Single Valued Neutrosophic Numbers and Analytic Hierarchy Process for Project Selection

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Abstract. Neutrosophic sets and its application to decision support have become a topic of great importance. In this paper, a new model for decision making in the selection of projects is presented based on single valued neutrosophic number (SVN-numbers) and the analytic hierarchy process (AHP). The proposed framework is composed of five activities, framework, criteria weighting, gathering information, rating alternatives and project selection. Project alternatives are rated based on aggregation operator and the ranking of alternatives is based on scoring and accuracy functions. The AHP method is included and allows a correct weighting of different criteria involved. Additionally the common decision resolution scheme for helping decision maker to reach a reliable decision is used giving methodological support t. A case study is developed showing the applicability of the proposal for information technologies project selection. Further works will concentrate in extending the proposal for group decision making and developing a software tool.

Keywords: Decision Analysis, SVN Numbers, analytic hierarchy process, project selection.

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1 Introduction

Fuzzy logic or multi-valued logic is based on fuzzy set theory proposed by Zadeh [1], for helping in modeling knowledge in a more natural way. The basic idea is the notion of the membership relation which takes truth values in the closed interval of real numbers [0, 1] [2].

The intuitionistic fuzzy set (IFS) on a universe was introduced by K. Atanassov as a generalization of fuzzy sets [3]. In IFS besides the degree of membership ($\mu_A(x) \in [0,1]$) of each element $x \in X$ to a set A there was considered a degree of non-membership $\nu_A(x) \in [0,1]$, such that:

$$\forall x \in X \mu_A(x) + \nu_A(x) \leq 1 \quad (1)$$

Later the neutrosophic set (NS) was introduced by F. Smarandache who introduced the degree of indeterminacy (i) as indepedent component [4].

Decision analysis is a discipline with the goal of computing an overall assessment that summarizes the information gathered and providing useful information about each evaluated element [5]. In real world decision making problems uncertainty is presented and the use of linguistic information to model and manage such an uncertainty is recommended [6].

Experts feel more comfortable providing their knowledge by using terms close to the way human beings use [7] by means of linguistic variables. A linguistic variable is a variable whose values are words or sentences in a natural or artificial language [8].

Because of the imprecise nature of the linguistic assessments new techniques have been developed. Single valued neutrosophic sets (SVNS) [9] for handling indeterminate and inconsistent information is a relatively new approach. In this paper a new model of project selection is developed based on single valued neutrosophic number (SVN-number) allowing the use of linguistic variables [10, 11] and the analytical hierarchy process (AHP) for weighting criteria according to its importance [12]. Weighting criteria is important in decision making problems. In some similar proposals weight are given but no method is explained [13] or [14]. Additionally the common decision resolution scheme for helping decision maker to reach a reliable decision is used giving solid methodological support.

This paper is structured as follows: Section 2 reviews some preliminaries concepts about decision analysis framework SVN numbers and AHP method to find the attributes weight. In Section 3, a decision analysis framework based on SVN numbers for project selection. Section 4 shows a case study of the proposed model. The paper ends with conclusions and further work recommendations.

2 Preliminaries

In this section, we first provide a brief revision of a general decision scheme, the use of linguistic information using SVN numbers project selection and the Analytic Hierarchy Process.

2.1 Decision Scheme

Decision analysis is a discipline with the purpose of helping decision maker to reach a reliable decision.

A common decision resolution scheme consists of following phases [6, 15]:

- Identify decision and objectives.
- Identify alternatives.
- Framework:
- Gathering information.
- Rating alternatives.
- Choosing the alternative/s:
- Sensitive analysis
- Make a decision

Inside the framework phase, the structures and elements of the decision problem are defined. Experts provides information, according to the defined framework.

The gathered information provided by experts is then aggregated in the rating phase to obtain a collective value of alternatives. In rating phase, it is necessary to carry out a solving process to compute the collective assessments for the set of alternatives, using aggregation operators [16].

Aggregation operator are important in decision making. Aggregation operator , $\mathbb{C}$[17], are function with the following form::

$$\mathbb{C}: \mathrm{N}^{\mathrm{n}} \rightarrow \mathrm{N} \qquad (2)$$

Some example of operators are the Bonferroni mean which is a very useful aggregation operator, and can consider the correlations between the aggregated arguments[18-20], the weighted geometric operator [21, 22], the Heronian means for considering the interrelationships between parameters [23, 24] and the power Heronian aggregation operator [25] among others

Project selection is a multicriteria decision problem [26] . This fact makes the process of selecting information systems projects suitable for decision analysis scheme model.

