The use of Fuzzy Modelling Regarding the Assurance of Environmental Protection

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***Abstract* — Environmental pollution has become a more stringently problem in recent years. The main reasons for increase of the environmental pollution at the level of the whole planet are represented by the increase of garbage amount and by the lack of special places for it's storage, the increased number of the toxic substances used in many fields of science that leads to a continuous pollution of the breathing air. Finally, another important reason for the increase of environmental pollution is represented by the continuously development of the technology that has a disastrous effect for natural ecosystems. Because of these factors, measures were taken in order to avoid disasters, like the dramatic decreased of ozone layer. Based on some fuzzy modelling, the aim of this paper is to design a system that ensure a better protection of the environment.**

***Index Terms* — fuzzy networks, sustainable development, importance-performance analysis, hybrid system**

I. INTRODUCTION

Nowadays, a special importance is given to the environmental protection from various harmful human actions, and environmental impact assessment on the further development of the area. The environment is considered an essential part of any development process and includes connections and interdependencies existing between people and resources. So, the frequent changes suffered by the environmental in time were not generated only by the natural events, but also by the implementation of some development models, practices and lifestyles. The life quality is influenced not only by the physical events, but also in an significant extent by social and economic events. Unfortunately, a big problem that still represents a large question is the pollution. It is hard to believe that it can fully eliminate pollution, but in recent years efforts are made for it is reduction. So, pollution's cost depends firstly by the nature of pollutant, by his toxicity grade and by his effects on biotic and abiotic environment. The maximum allowable concentrations for each of the pollutant vary from a country to another. Because of this there are both extremely polluted countries and also less polluted countries.

The harmful effects of the environment pollution, which are leading to serious health problems and disruption of ecological balance, were discussed at various international conferences. One of the most important conference were in 1992, at Rio de Janeiro, a conference named "The Earth Summit". These conferences has lead to extensive movements for environment protection both in developed and in poor countries. The main characteristic of this movement is the generating of a new perspective for the evolution of attitudes and knowledge from this field.

A first important notion studied in recent years is the environmental impact statements (EIS) that can be defined as the process of identifying, predicting, evaluating and mitigating the biophysical, social, economic and other relevant effects of development proposals before major decisions are taken and commitments made [1]. A development proposal for which there is concern of adverse impact on the environment should prepare an environmental impact assessment (EIA) for the first-stage EIA, and then transfer to EIS to the competent authority for review. A second important notion is represented by the environmental impact assessment report (EIRA). The researcher should edit an EIRA for the second-stage EIA for those circumstances in which the review result of the EIS is concerned with a significant impact on the environment.

In this paper is done a fuzzy approach on a very important parameters referred to the environmental, approach which emphasize factors that are most harmful to the environment sustainable development. In the end of the paper this approach is exemplified by presenting a case study based on a concrete system.

II. ENVIRONMENTAL MANAGEMENT AND SUSTAINABLE DEVELOPMENT

The environmental management is a method which organizes human activities affecting the environmental, in order to maximize social welfare and to prevent and decrease environmental impacts generated, by treating the generating causes. The environmental problems cannot be view in isolation, but these must be addressed with the development problems. Of great importance is maintaining a proper balance between economic development, population growth, a rational use of natural resources, environmental protection and conservation.

A basic principle of environmental management is represented by the *sustainable development* of the countries, a fundamental principle in most of national environmental laws and also in Constitution. As a simple definition, we can say that sustainable development is a fundamental aspect of proper business administration, so the aspiration to an economic growth and the promotion of an healthy environmental be related in a non-destructive manner.

The primary requirement of this principle is represented by the integration of environmental considerations into all areas of economic and social activities. Thus, a state must have a national authority with the power to develop environmental policy. This authority must be supported by various local authorities having the power to implement policy environment. Also, the local organizations must be carefully on the effects of air, water and soil pollution on population's health. They must be empowered to take requiring decisions to reduce pollution and environmental protection [2]. But, it's necessary to have a policy, a legislative framework, mechanisms and procedures in order to act. Functionality standards and procedures for implementation and enforcement should be checked and reported. The results of inspections must be used to apply corrective measures when it is necessary. So, the environmental management becomes a cyclic activity like the development. The main objective of the concept of sustainability development is selecting the optimal solution regarding the interaction of the economic, technological, environmental and human systems [3].

A *sustainable development strategy* is an ensemble of coordinated participatory processes that allow the permanent progress in the field of analysis, debate, building capacity, planning and mobilization of existing resources, in order to reconcile economic, social and environment aspects of the society on long and short term, due to the implementation of strategies that support each other when it is possible.

