Neutrosophic Sets and Systems

Volume 32 Article 22

3-22-2020

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Neutrosophic Sets and Systems, Vol. 32, 2020
University of New Mexico

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Abstract. Usually, companies confront the difficulty to make the best decision about the way to invest their recourses in different project alternatives. The company acquires competitive advantages when their software development projects are well evaluated and correctly selected. Selecting projects in the Information Technology field presents challenges in many senses; e.g., the difficulty that entails assessing intangible benefits, projects are interdependent and companies impose self-constraints. In addition, the framework to make the decision is generally uncertain with many unknown factors. This paper aims to propose a model that integrates methods, techniques and tools such as the Balanced Scorecard Model, neutrosophic Analytic Hierarchy Process and zero-one linear programming. The proposed model is designed to select the best portfolio of Information Technology projects, it overcomes the obstacles mentioned above and can be coherently incorporated in the strategic plan process of any company. In addition, it eases the course of experts' decision making, because it is based on Neutrosophy and hence incorporates the indeterminacy term.

Keywords: Information Technology Project, Balanced Scorecard Model, Neutrosophic Analytic Hierarchy Process, zero-one linear programming.

1. Introduction

According to the guide to the project management body of knowledge (PMBOK) [1], "project management is the application of knowledge, skills, tools and techniques to projects activities to meet project requirements". The guide to the PMBOK also makes reference to the multiple project management. Some authors acknowledge that sometimes exist missing or vaguely defined processes in any commercial corporations; some of them are the coordination in a multi-project environment and the strategic processes [2].

Later on, Project Management Institute published in detail additional standards for the Programs and Portfolio management [1, 3, 4]. A Program is defined as a related group of projects, which are coordinately managed to obtain benefits and controls, under the constraint that these benefits and controls would not be available, in the case they were managed individually.

On the other hand, a Project Portfolio is a group of projects performed during a certain time span and which share common resources. Some kinds of relationships that can exist among the projects are complementariness, incompatibility and synergies, which are derived from the division of costs and benefits obtained from the performance of more than one project simultaneously [5]. See schematized of an example in Fig. 1.

The foundations of project portfolio management have been developing since the seventies. Its roots can be found in the theory of Harry Markowitz, which deserved the Nobel Prize in Economic Sciences. He shared this award with Merton H. Miller and William F. Sharpe, for their work in the field of financial economics theory. Its basic contribution is the "portfolio choice theory". He proposed a model for the choice of a portfolio of securities in conditions of uncertainty in which it reduced it to a two-dimensional dilemma: the expected income and the variance.

Nevertheless, some authors point out that significant differences exist between the theory of project portfolio management and Markowitz's theory [6, 7].

Four of the six responsibilities in project portfolios management, which were emphasized by Kendall and Rollins, are the following, [8]:

- To determine a suitable combination of projects such that the company's goal could be achieved.
- To attain an adequate balance in the portfolio, where the combination of projects has an adequate balance between risks and rewards, research and development and so on.
- To assess the possible existence of new opportunities for the present portfolio, taking into account the company's capacity for execution.
- To provide information and recommendations for decision makers at every level.

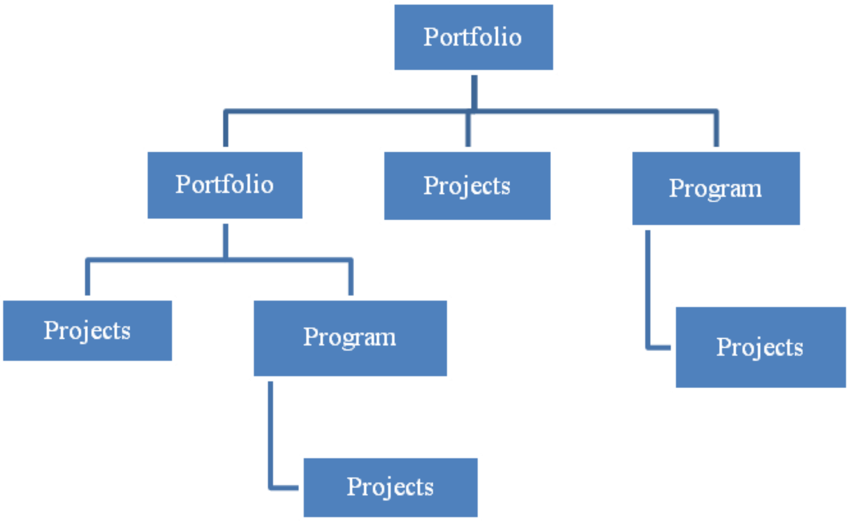

Figure 1: Scheme of a possible Portfolio-Program-Project relationship

The project portfolio management is inherently strategic, it is more related to efficacy (to perform the adequate project) than the efficiency (to execute the project correctly). It should avail a framework of work for assessing decisions about to invest, maintain and remove [9].