2.2 SVN-numbers

Neutrosophy is mathematical theory developed by Florentín Smarandache for dealing with indeterminacy. [27]. It has been the base for developing of new methods to handle indeterminate and inconsistent information like neutrosophic sets an neutrosophic logic and specially in in decision making problems [28, 29] .

The truth value in neutrosophic set is as follows [30]:

Let N be a set defined as: $N = \{(T, I, F) : T, I, F \subseteq [0,1]\}$, a neutrosophic valuation n is a mapping from the set of propositional formulas to N , that is for each sentence p we have $v\ (\mathrm{p}) = (T, I, F)$.

Single valued neutrosophic set (SVNS) [9] was developed with the goal of facilitate real world applications of neutrosophic set and set-theoretic operators. A single-valued neutrosophic set is a special case of neutrosophic set .proposed as a generalization of crisp sets, fuzzy sets, and intuitionistic fuzzy sets in order to deal with incomplete information [10].

A single valued neutrosophic set (SVNS) is defined as follows (Definition 1) [9]:

Definition 1: Let X be a universe of discourse. A single valued neutrosophic set A over X is an object having the form of:

$$A = \{\langle x, (x), (x), (x)\rangle : x \in X\} \qquad (3)$$

where$u_A(x): X \rightarrow [0,1]$, $r_A(x), : X \rightarrow [0,1]$ and $v_A(x): X \rightarrow [0,1]$ with $0 \leq u_A(x) + r_A(x) + v_A(x) \leq 3$ for all

$x \in X$. The intervals $u_A(x)$, $r_A(x)$ y $v_A(x)$ denote the truth- membership degree, the indeterminacy-membership degree and the falsity membership degree of x to A respectively.

Single valued neutrosophic numbers (SVN number) are denoted by $A=(a,b,c)$, where $a,b,c \in [0,1]$ and $a+b+c \leq 3$.

Alternatives are frequently rated according Euclidean distance in SVN [31-33].

Definition 2: Let $A^* = (A_1^*, A_2^*, \ldots, A_n^*)$ be a vector of n SVN numbers such that $A_j^* = (a_j^*, b_j^*, c_j^*)$ j=(1,2, … , n) and $B_i = (B_{i1}, B_{i2}, \ldots, B_{im})$ ($i = 1,2, \ldots, m$) be m vectors of n SVN numbers such that $B_{ij} = (a_{ij}, b_{ij}, c_{ij})$ ($i = 1,2, \ldots, m$), ($j = 1,2, \ldots, n$). Then the separation measure between $B_i's$ y A^* is defined as follows:

$$s_i = \left(\frac{1}{3} \sum_{j=1}^{n} \left\{ \left(\left| a_{ij} - a_j^* \right| \right)^2 + \left(\left| b_{ij} - b_j^* \right| \right)^2 + \left(\left| c_{ij} - c_j^* \right| \right)^2 \right\} \right)^{\frac{1}{2}} \quad (4)$$

($i = 1,2, \ldots, m$)

Some hybrid vector similarity measures and weighted hybrid vector similarity measures for both single valued and interval neutrosophic sets can be found on [34].

In real world problems, sometimes we can use linguistic terms such as 'good ', 'bad ' to describe the state or performance of an alternative and cannot use some numbers to express some qualitative information [35].

The 2-tuple linguistic model could be used[36] for qualitative information but lack indeterminacy. In this paper the concept of linguistic variables [37] is used by mean of single valued neutrosophic numbers [32]for developing a framework to decision support due to the fact that provides adequate computational models to deal with linguistic information [37] in decision allowing to include handling of indeterminate and inconsistent in project selection .

2.3 AHP Method

The Analytic Hierarchy Process (AHP) is a technique created by Tom Saaty [38] for making complex decision based. The steps for implementing the AHP model are [39]:

1. Decompose the problem into a hierarchy of goal, criteria, sub-criteria and alternatives.
2. Collect data from experts or decision-makers corresponding to the hierarchic structure, in the pairwise comparison of alternatives on a qualitative scale.
3. Assign a weight to criteria and sub-criteria.
4. Calculate the score for each of the alternatives through pairwise comparison.