Unfortunately, it is clear that development is currently unsustainable. The main signals that provide this situation are ozone depletion, global warning, depletion of aquifers, species extinction, collapsing of fisheries, soil erosion and air pollution [4].

III. THE COMBINED MODEL USING FUZZY MODELING AND IMPORTANCE-PERFORMANCE ANALSYSIS

A very important part of this paper is related to *artificial intelligence*. In environment protection field, the artificial intelligence has become an important domain because it's branches like expert systems, fuzzy logic, Bayesian networks, genetic algorithms and neural networks have been applied with a lot of success in various studies referred to environmental protection. Each branch of artificial intelligence has advantages and disadvantages. There is several techniques that can produce very effective hybrid systems by using the advantages of each component method. The combination of two or more different techniques is a very active research area in artificial intelligence [5] Spitz and Lek have used some techniques of neural networks to make various predictions about the damage of wildlife caused by environmental impact. They considered relationships in complex ecological non-linear systems. Gupta used fuzzy networks to take into account the uncertainty in assessing the environmental impact of landfill siting [6]. Tan used heuristic rules from a set of training data based on rough set theory. Then, he used the rules generated through data to compare and rank alternatives. Hudik presented the evolution of Machine Learning techniques which had an extremely important impact on environmental risk assessment [7]. Pai constructed and evaluated the relationship between the quantified impact levels and the plant scale factors of 10 incinerator plants using grey model GM(1,N) [8]. Van Kouwen used a qualitative Bayesian network in order to bridge the gap between simulation models and policy-making [9]. Comas has developed a risk assessment model and then implemented this model in a fuzzy rule-based system for settling problems of microbiological origin in activated sludge systems.

Zadeh provided, in the year 1996, a fuzzy reasoning for qualitative risk forecast [10]. So, it's provided a mechanism of computing with the aid of words in order to model the qualitative human thought processes in analysis of complex systems and decisions. The uncertainty in forecasting the EIA review arises from the situations in which similar proposal may incur different review results because of unexpected specific considerations.

The current trend in control of all systems is "the humanization" of them by making controllers that each contain one model of information processing, a model that is specific for human thinking. Practically, the model can supported a general rule, so can be a support system for decision making. Thus, fuzzy modelling approach not only the purely mental processes of human brain, they were also able to reflect the nature of neuro-motor processes.

Collecting relative data is a very important operation, because the quantitative risk assessment approaches such fault tree analysis, event tree analysis and equivalent annual fatality analysis rely on statistical information [11]. A good statistical analysis is impossible without a relevant data. The concept of fuzzy modelling originates from the definition of fuzzy sets. Fuzzy sets are defined through the membership functions and each element can belong to them to a degree of membership between 0 and 1. This type of fuzzy logic appeared in the year 1930 when polish mathematician Jan Lukasiewicz realised a system when all the values can take values on the interval [0,1].

The fuzzy inference process can be defined as a mapping process from a particular input to an output, using the fuzzy logic. There are two main types of fuzzy systems: Mamdani fuzzy model and Sugeno-Takagi fuzzy model. In this paper we use the Mamdani inference fuzzy system. This is also known as Mamdani method and contains the following four steps:

1. the fuzzification of input variables;
2. the inference process;
3. the aggregation rule of results;
4. defuzzification.

In the first stage it is determined, for all of the parameters taken into account, the membership grade at their fuzzy sets. The inputs are represented always by the numerical values that are limited to the universe of discourse of the variable. The size of universe of discourse is determined based on the responses provided by the experts. Once the inputs are obtained, they are fuzzified in relation to all membership functions. The membership functions are triangular, rectangular, trapezoidal, bell-shaped and their selection is very important.

In the second stage the antecedent fuzzy rules are applied to the fuzzified inputs from the first stage. If a fuzzy rule has more antecedents, the fuzzy operator (AND or OR) is used to obtain a single number that represent the result of antecedents evaluation. This number is applied to the membership function.

In the stage 3 takes place the aggregation of the results that represents the outputs unified process from all of the rules. So, it is considered the membership consequence functions of all scaled rules, that then must combined into a single fuzzy set.

The stage 4 represents the defuzzification. The fuzzification is very useful in rules evaluation, but the final result of a fuzzy system must be a number. Through the defuzzification method the most used is the centroid method. The goal is to observe the point where a vertical line divides the aggregate surface in two equal quantities.

