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ARTICLE

Fuzzy-logic Method for Global Quality Optimization Problem of the Programmed Action Investment

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ABSTRACT

In order to analyze the planning of a transport linear infrastructure (railway or ordinary road), in order to optimize a relationship work-environment after-work, the study team (engineers,architects, economists, etc), realize a careful prearranged analysis about the characteristic of the site and the large area which are involved by the work project and, once one found all possible alternative solutions, he should compare them through the use of suitable technical, economical and environmental parameters, choosing that one which maximize the global utility of the public investment. In this paper we study a fuzzy-logic method in order to help the decision maker in the analysis of the programmed action public investment.

1. Introduction

For the optimization process of the "artwork-environment" system, in the modern application of the mathematical and statistics science to the project and planning problems of the measures related to the infrastructural net of the area, the fuzzy-logic takes a particular importance.

This new systematic analysis technique for the complex and articulate relationships existing between a railway engineer work and the environmental context, where it is placed, it can appropriately be deal with jointly within the possibility to reach the "optimal" choice among the different alternatives of intervention (new projects, functional improvement of the existing things, extraordinary maintenance of the net, etc.), taking carefully into account the area particularity where the artwork extrinsic its own direct and indirect effects (prior evaluation of the after-work scenarios).

We can use some appropriate mathematical models which helps the take a decision, characterizing the problem in matrix terms, regardless a group of criterions (attributes, objectives, dimensions, impacts, etc.).

This innovative way of performing can represent, this way, a central moment of any evaluation procedure not only for the designer or for the team which is asked to prepare an environmental impact study (planning), but also for the public decision-maker who should establish the compatibility or non-compatibility of the intervention to carry out in the area, keeping also attention to some possible particular restrictions for the environmental protection and conservation.

Many of the factors taken into account are soft or

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qualitative nature, and they do not lend themselves to a quantification/evaluation through classical procedures, both ordinal and cardinal. Often some of these criterion can only be expressed through some value judgment for their subjective nature (i.e. interference evaluation above the agricultural landscape, etc.) and then they are vague, inaccurate, with the "uncertain boarders".

The explicit recognition of the vague and inaccurate nature of many value judgements – based on the natural language – is at the bottom of the methodological development that one wants to present and which is referred to the polyvalent logic and to the fuzzy sets theory.

The principal objective of the present paper is to introduce a methodological approach, systemic, allows to evaluate in a combined way for each work hypothesis considerate (variation of the

considered elements, particular materials used, specific considerations of the artwork, etc.), the complex of the positive and negative effects generated both in the network interested by the intervention and in environmental interest context, in order to easily arrive to the best solution choice of the project, with respect for the related economic limits and obviously for the legal sector ones (safety standards, quality, etc.) and the time limits for the release for the exercise.

2. Literature Review and Theoretical Background

Multiattribute decision-making is pervasive and active around human beings' practical activities. It is an effect and basic method to solve large quantitative and qualitative problems as information fusion, pattern recognition, alternatives selection and evaluation, clustering analysis, military applications, and so forth. However, with the increasing complexity of the decision-making's environments, the attributes tend to be more and more uncertain. The traditional decision-making methods cannot address these conditions. Therefore, the fuzzy multiattribute decision-making is introduced and widely used to tackle this uncertainty since Zadeh [1] initially proposed the theory of fuzzy set in 1965.

