the management team.

For each P_j plan will therefore result an aggregate fuzzy score, displayed as a trapezoidal fuzzy number:

$$S(P_j) = (x_{j1}, x_{j2}, x_{j3}, x_{j4}),\ j = 1, \ldots, n. \tag{13}$$

For the final ranking and for the selection of the best plan, the fuzzy numbers do not allow an objective and fair assessment. Thus, is required their transformation in crisp, real numbers, through the defuzzification process and using the centroid method, as follows:

$$D(P_j) = \left(\frac{x_{j1} + x_{j2} + x_{j3} + x_{j4}}{4}\right),\ j = 1, \ldots, n. \tag{14}$$

Following the hierarchy of all scores resulted $D(P_j)$ from defuzzification process, the sustainable development plan with the highest score will be selected for implementation.

4. Case study

In the present article, which develops a practical study on the selection of the best alternative strategy for sustainable development within the mining project from Roşia Montană, it can affirm that, from the research conducted until now, that the project itself was conceived as a vehicle for the development of the entire community of Roşia Montană and surrounding areas. The sustainable development in a project of this scale ensures long-term welfare of the community and thus the impact is measured not only in economical terms, but also in terms of social, ethical and environmental. As an overview on the objectives that sustainable development should accomplished within a mining project, there should not miss the following:
- the effective management of the environment within the project mining will develop itself;
- the preservation of the local cultural heritage;
- providing local jobs;
- infrastructure development in the area;
- improving access to health services, education services and cultural activities.

The basic premise in shaping a strong strategy for sustainable development is that the businesses sector may be the main driver for local sustainable development when it takes into account the communities needs and opportunities

in which it developes itself and it is included in the rational use of the local resources. The strategy plan which will be adopted should cover diverse issues, in fact which are well known in the local community and in the area of specialists who support the socio-economical and ecological reconstruction of Roşia Montană area:
- lack of jobs (Roşia Montană has the highest unemployment level of the minig areas of Western Mountaines and Alba County - over 80%, highly likely the highest unemployment rate in the entire history of this community);
- poverty at household and communal level;
- corruption within the public autorities;
- division of community around the two large development options - with or without mining;
- historical pollution of waters and soils, caused by the mining activities ceased just in 2006;
- enhanced degradation of cultural heritage - historical, architectural and industrial - and of local mountain landscape;
- rapid depopulation of the village, at a rate well above the normal rate found in most rural communities in Romania and in Western Mountains.

All these key issues are closely interlinked and can not be reduced only through a unified, complex and lengthy approach, based on partnership and a good coordination.

4.1 Establishing of alternative sustainable development plans, of strategic criteria and tactical subcriteria selection

In pursuing the alternative strategy for sustainable development it must take into account a series of assumptions which briefly outlines the current socio-cultural, economical and environmental situation and the alternatives of sustainable capitalization of local resources in Roşia Montană. The future strategy will play a role in stirring the various actors involved into the development of Roşia Montană. Thus it is put in question the election or joining of such a national plan or program of sustainable development that must fully meet the requirements of a robust strategy over at least the next ten years and that reinvigorate the area both economically, socially-heritage and also environmental. The nationals alternatives plans for sustainable development likely to be chosen for implementation are listed in table 2.

Tabel 2 The national alternative plans for sustainable development

P_1	The National Strategic Plan for Rural Development
P_2	The National Development Plan
P_3	The Regional Development Plan - Central Region
P_4	The National Program of Mine Closure and Reconversion of Mining Areas
P_5	The Master Plan and the Action Plan for National Tourism Development
P_6	The National Strategy and National Action Plan for Environmental Protection
P_7	The National Plan for Development of Mountain Areas
P_8	The Common Agricultural Policy of European Union

The purpose of establishing these alternatives lines of action for sustainable development, synthesized by these eight national plans, aims to identify the best strategy for sustainable development, taking into account certain strategic and tactical subcriteria, that will be set out below.

As I mentioned until now, the strategic criteria are established at a level of a group that contains the management team members and as a method of interrogation in this case we deal with the Delphi method. The actors involved in decision making process and the share of evaluation by everyone in the final amount of the decision importance can be followed in table 3. Also, the tactical subcriteria which practically are a component of the strategic ones are set out by the same group, but this time the estimation of the performance of each alternative plan with respect to these subcriteria is assessed by a single expert, namely the Vicepresident of Cultural Heritage and Sustainable Development.