There is three major clusters considered in the EIA: *environmental pollution*, *ecological alteration* and *socioeconomic disturbance*. Each of these three clusters contains some indicators. The environmental pollution contains a number o five indicators: air (EP_1), water (EP_2), soil (EP_3), solid waste (EP_4) and noise (EP_5). The ecological alteration contains two indicators: terrestrial (EA_1) and aquatic (EA_2). The socioeconomic disturbance includes three indicators: economics (SD_1), society (SD_2) and culture (SD_3). These indicators have also a list of subindicators [12]. So, the air pollution (EP_1) have following subindicators: carbon monoxide (EP_{11}), sulfuric dioxide (EP_{12}), nitrogen dioxide (EP_{13}), total suspended particulates (EP_{14}). Water pollution (EP_2) involves: dissolved oxygen (EP_{21}), biochemical oxygen demand (EP_{22}), suspended solids (EP_{23}) and ammonia nitrogen (EP_{24}). Soil pollution (EP_3) have the level of heavy-metal pollution (EP_{31}). Solid waste (EP_4) contains rubbish (EP_{41}) and industrial waste (EP_{42}). Noise pollution (EP_5) have indicates noise (EP_{51}) and vibration (EP_{52}) that is induced by the construction equipment. Terrestrial (EA_1) contains the threatened percentages of terrestrial animals (EA_{11}), plants (EA_{12}) and endangered species (EA_{13}). Aquatic (EA_2) contains the threatened percentages of aquatic animals (EA_{21}), plants (EA_{22}) and endangered species (EA_{23}). Economics (SD_1) encompasses disturbances in land-use and development (SD_{11}), life quality (SD_{12}) and economic activities (SD_{13}). Society (SD_2) takes into account inaccessibilities in public facilities (SD_{21}) and transportation (SD_{22}), and disconnection in communities (SD_{23}). Culture (SD_3) includes destroyed cultural heritage (SD_{31}) and landscapes (SD_{32}). A big part of these subindicators can be measured by instruments and this type of measurement is considered objective. The subindicators that can be measured directly by instruments are: EP_{11}, EP_{12}, EP_{13}, EP_{14}, EP_{21}, EP_{22}, EP_{23}, EP_{24}, EP_{51}, EP_{52}. The rest of the subindicators can be only estimated by experts on the basis of collected information.

The concept of importance-performance analysis (IPA) was firstly introduced by Martilla and James [13] in 1977 as a tool to develop companies' management strategies. There is a very practically framework and his goal is to identify which product or service attributes should focus a company in order to increase customer satisfaction. This method combines measures of attribute importance and performance into a two-dimensional grid. In the Fig. 1 can see that along x-axis are showed attribute performance and along y-axis are showed attribute importance.

As seen from the figure, the grid is divided into four quadrants: the first quadrant (high importance/high performance) has the label „Maintain performance". The attributes located here indicate major strengths for achieving or maintaining competitive advantage. The second quadrant (high importance/low performance) has the label „Focus effort here" and this quadrant's attributes represent key challenges that require immediate corrective action. The third quadrant (low importance/low performance) has the label „Low priority" and the attributes from this quadrant are low weaknesses and don't require extra effort. Finally, the fourth and last quadrant (low importance/high performance) is showed as „Reduce emphasis". The attributes from this quadrant are strength, but their importance in the final system is irrelevant.

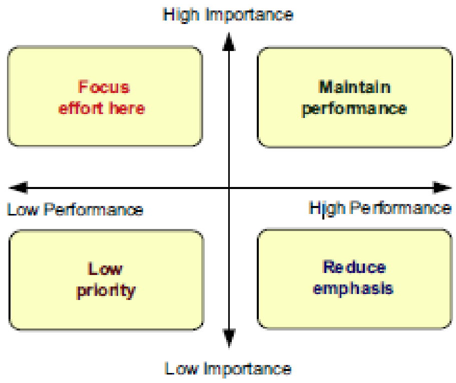

Figure 1. Attribute performance vs. attribute importance.