Many researchers have devoted themselves to the fuzzy multiattribute decision-making with diferent types of fuzzy sets, from the traditional fuzzy set to the intuitionistic fuzzy sets and hesitant fuzzy sets. intuitionistic fuzzy sets and hesitant fuzzy sets are the two most popular fuzzy sets at present, which have been extensively paid attention to. Xu [2] firstly introduced the intuitionistic fuzzy weighted averaging and intuitionistic fuzzy ordered weighted averaging operators to make the decision. Further, Zhou et al. [3–6] extended these operators by diferent measures of the intuitionistic fuzzy sets. Recently, Liu et al. [7–15] provided some newest achievements of intuitionistic fuzzy weighted averaging and intuitionistic fuzzy ordered weighted averaging operators for intuitionistic fuzzy sets and their extensions by using diferent kinds of aggregation methods to deal with fuzzy multiattribute decision-making, which greatly perfect this theory. It also attracted great interest from scholars all over the world. Xu and Xia [16, 17], Farhadinia [18, 19], Zeng et al. [20], Zhao et al. [21], Chen et al. [22], and Liao et al. [23] provided a variety of distance, similarity, entropy, and correlation measures for hesitant fuzzy sets. Xia et al. [24, 25] and Liao et al. [26, 27] also presented some basic operations and aggregation operators for hesitant fuzzy sets. With the help of these basic information measures and aggregation operators, decision can be made with hesitant fuzzy information. He et al. [28] first introduced the expected value and the geometric average value of hesitant multiplicative element to group decision-making problems. Xu and Zhang [29] developed a novel approach based on tecnique for order of preference by similarity to ideal solution and the maximizing deviation method for solving Multiattribute decision-making problems with hesitant fuzzy information. Further, Sun et al. [30] constructed an innovative tecnique for order of preference by similarity to ideal solution based on synthetic correlation coefcient between hesitant fussy set which can handle negative values. Zhang and Xu [31] proposed an interval programming method for solving multiattribute decision-making problems with hesitant fuzzy alternatives based on linear programming technique for multidimensional analysis of preference. Ashtiani and Azgomi [32] proposed a hesitant fuzzy multiattribute decision-making based computational trust model capable of taking into account the fundamental building blocks corresponding to the concept of trust. Ebrahimpour and Efekhari [33] proposed an innovative method to deal with feature subset selection with hesitant fuzzy set based on maximum relevancy and minimum redundancy approach. Rodrıguez et al. [34] introduced the concept of a hesitant fuzzy linguistic term set to provide a linguistic and computational basis. Liao et al. [35] developed a method to solve the MCDM problem within the context of hesitant fuzzy linguistic term set. Wang et al. [36] developed a likelihood-based prospect theory approach for the selection and evaluation with multihesitant fuzzy linguistic information. Meng et al. [37] presented a similarity measure for uncertain linguistic hesitant fuzzy sets and constructed the optimal weight vector for multiattribute decision-making for evaluating corporate environmental performance. Feng et al.[38] proposed a consistency measure method based on

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the hesitant goal programming model to defne the consistency hesitant fuzzy linguistic preference relations. Wu and Xu [39] proposed a large-scale group decision-making consensus model with possibility distribution based hesitant fuzzy preference. Li et al. [40] personalized individual semantics in group decision-making with hesitant fuzzy linguistic terms sets by consensus model. Zhang et al. [41] defned three kinds of additive consistency indices to measure the consistency level of hesitant fuzzy preference relation. Li et al. [42] used the modifed prospect theory to solve multiattribute decision-making issue of mineral resources evaluation and resources management with hesitant fuzzy linguistic information. Xue and Du [43] defned the multiplicative consistency of hesitant fuzzy preference relations to relax the same number for all elements in hesitant fuzzy set and made the decision by fuzzy linear programming method. Liu et al. [44] used the continuous entropy weights and improved Hamacher information aggregation operators to aggregate interval-valued hesitant fuzzy information. Yang et al. [45] used the possibility degree to present a new comparative law for multiattribute decision-making problems with interval-valued hesitant fuzzy sof sets.

The peculiarities of the Fuzzy-Logic ere essential to overcome the descriptive difficulties to define the risks calculated and the potential "impacts" on the expected utility flows: the multi-semantic nature of the common use words makes the inaccuracy and the vagueness non-eliminable components of a decision process for the economic, engineer sciences, and more in general for all the applied sciences, because of the main use of the natural language, much more common than the formal language and the symbolic logic. The fuzzy sets theory was born exactly for the exigency to operate a "modeling of an uncertain reasoning", to find a logical-mathematical instrumentation which leads the natural language capacity to represent the versatility and the uncertainty, with the advantages of the algebra formalization and the numerical representation.

In fact, Zimmermann [46, 47] begin to show the role of fuzzy logic for the applications, in particular for transport problem Lo Bosco et al. [48, 49], for risk analysis of hazardous materials and Collan et al. [50] which consider a fuzzy pay-off for the options valuation.

At the bottom of these considerations, it is possible to apply properly the fuzzy-logic typical concepts to the environmental impact study of a work or a set of interventions, meaning to a public decision process which characterizes the generic element x_{ij} of the indicators matrix built especially for the characterization of the problem, as it is shown above,

$$X \equiv \left\| x_{ij} \right\|$$

3. A Method for the Applications to the Problems of Public Work Project

A problem MADM (Multi Attribute Decision Making) can be easily represented trough a decisional matrix X of $n \times m$ dimension:

	g_1	g_2	…	g_m
a_1	x_{12}	x_{12}	…	x_{1m}
a_2	x_{21}	x_{22}	…	X_{2m}
⋮	⋮	⋮	⋮	⋮
a_n	x_{n1}	x_{n1}	…	x_{nm}