One of the great advantages of the analytic hierarchy process is simplicity. Regardless of how many criteria are involved in making the decision, the AHP method only requires comparing a pair of elements. Another important advantage is that it allows the inclusion of tangible variables such as , cost, time as well as intangible ones as criteria such as, comfort, beauty in the decision [40].

Weighting criteria is important in decision making problems in some example weight are given but no method is explained [13] or [14]. In this work the integration of AHP model with project selection allows to assign a weight to each of the criteria involved this more in line with reality and therefore more reliable.

3 Proposed framework.

Our aim is to develop a framework for project selection based on SVN numbers and AHP method. The model has been adapted from the common decision scheme that was showed in Fig. 1.

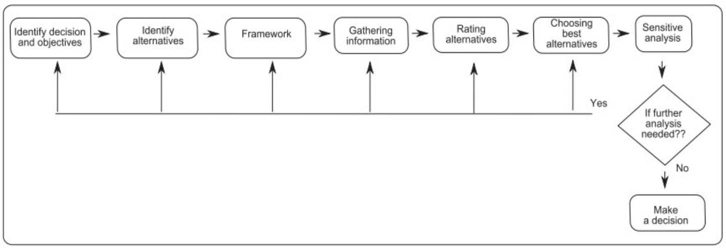

Figure 1: Decision resolution scheme.

The model consists of the following phases (fig. 2).

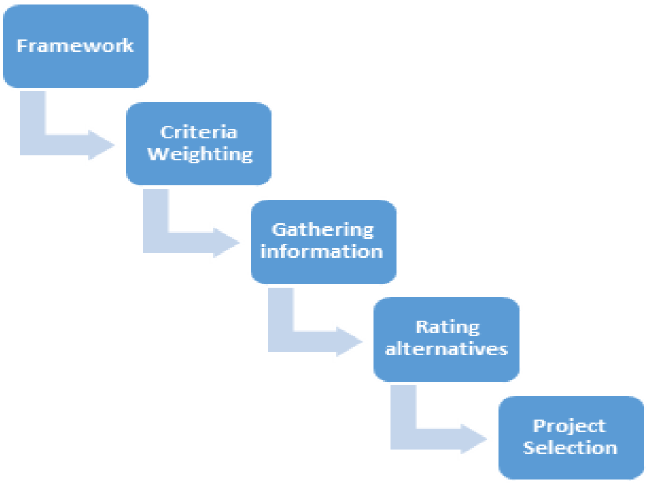

Figure 2: A framework for project selection.

The proposed framework is composed of five activities:

- Framework
- Criteria weighting
- Gathering information,
- Rating alternatives
- Project selection.

Following, the proposed decision method is described in further detail, showing the operation of each phase

Framework

In this phase, the evaluation framework, the decision problem of project selection is defined. The framework is established as follows:

- C=$\{c_1, c_2, \ldots, c_n\}$ with $n \geq 2$, a set of criteria.
- E=$\{e_1, e_2, \ldots, e_k\}$ with $k \geq 1$, a set of experts.
- $X = \{x_1, x_2, \ldots, x_m\}$ with $m \geq 2$, a finite set of information technologies projects alternatives.

Criteria and experts might be grouped. The set of experts will provide the assessments of the decision problem.

Criteria Weighting

The first step in an AHP analysis is to build a hierarchy, also called decision modeling and it simply consists of building a hierarchy to analyze the decision.
Second step in the AHP process is to derive the relative weights for the criteria. It is called relative because the obtained criteria priorities are measured with respect to each other using Saaty's pairwise comparison scale (Table I).

TABLE I. TABLE I. SAATY'S PAIRWISE COMPARISON SCALE

Verbal judgment	Numeric value
Extremely important	9
	8
Very Strongly more important	7
	6
Strongly more	5

important	4
Moderately	3
more important	2
Equally important	1

Based on the responses of the experts, a preference matrix is derived for each respondent for each the criteria involved in the decision with the following format.

TABLE II. PAIRWISE COMPARISON MATRIX OF CRITERIA

Goal	*Criteria1*	*Criteria 2*	...	*Criteria n*
Criteria 1				
Criteria 2				
...				
Criteria n				

Cells in comparison matrices will have a value from the numeric scale shown in Table I, to reflect relative preference also called intensity judgment or simply judgment in each of the compared pairs [40].

If a_{ij} is the element of row i column j of the matrix, then the lower diagonal is filled using the following formula:

$$a_{ji} = \frac{1}{a_{ij}} \quad (5)$$

Note that that all the element in the comparison matrix are positive, $a_{ij} > 0$.