Tabel 3 The RMGC company team of decision-makers and their associated weights

President and CEO - D_1	$p_1 = 0.40$
General Manager - D_2	$p_2 = 0.25$
Senior Vice President of Government Affairs and Community Relations - D_3	$p_3 = 0.20$
Vice President of Environment - D_4	$p_4 = 0.15$

The strategic criteria or the overall strategic objectives and also the tactical subcriteria established following queries and discussions using the Delphi method are summarized in table 4. In establishing the strategic criteria and tactical subcriteria I took into account that these must meet the 5 SMART requirements:
-Specific - to address unit issues;
-Measurable - through quantitative and qualitative indicators;
-Acceptable - by all involved partners;
-Realistic - in relation with beneficiaries possibilities;
-Time - well defined in time.

Tabel 4 The strategic criteria and tactical related subcriteria

C_1 Ecological reconstruction of the areas affected by mining	C_{11} The evaluation of environmental quality in the area affected by mining exploitation (constraints, problems, opportunities, vulnerability and hazard) C_{12} Measures needed for the ecological reconstruction of the affected areas C_{13} Monitoring environmental quality and health of the population
C_2 Rehabilitation and development of infrastructure and public services	C_{21} Rehabilitation and expansion of the transport, water, sanitation and energy networks C_{22} Improving the quality of medical services, of social welfare, education, culture, of public administration, post and telecommunications
C_3 Restoration and preservation of cultural heritage	C_{31} Restoration and preservation of industrial mining heritage C_{32} Restoration and preservation of historical-archaeological heritage C_{33} Restoration and preservation of architectural heritage C_{34} Restoration and preservation of intangible heritage C_{35} Integrating heritage of Ro?ia Montan? in international networks
C_4 Developing of a diverse, sustainable and competitive business environment	C_{41} Development of the rural and cultural tourism C_{42} Support the development of agriculture and forestry C_{43} Supporting the development of small industries, of microbusiness and of traditional crafts C_{44} The creation of economic added value through the sustainable use of local resources
C_5 Developing of social capital and of community partnerships	C_{51} Promoting and implementing the concepts of social cohesion, civic society and developing the community partnerships through public participation in decision making C_{52} Development of local entrepreneurship C_{53} Fighting social problems in the community C_{54} Attitude towards tourism C_{55} Retaining and attracting people in the area

4.2 The evaluation of the importance of strategic criteria and the estimation of the performances of the alternative sustainable development plans with respect to the tactical selection subcriteria

After establishing the framework of expression of the decision making process and of the working methodology, in the following we will see which is the importance of the strategic criteria, from processing the views of the management team members using fuzzy logic by equation (9), as can be seen from table 5.

	D_1	$p_1 = 0,40$ **fuzzy**	D_2	$p_2 = 0,25$ **fuzzy**	D_3	$p_3 = 0,20$ **fuzzy**	D_4	$p_4 = 0,15$ **fuzzy**	Ic **fuzzy**
C_1	**H**	(5,6,7,8)	**H**	(5,6,7,8)	**M**	(3,4,5,6)	**VH**	(7,8,9,10)	**(4.9,5.9,6.9,7.9)**
C_2	**M**	(3,4,5,6)	**M**	(3,4,5,6)	**L**	(1,2,3,4)	**VL**	(0,0,1,2)	**(2.15,3,4,5)**
C_3	**VH**	(7,8,9,10)	**L**	(1,2,3,4)	**VH**	(7,8,9,10)	**M**	(3,4,5,6)	**(4.9,5.9,6.9,7.9)**
C_4	**H**	(5,6,7,8)	**VH**	(7,8,9,10)	**VH**	(7,8,9,10)	**L**	(1,2,3,4)	**(5.3,6.3,7.3,8.3)**
C_5	**L**	(1,2,3,4)	**M**	(3,4,5,6)	**H**	(5,6,7,8)	**M**	(3,4,5,6)	**(2.6,3.6,4.6,5.6)**

Next come into play the experience and knowledge of expert, respectively we refer to the Vicepresident of Cultural Heritage and Sustainable Development, for estimating the performance of each of the eight nationals alternatives sustainable development plans with respect to each tactical selection subcriteriu. The average of the subcriteria weights will correspond to the strategic criteria weight from which belongs to, as shown in equation (10). The summary of calculations is shown in table 6 and 7.