The decisional $X = \left[x_{ij} \right]_{nxm}$ matrix can be transformed in a new matrix C_{nxm} composed of fuzzy elements (included between 0 and 1), where $C_1(x)$, $C_5(x)$, $\cdots$, $C_m(x)$, ($C_j(x) \in [0,1]$) represent the membership function related to the attributes g_1, g_2, …., g_m, meaning, the "*performance*" of the alternative a_i, when it is examined in reference to the attribute g_j (which characterizes "how much" a determined alternative satisfies a certain objective);

Examining the elements which compose this new matrix, one can affirms that the generic alternative a_i satisfies all the constraints with the degree $D(a_i)$, according to the following relation:

$$D(a_i) = \ min\{C_1(x_{i1}), \ldots, C_m(x_{im})\} \qquad (1)$$

The best alternative, indicated with a_*, can be written as follows:

$$a_* = arg\{max_{ai \in A} D(a_i)\}$$

Where, with a_* it is indicated the index corresponding to the maximum value of $D(a_i)$.

If the objectives and constraints have a different degree of importance in relation to some particular aspects of the optimization process analyzed, the relation (1) can be modified introducing the relative weights w_1, w_5, … , w_l, in this case $D(a_i)$ is easily definable trough the following relation:

$$D(a_i) = \min\left\{ C_1^{a_1}(x_{i1}), \ldots, C_m^{a_m}(x_{im}) \right\}.$$

The following problem is the definition of a proper measurement ladder of the relative importance of the different target considered; the most used method has as a starting point the comparison of the elements, taken two at once.

Therefore, it is necessary to operate generally a total of $m(m$-1)/2 comparisons for m elements which characterize the problem.

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Table. 1 example of value ladder from 1 to 9

INDEX OF POWER	Definition
1	*Same weight*
3	*Weakly greater weight of an objective compared with another*
5	*Significat power of an objective compared with another*
7	*Demostrated relevance of an objective compared with another*
9	*Absolute relevance domination of an objective compared with another*
2, 4, 6, 8	*Intermediate values between two adjacent judgiment (compromise's value)*

4. A practical application of the Method

The proposed mathematical method is easy to apply for the global optimization of the choices of economic policy, or "project management", operatively comparing the specific technical, socio-economic, financial and environmental profiles of the respective alternatives for the intervention of public works to be carried out in the territory. The construction of the alternatives set is the point of departure for the solution and data of different type. This transformation of technical data in values of utility, is a delicate passage that concerns the valuation of the membership function.The characterization of the indicators ca be analyzed by the construction of dominance hierarchy. In Fig. 1 it is reported the operational scheme for the individualization, through this model of decomposition, of the principal attributes for the analysis of the system. The fuzzy decisional matrix can be built determining for every terminal element of the scheme reported in Fig. 1 the correspondent fuzzy value by the following two membership functions:

$$C_j(x_{ij}) = \frac{x_{ij} - x_i^{\min}}{x_i^{\max} - x_i^{\min}}, i = 1, \ldots, m, \quad j = 1, \ldots, n,$$

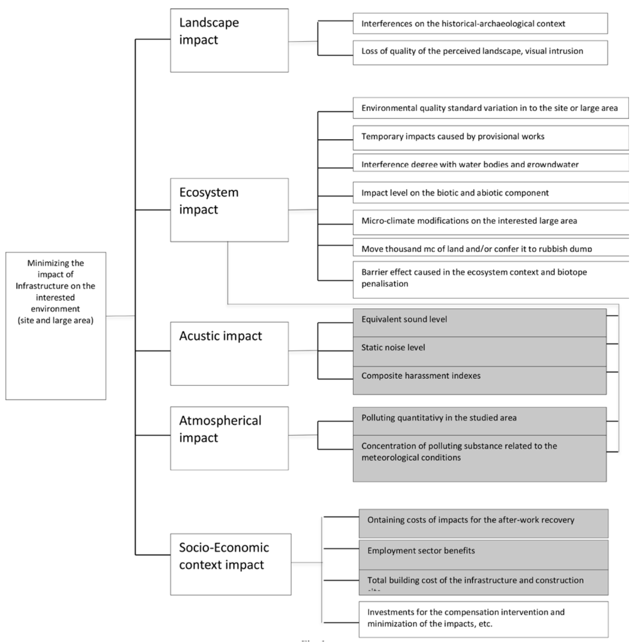
for the positive impacts,

$$C_j(x_{ij}) = \frac{x_i^{\max} - x_{ij}}{x_i^{\max} - x_i^{\min}}, i = 1, \ldots, m, \quad j = 1, \ldots, n,$$

for the positive impacts, where $x_i^{\max}$ and $x_i^{\min}$ are given by:

$$x_i^{\max} = \max\{x_{i1}, x_{i1}, x_{i1}, \ldots, x_{i1},\}, \quad i = 1, \ldots, m,$$

$$x_i^{\min} = \min\{x_{i1}, x_{i1}, x_{i1}, \ldots, x_{i1},\}, \quad i = 1, \ldots, m,$$



The evaluation of the weights is more complex, in fact to determine the importance of every element in relation to the strategic objectives it is necessary to multiply the local weights of every element for those of the correspondents upper elements and the products so obtained must added.