IV. THE CASE STUDY

Iasi is one of the most important economic, cultural and financial centre of Romania. This city is also the capital of Moldova region and also an important border area. Unfortunately, a big problem of the city is represented by the traffic, which is extremely difficult. The reason for this problem is represented by the roads, which are in a disastrous condition. Also, the parking places are very few and their number is insufficient. One of first measure being taken by the local authorities, in the autumn of the year 2007, was the achievement of underpass in one of the most circulated areas, the Central Hall area, very close to Europe Hotel. In order to prevent a lateral impact on the neighbouring environment, the local authorities conducted an EIS concerning the natural, biological, social and economical impacts. This paper focuses on the construction phase of underpass. In our study we use ten indicators and for each of these indicators are established three case bases: conditional approval, a second-stage EIA or disapproval. For each subindicator of the indicators should be discussed three conditions. The first is *the baseline condition before the development activity*, which is represented by the ratio (BC/S) of baseline measurement (BC) to the standard values (S). The second condition is *the prediction of the pollution increment caused by the development activity without consideration mitigation measures*. This measure is described by the ratio (PIWOM/BC) of predicted pollution increment (PIWOM) to baseline measurement (BC). The last one is the *prediction of the pollution increment with mitigation measures* which is depicted by the ratio (PIWM/BC) of predicted pollution increment with mitigation measures (PIWM) to baseline measurement (BC). Each of the ten indicators has a number of features of: EP_1 – 16, EP_2 – 8, EP_3 – 3, EP_4 – 3, EP_5 – 4, EA_1 – 4, EA_2 – 1, SD_1 – 4, SD_2 – 3, SD_3 – 2.

Then, a number of ten systems are constructed, one each for every indicator. Every system consists of three case bases: conditional approval, second-stage EIA and disapproval. So, they are in total 30 base cases. We introduce now a dissimilarity measure that is defined by the following formula:

$$ds(C^j_{new}, C^j_i) = \sqrt{\sum_{k=1}^{n} w^2_{1k} w^2_{2k} (x^j_{new-k} - x^j_{i-k})^2} \qquad (1)$$

So, the C^j_i represents one of the ten indicators from this problem in the *i*-th case and C^j_{new} represents one of the ten indicators for a new case, x^j_{i-k} represents the *k*-th feature value, w_{1k} is the weight of the *j*-th feature, according to experts and w_{2k} is the reciprocal of the standard deviation of the *j*-th feature in order to eliminate the domination of some features with larger standard deviation. The similarity measure can be defined following the next formula:

$$S(C^j_{new}, C^j_i) = \exp^{-ds(C^j_{new}, C^j_i)} \quad (2)$$

So, in the rows below we presented some of the examples regarding these formula. Consider that the indicator EP_1 (air) is denoted as $C^{EP_1}_{new}$. The retrieval result is $C^{EP_1}_A$ from the condition approval case base with a similarity of 0.896. $C^{EP_1}_B$ from the second stage EIA base cases has a similarity of 0.767 and $C^{EP_1}_C$ from the disapproval case has a slow similarity of 0.124. In our study the experts are the logistic specialists from the Local Council of Iasi, the institution which is responsible for the project.

For each of the ten indicators we have a number of six pairs that compute the similarities: S^j_A for C^j_{new} and C^j_A, S^j_B for C^j_{new} and C^j_B, S^j_C for C^j_{new} and C^j_C, S^j_{AB} for C^j_A and C^j_B, S^j_{BC} for C^j_B and C^j_C, S^j_{AC} for C^j_A and C^j_C. In the rows above, the similarity $S^{EP_1}_A$ is 0.896, similarity $S^{EP_1}_B$ is 0.767 and similarity $S^{EP_1}_C$ is 0.124.

Finally, for the fuzzy reasoning we have following linguistic variables: S^j_A, S^j_B, S^j_{AB} and $P^j_{A_1}$, when S^j_A is the similarity between C^j_{new} and C^j_A, S^j_B is the similarity between C^j_{new} and C^j_B, S^j_{AB} is the similarity between C^j_A and C^j_B, $P^j_{A_1}$ represents the probability of conditional approval: "very low", "low", "moderate", "high", "very high".

In this paper we proposed a method for the evaluation on the risk in order to help the developer to identify earlier the possible risks when he wants to make buildings that implies many risks. We can achieve the risk management using some of the several artificial intelligence methods, the methods that are more sensitive and emulates the human behaviour. A good implementation of the method is impossible to make without a careful data collection and without an authorized expertise from the specialists. The environmental protection is so important and all of the building developers have the obligation to respect the laws referred to environmental.

V. CONCLUSIONS

In this paper, based on solid theoretical concepts referred to few of the most important notions of environmental protection (EIS, EIR, EIRA), we have proposed a system of environmental protection for the city of Iasi, in order to reduce the disastrous effect of the various architectural projects over the quality of the breathing air. As is known, the quality of breathing air is a major factor related to human health, a big number of diseases being determined by a pronounced pollution. As a future direction, we will try to improve this system by considering more aspects, depending on the evolution of the approached project.

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