4.3 The final ranking and the selection of the best national plan for sustainable development

According to equation (11), the fuzzy weights describing the importance of each strategic criterion will be implemented in a matrix with one row and five columns, as follows:

$$lc = ((4.6, 5.9, 6.9, 7.9)\ (2.15, 3, 4, 5)\ (4.9, 5.9, 6.9, 7.9)\ (5.3, 6.3, 7.3, 8.3)\ (2.6, 3.6, 4.6, 5.6))$$

To quantify the final performance of each plan, the above matrix will be multiplied with each matrix consisting of $E_{ij}, j = 1, \ldots, n, j = 1, \ldots, m$, according to equation (12). The E_{ji} matrixis practically correspond to the evaluation of j plan with respect to each i criterion and it is a matrix with five lines and one column in our practical example, which initially contains trapezoidal fuzzy numbers, as can be seen in table 7, which represents the synthesis of the performance estimation of j plan, where $j = 1, \ldots, 8$with respect to each i criterion, where $i = 1, \ldots, 5$.
According to equation (12) and (13), result:

$$S(P_1) = lc \star E_{1i} = (69.92, 110.43, 164.03, 227.63)$$

$$S(P_2) = lc \star E_{2i} = (69.79, 110.96, 163.39, 225.82)$$

$$S(P_3) = lc \star E_{3i} = (94.04, 143.34, 202.64, 271.94)$$

$$S(P_4) = lc \star E_{4i} = (84.82, 129.19, 183.35, 247.51)$$

$$S(P_5) = lc \star E_{5i} = (98.24, 146.02, 203.32, 270.62)$$

$$S(P_6) = lc \star E_{6i} = (83.71, 126.92, 179.62, 242.32)$$

$$S(P_7) = lc \star E_{7i} = (93.89, 142.82, 201.05, 269.28)$$

$$S(P_8) = lc \star E_{1i} = (65.19, 104.7, 154.16, 213.62)$$

For the final ranking and for selection of the best plan, the fuzzy numbers as are shown do not allow an objective and fair assessment. Therefore, we need to transform them in real, crisp numbers, by the centroid defuzzification method, according to equation (14), as follows:

$$D(P_1) = 143.00$$

$$D(P_2) = 141.99$$

$$D(P_3) = 177.99$$

$$D(P_4) = 161.21$$

$$D(P_5) = 179.55$$
$$D(P_6) = 158.14$$
$$D(P_7) = 176.76$$
$$D(P_8) = 134.41$$

It is noted so, that after the defuzzification process, the sustainable development plan P_5 which is corresponding to the Master Plan and the Action Plan for National Tourism Development from the table 2 has the highest score, followed then at a short distance by the P_3 - The Regional Development Plan - Central Region and P_7 - The National Plan for Development of Mountain Areas. The other plans are ranked on a relatively large distance from the first three positions. Refering to the scores of those located on the podium, within the difference between them is relatively very small, it can be said that a combination of their objectives could be the ideal solution for a sustainable development of the Roşia Montană mining area, in which the highest accent must be on developing the local tourism as an alternative for the sustainable development of the area in general.

Tabel 6 The performance estimations of the sustainable development plans with respect to tactical subcriteria