Once calculated the global weights, it is possible to build the weighted matrix of the impacts and easily apply (1) and obtain the "best" alternative.

5. Example

For example we consider possible project alternative A_i (i = 1, … ,5) to implement an investment related to an urban crossing road, the global effects have been algebraically evaluated. and indirect, generated in the territory (urban site and "vast area") for and different stages of opening and management of the building site, construction, operation and maintenance.

The weights w_i reported in the following tables, therefore, are affected by the indicators associated to the projects in terms of intrinsic safety of the road (including the resolutive type adopted to separate the "weak users" from the traffic - see figure), and the variations of positive and negative usefulness) to "whole life" and finally of the ecosystem costs (on the quality of life, on health, etc.), also taking into account the mitigation works envisaged in the project. Finally, the criteria C_i concern, respectively, the different elements of judgment represented by the information provided by the vector x (formed by m vectors column $x_j^{-w_j}$ generated by the design data of the alternatives,which is associated with the relative weight w_j.

Considering the following five criterias:

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C_1 → criterion based on technical − regulatory elements
C_2 → criterion that takes into account the economic − financial aspects
C_3 → criterion that evaluates the correlation "work − environment"
C_4 → criterion that analyzes the effects in operation and the network context
C_5 → criterion based on scheduled maintenance and "residual value"

The proposed methodology has been applied and the considered criteria are those illustrated above, we have the follow decision matrix

	C_1	C_2	C_3	C_4	C_5
A_1	10	110	1005	0,32	0,15
A_2	15	120	1404	0,40	0,37
A_3	18	90	1233	0,23	0,21
A_4	23	87	1786	0,52	0,40
A_5	21	94	892	0,39	0,31

Introducing the relative weights we have the Normalized matrix:

	C_1	C_2	C_3	C_4	C_5
w	*0,1*	*0,2*	*0,4*	*0,1*	*0,2*
A_1	0.11	0.22	0.16	0.17	0.10
A_2	0.17	0.24	0.22	0.22	0.26
A_3	0.21	0.18	0.20	0.12	0.15
A_4	0.26	0.17	0.28	0.28	0.28
A_5	0.24	0.19	0.14	0.21	0.22

and applying the (1) we obtain:

	C_1	C_2	C_3	C_4	C_5	$D(ai)$
A_1	1,242	1,354	2,087	1,192	1,572	7,447
A_2	1,192	1,331	1,825	1,166	1,312	6,827
A_3	1,171	1,410	1,923	1,232	1,470	7,205
A_4	1,142	1,419	1,658	1,136	1,292	6,647
A_5	1,153	1,397	2,188	1,169	1,360	7,267

then we can check that the best alternative is A_1 .

6. Discussion and Conclusions

The mathematical model proposed for the systemic analysis of the public investments in infrastructure work, founded on the fuzzy-logic, allows to reach the "multi-sector" optimization of the engineer project problems, in an overall view which take into account both the elements that characterize the trinomial "artwork-economy-environmental" and the different strategic objectives of the public decision-maker.

The "optimal" intervention solution has been found considering jointly all the different "subjects" interested into the definition of the scenario "after-work". As result it produces in the socio- economic context and in the large area of the programmed intervention some utility flows much more relevant than those associated to the "sector" analysis model which optimize each single aspect of the multidisciplinary problem. In this way one ignores the interaction among the characteristic elements of the complex study system.

With this target, trough apposite "alternative-indicator" matrix, using the fuzzy logic, it is possible to find the "optimal" project alternative, analyzing in a systematic way the set of direct, indirect and "associated" effects that the intervention will produce on the territory (site and large area interested) during the during the whole lifetime.

It has also been analysed a practical application of the foretold model for the public work project, identifying, trough the construction of a dominance hierarchy, the proper objectives (indicators) for the construction of the evaluation matrix and the related weights.

In this paper we want to present a mathematical method which may be to help the decision maker in the analysis of an alternative investment public. The variables of the mathematical model used to optimize the results of the problem are the unknowns on which the decision must be made. The goal set by the decision maker in making the choice among the n possible alternatives constitutes the objective function of the model.

On the basis of these mathematical indicators it is possible, case by case, to build others to further refine the analysis undertaken, or to highlight other aspects of the problem, thus allowing to optimize the overall results for the entire time frame of the effects that the choices will have. taken by the final decision maker.

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