For calculating criteria weights the approximate method is considered simplest. Approximate method for AHP requires the normalization of the comparison matrix adding the values in each column. Next, each cell is divided by the total of the column.

Another approach is proposed in [41]based on row geometrics means of the pairwise comparison matrix:

$$w_i = \frac{\sqrt[n]{\prod_{j=1}^{n} a_{ij}}}{\sum_{i=1}^{n} \sqrt[n]{\prod_{j=1}^{n} a_{ij}}} \quad (6)$$

Saaty [42] proposed the eigenvalue method by calculating the principal eigenvectorw'. This vector corresponds to the largest eigenvalue, λmax of matrix D, as follows:

$$Dw' = \lambda_{max} w' \quad (7)$$

Some discussions have been developed but there is no clear conclusion about the better method for weight determination.

Once judgments have been entered, it is necessary to check that they are consistent. AHP calculates a consistency ratio (CR) comparing the consistency index (CI) of the matrix with our judgments versus the consistency index of a random-like matrix (RI) [43]:

$$CR = \frac{CI}{RI} \quad (8)$$

A consistency ratio (CR) of 0.10 or less is acceptable to continue the AHP analysis. If the consistency ratio is greater than 0.10, it is necessary to revise the judgments to locate the cause of the inconsistency and then correct it [43].

Gathering information

In this phase, each expert, e_k provides the assessments by means of assessment vectors:

$$U^K = (v_{ij}^k, i = 1, \dots, n,\ j = 1, \dots, m) \quad (9)$$

The assessmentv_{ij}^k, provided by each experte_k, for each criterion c_i of each project alternative x_j, is expressed using SVN numbers.

Since humans might feel more comfortable using words by means of linguistic labels or terms to articulate their preferences, the ratings of each alternative with respect to each attribute are given as linguistic variables characterized by SVN-numbers in the evaluation process.

Granularity of the linguistic assessments could vary according to the uncertainty and the nature of criteria as well as the background of each expert.

Rating alternatives

The aim of this phase is to obtain a global assessment for each alternative. Taking into account the previous phase, an assessment for each alternative is computed, using the selected solving process that allows to manage the information expressed in the decision framework.

Information is aggregated selecting aggregation operators in order to obtain a global assessment for each alternative that summarizes its gathered information.

In this case alternatives are rated according to single valued neutrosophic weighted averaging (SVNWA) aggregation operator was proposed by Ye [44] for SVNSs as follows[10]:

$$F_w(A_1, A_2, \dots, A_n) = \langle 1 - \prod_{j=1}^{n}\left(1 - T_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(I_{A_j}(x)\right)^{w_j}, \prod_{j=1}^{n}\left(F_{A_j}(x)\right)^{w_j} \rangle \quad (10)$$

where $W = (w_1, w_1, \dots, w_n)$ is the waiting vector of $A_j\ (j = 1, 2, \dots, n)$, $w_n \in [0, 1]$ and $\sum_j^n w_j = 1$.

or the single valued neutrosophic weighted geometric averaging aggregation operator (G_w) [44] :

$$G_w(A_1, A_2, \dots, A_n) = \langle 1 - \prod_{j=1}^{n} T_{A_j}(x)^{w_j}, \prod_{j=1}^{n} I_{A_j}(x)^{w_j}, \prod_{j=1}^{n} I_{A_j}(x)^{w_j} \rangle \quad (11)$$

where $W = (w_1, w_1, \dots, w_n)$ is the waiting vector of $A_j\ (j = 1, 2, \dots, n)$, $w_n \in [0, 1]$ and $\sum_j^n w_j = 1$.

Weights (w) in both cases are obtained by the AHP method in phase 2.

Project Selection

In this phase of the alternatives are ranked and the most desirable one is chosen by the score function [45, 46].According to the scoring and accuracy functions for SVN-sets, a ranking order of the set of the alternatives can be generated [47]. Selecting option(s) with higher scores.

For ordering alternatives a scoring function is used [48]:

$$s(V_i) = 2 + T_i - F_i - I_i \quad (12)$$

Additionally an accuracy function is defined 31]:

$$a(V_i) = T_i - F_i \quad (13)$$

And then

1. If $s(Vj) < s(Vi)$, then Vj is smaller thanVi, denoted by $Vj < Vi$
2. If $s(Vj) = s(Vi)$
   a. If $a(Vj) < a(Vi)$, then Vj is smaller thanVi, denoted by $Vj < Vi$
   b. If $a(Vj) = a(Vi)$, then Vj and Vi are the same, denoted by $Vj = Vi$

Another option is to use the scoring function proposed in [32]:

$$s(V_i) = (1 + T_i - 2F_i - I_i)/2 \quad (14)$$

where $s(V_i) \in [-1,1]$.