		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8
C_1	C_{11}	**L (1,2,3,4)**	**M (3,4,5,6)**	**H (5,6,7,8)**	**VH(7,8,9,10)**	**VH(7,8,9,10)**	**VH(7,8,9,10)**	**H (5,6,7,8)**	**H (5,6,7,8)**
	C_{12}	**M (3,4,5,6)**	**H (5,6,7,8)**	**M (3,4,5,6)**	**H (5,6,7,8)**	**VH(7,8,9,10)**	**VH(7,8,9,10)**	**H (5,6,7,8)**	**H (5,6,7,8)**
	C_{13}	**VL (0,0,1,2)**	**H (5,6,7,8)**	**L (1,2,3,4)**	**H (5,6,7,8)**	**VH(7,8,9,10)**	**VH(7,8,9,10)**	**M (3,4,5,6)**	**VH(7,8,9,10)**
	Average	**(1.33,2,3,4)**	**(4,33,5.33,6.33,7.33)**	**(3,4,5,6)**	**(5.66,6.66,7.66,8.66)**	**(7,8,9,10)**	**(7,8,9,10)**	**(4.33,5.33,6.33,7.33)**	**(5.66,6.66,7.66,8.66)**
C_2	C_{21}	**H (5,6,7,8)**	**M (3,4,5,6)**	**H (5,6,7,8)**	**L (1,2,3,4)**	**M (3,4,5,6)**	**VL (0,0,1,2)**	**M (3,4,5,6)**	**L (1,2,3,4)**
	C_{22}	**VH(7,8,9,10)**	**H (5,6,7,8)**	**VH(7,8,9,10)**	**H (5,6,7,8)**	**L (1,2,3,4)**	**L (1,2,3,4)**	**H (5,6,7,8)**	**L (1,2,3,4)**
	Average	**(6,7,8,9)**	**(4,5,6,7)**	**(6,7,8,9)**	**(3,4,5,6)**	**(2,3,4,5)**	**(0.5,1,2,3)**	**(4,5,6,7)**	**(1,2,3,4)**
C_3	C_{31}	**VL (0,0,1,2)**	**VL(0,0,1,2)**	**M (3,4,5,6)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**M (3,4,5,6)**	**VL (0,0,1,2)**
	C_{32}	**L (1,2,3,4)**	**L (1,2,3,4)**	**L (1,2,3,4)**	**VH(7,8,9,10)**	**VH(7,8,9,10)**	**M (3,4,5,6)**	**L (1,2,3,4)**	**L (1,2,3,4)**
	C_{33}	**M (3,4,5,6)**	**M (3,4,5,6)**	**H (5,6,7,8)**	**VH(7,8,9,10)**	**VH(7,8,9,10)**	**M (3,4,5,6)**	**H (5,6,7,8)**	**L (1,2,3,4)**
	C_{34}	**H (5,6,7,8)**	**VL 0,0,1,2)**	**VH(7,8,9,10)**	**M (3,4,5,6)**	**VH(7,8,9,10)**	**L (1,2,3,4)**	**VH(7,8,9,10)**	**M (3,4,5,6)**
	C_{35}	**L (1,2,3,4)**	**L (1,2,3,4)**	**VH(7,8,9,10)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**L (1,2,3,4)**
	Average	**(2,2.8,3.8,4.8)**	**(1,1.6,2.6,3.6)**	**(4.6,5.6,6.6,7.6)**	**(5.4,6.4,7.4,8.4)**	**(6.2,7.2,8.2,9.2)**	**(3.4,4.4,5.4,6.4)**	**(4.2,5.2,6.2,7.2)**	**(1.2,2,3,4)**
C_4	C_{41}	**VH(7,8,9,10)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**M (3,4,5,6)**	**VH(7,8,9,10)**	**H (5,6,7,8)**	**VH(7,8,9,10)**	**M (3,4,5,6)**
	C_{42}	**H (5,6,7,8)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**VL(0,0,1,2)**	**VH(7,8,9,10)**	**H (5,6,7,8)**	**VH(7,8,9,10)**
	C_{43}	**H (5,6,7,8)**	**M (3,4,5,6)**	**VH(7,8,9,10)**	**H (5,6,7,8)**	**M (3,4,5,6)**	**M (3,4,5,6)**	**VH(7,8,9,10)**	**H (5,6,7,8)**
	C_{44}	**H (5,6,7,8)**	**VH(7,8,9,10)**	**VH(7,8,9,10)**	**M (3,4,5,6)**	**VH(7,8,9,10)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**M (3,4,5,6)**
	Average	**(5.5,6.5,7.5,8.5)**	**(5,6,7,8)**	**(6,7,8,9)**	**(4,5,6,7)**	**(4.25,5,6,7)**	**(5,6,7,8)**	**(6,7,8,9)**	**(4.5,5.5,6.5,7.5)**
C_5	C_{51}	**M (3,4,5,6)**	**M (3,4,5,6)**	**L (1,2,3,4)**	**M (3,4,5,6)**	**L (1,2,3,4)**	**VL(0,0,1,2)**	**H (5,6,7,8)**	**M (3,4,5,6)**
	C_{52}	**H (5,6,7,8)**	**VH(7,8,9,10)**	**VH(7,8,9,10)**	**L (1,2,3,4)**	**M (3,4,5,6)**	**L (1,2,3,4)**	**H (5,6,7,8)**	**H (5,6,7,8)**
	C_{53}	**M (3,4,5,6)**	**L (1,2,3,4)**	**H (5,6,7,8)**	**VL(0,0,1,2)**	**L (1,2,3,4)**	**M (3,4,5,6)**	**H (5,6,7,8)**	**VL (0,0,1,2)**
	C_{54}	**H (5,6,7,8)**	**M (3,4,5,6)**	**VH(7,8,9,10)**	**H (5,6,7,8)**	**VH(7,8,9,10)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**M (3,4,5,6)**
	C_{55}	**VH(7,8,9,10)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**VL(0,0,1,2)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**H (5,6,7,8)**	**M (3,4,5,6)**
	Average	**(4.6,5.6,6.6,7.6)**	**(3.8,4.8,5.8,6.8)**	**(5,6,7,8)**	**(1.8,2.4,3.4,4.4)**	**(3.4,4.4,5.4,6.4)**	**(2.8,3.6,4.6,5.6)**	**(5,6,7,8)**	**(2.8,3.6,4.6,5.6)**