If $s(Vj) < s(Vi)$, then Vj is smaller thanVi, denoted by $Vj < Vi$

According to the scoring function ranking method of SVN-sets, the ranking order of the set of project alternatives can be generated and the best alternative can be determined.

4 Illustrative Example

In this section, we present an illustrative example in order to show the applicability of the proposed framework for information technologies project selection.

An information technology project is a temporary effort undertaken by or on behalf of an organization that [49]:

- Establishes a new technology-based system or service
- Facilitates a significant business process transformation using technology

- Includes a major change in technology architecture or a system migration beyond that considered as general maintenance, enhancement, or refresh activity

An information technology project typically performs one or more of these functions:

- Develop a new system or service
- Improvements to a system or service
- Improve business processes or introduce new ones
- Build or enhance infrastructure
- Apply new technologies
- Upgrade enterprise applications

In this case study the evaluation framework is compose by an expert evaluate 3 alternatives (information technologies development projects).

x_1: CRM
x_2: ERP
x_3: BI

These projects are described in Table #1.

TABLE III. PROJECTS OPTIONS

Id	Name	Description
1	CRM.	Custumer Relation Management Software
2	ERP	Enterprise Relationship Managemet Software
3	BI	Business intelligence System

3 criteria are involved, which are shown below:

c_1: Benefits
c_2: Feasibility
c_3: Cost

In Table 2, we give the set of linguistic terms used for experts to provide the assessments.

TABLE IV. LINGUISTIC TERMS USED TO PROVIDE THE ASSESSMENTS [32]

Linguistic terms	SVNSs
Extremely good (EG)	(1,0,0)
Very very good (VVG)	(0.9, 0.1, 0.1)
Very good (VG)	(0.8,0,15,0.20)
Good (G)	(0.70,0.25,0.30)
Medium good (MG)	(0.60,0.35,0.40)
Medium (M)	(0.50,0.50,0.50)
Medium bad (MB)	(0.40,0.65,0.60)
Bad (B)	(0.30,0.75,0.70)
Very bad (VB)	(0.20,0.85,0.80)
Very very bad (VVB)	(0.10,0.90,0.90)
Extremely bad (EB)	(0,1,1)

Once the evaluation framework has been determined the information about the projects is gathered (see Table 3).

TABLE V. RESULT OF GATHERING INFORMATION

	x_1	x_2	x_3
c_1	MG	EG	MB
c_2	G	MG	M
c_3	MG	MG	G

Using the AHP method the following weights structure (Table IV) was obtained. These are translated into weight vector associated with the criteria W = (0.55, 0.26, 0.19).

TABLE VI. CRITERIA WEIGHTS CALCULATION

Weights

Criteria	c_1	c_2	c_3	**Weights**

c_1	1	3	2	0.55
c_2	1/3	1	2	0.26
c_3	½	½	1	0.19

For rating alternatives an initial aggregation process is developed. Then the aggregated SVN decision matrix obtained by aggregating of opinions of decision makers is constructed by Eq. (10). The result is given in Table V.

TABLE VII. DISTANCE TO THE IDEAL SOLUTION

	Aggregation	Scoring function	Ranking
x_1	(0.53, 0.4, 0.56)	1.73	2
x_2	(0.43, 0.0, 0.0)	2.43	1
x_3	(0.66, 0.52, 0.63)	1.62	3

According the scoring function, three alternatives are ranked as: $x_2 \succ x_1 \succ x_3$.

5 Conclusions.

Recently, neutrosophic sets and its application to multiple attribute decision making have become a topic of great importance for researchers and practitioners. In this paper a new model project selection based on SVN-number applied allowing the use of linguistic variables. The AHP method is included and allows a correct weighting of different criteria involved.

To demonstrate the applicability of the proposal an illustrative example is presented. Our approach has many application project selection that include indeterminacy and the weighting of criteria

Further works will concentrate extending the model for dealing with heterogeneous information. Another area of future work is the developing of new aggregation models based like the prioritized ordered weighted average operator [50] and the Choquet integral by considering the correlations between the attributes [51] .

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