Tabel 7 The synthesis of performance estimation of plan j with respect to each i criterion (E_{ij})

	E_{1i}	E_{2i}	E_{3i}	E_{4i}	E_{5i}	E_{5i}	E_{7i}	E_{8i}
C_1	(1.33,2,3,4)	(4.33,5.33,6.33,7.33)	(3,4,5,6)	(5.66,6.66,7.66,8.66)	(7,8,9,10)	(7,8,9,10)	(4.33,5.33,6.33,7.33)	(5.66,6.66,7.66,8.66)
C_2	(6,7,8,9)	(4,5,6,7)	(6,7,8,9)	(3,4,5,6)	(2,3,4,5)	(0.5,1,2,3)	(4,5,6,7)	(1,2,3,4)
C_3	(2,2.8,3.8,4.8)	(1,1.6,2.6,3.6)	(4.6,5.6,6.6,7.6)	(5.4,6.4,7.4,8.4)	(6.2,7.2,8.2,9.2)	(3.4,4.4,5.4,6.4)	(4.2,5.2,6.2,7.2)	(1.2,2,3,4)
C_4	(5.5,6.5,7.5,8.5)	(5,6,7,8)	(6,7,8,9)	(4,5,6,7)	(4.25,5,6,7)	(5,6,7,8)	(6,7,8,9)	(4.5,5.5,6.5,7.5)
C_5	(4.6,5.6,6.6,7.6)	(3.8,4.8,5.8,6.8)	(5,6,7,8)	(1.8,2.4,3.4,4.4)	(3.4,4.4,5.4,6.4)	(2.8,3.6,4.6,5.6)	(5,6,7,8)	(2.8,3.6,4.6,5.6)

5. Conclusions and future proposals

The proposed methodology can be successfully applied for the purposes of pursuing a course of action in terms of developing a solid plan for sustainable development, which should have a significantly effect on the local community from a mining area and which join to a national strategic plan for sustainable development. To achieve the performance requirements of such a plan, which would otherwise be implemented within the strategy of the company which operates in this area, it was needed of the experience and knowledge of the management team for determining the strategic criteria and tactical subcriteria for choosing the best plan to follow.

Thus, by using Fuzzy-Delphi method, the management team has established the importance of the strategic criteria of selection and every member from the composition of the decision-maker had a greater or lesser influence in the total weight of the decision depending of the hierarchy position they occupy in the management staff. The estimation of the performance of each possible plan to forward with respect to each tactical subcriteriu was assessed by the company's Vicepresident of Cultural Heritage and Sustainable Development and the weight of the performance estimation of each plan with respect to each strategic criterium was implemented as a matrix that after multiplying operation with the matrix of criteria importance it resulted a score for each alternative sustainable development plan from which we could achieve an objective hierarchy for choosing and implementing the best one, of course after the defuzzification process.

Following the final classification, due to the very tight score of the first three plans, it could propose for implementation an aggregate plan, that consists a combination of the objectives and of the strategies of the three ones, which must meet the expected performance and must provide a viable guarantee for a solid sustainable development, which primarily takes into account the development of local tourism as an alternative for a sustainable development of the area in general.

The proposed methodology can be also successfully applied in other uncertainty circumstances of the decision making process, within the evaluation of human reasoning is ambiguous and imprecise and otherwise requires modeling using fuzzy logic, that is an instrument of real benefit and with satisfactory results for implementation of the best decisions.

For the future it could create certain programs in programming languages (C++, Java) or databases for easier handling of input data and for the return of results in a short time and also to eliminate some possible errors within the arithmetic process of calculation which has a highest probability of manifestation in the case that this calculations are conducted in a classical way for example.

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