According to the reports of A. T. Kearney, which is an American global management consulting firm that focuses on strategic and operational CEO-agenda issues, the plan in investment projects have barely changed in enterprises since the 1920s, see [10]. The forthcoming necessities of the company are not forecasted, instead, decision makers assign the budget that they consider sufficient to carry out each project individually, no doubt this is a drawback, see [11, 12]. The second drawback is when decision makers do not identify potential synergies that could exist among the projects and therefore, unexpected increases in project costs could arise.

Kaplan and Norton introduced a framework of work to measure the effectiveness of a company; they called it Balanced Scorecard (BSC). This model integrates four perspectives, namely, financial, customer, business process and learning and growth [13]. Additionally, this is a way to display the strategies inside the company. Particularly, BSC is useful to select measures that guarantee the balance in project portfolios of Information Technologies [6].

The relationship existing between strategy and Project Management is a subject that has considerably evolved during the years pass. One example is project portfolio management, consisting of a close relationship that connects strategy with Project Management by selecting and prioritizing those projects which satisfy strategic objectives. Both selection and prioritization are based on criteria that could perfectly coincide with indicators proper of the Balanced Scorecard model designed for this company [5, 8].

The economic importance of Information Technology projects is evident. Frequently, Information Technology projects represent a significant portion of the set of projects inside a company [2]. In the present-day, the hardware is considered as a commodity, whereas software provides the major part of a computational system [14].

Information Technology (IT) management is a subject that has quickly grown since the very near past. Pells in [15] presented the factors which have repercussions on the growth of the IT projects management, they are the following:

- The massive investment in IT all over the world.
- The natural orientation of the project management toward the IT industry.
- The fast change of technologies.
- Failures in IT projects.
- The arrival of the Information Era.
- IT embraces every industry, company and project.

When these factors are taken into consideration as a whole, they conduce to other important trends and developments in the fields of project management, project portfolio management and complex project management.

In this present research, the authors used a balanced scorecard model as a tool to determine the coherence of the project with company's strategy, particularly considering their perspectives. Moreover, the criteria to determine the project feasibility have been included. The proposed model is based on the balanced scorecard model, neutrosophic analytic hierarchy process and zero-one linear programming.

The analytic hierarchy process (AHP) was created by Aczél et al. [16]. It is a well-known multicriteria decision-making technique founded on mathematics and cognitive psychology. This technique has been widely applied to make decisions in complex situations.

Buckley in [17, 18] designed a fuzzy hierarchical analysis, where the crisp decision ratio of the classical AHP is substituted by a fuzzy ratio represented by a trapezoidal membership function. This approach introduces uncertainty and imprecision from the fuzzy viewpoint.

Abdel-Basset et al. in [19] designed a neutrosophic AHP-SWOT model, based on neutrosophic sets, where a neutrosophic set is a part of neutrosophy that studies the origin, nature and scope of neutralities, as well as their interactions with different ideational spectra [20]. The neutrosophy included for the first time the notion of indeterminacy in the fuzzy set theory, which is also part of real-world situations. Neutrosophic AHP permits that experts could express their criteria more realistically, by indicating the truthfulness, falseness and indeterminacy of the decision ratio.

This paper aims to present a new mathematical model to select the best information technology projects. In the first step, a balanced scorecard model is applied to establish the criteria selection. The second stage consists in applying a neutrosophic AHP technique, where crisp weights of project importance are output. During this step neutrosophic triangular numbers and the operations among them are used for calculating. These weights of each project's importance are inputs to the third stage. The third stage consists of a zero-one linear programming model for selecting the best projects that satisfy the feasible constraints.

Hybridizing different Multicriteria Decision-Making (MCDM) methods for creating new project selection models have become recurrent in the literature that is why the model proposed in this paper can also be of interest to researches and decision makers. In [21] the state of the art in project selection problem is studied for 60 papers published in the period from 1980 to 2017 and it is concluded that the most popular techniques to perform hybridizations are the Order of Preference by Similarity to Ideal Solution (TOPSIS) and the analytic hierarchy process / analytic network process followed by the VI-

KOR method. For example, in [22] the AHP technique is hybridized with PROMETHEE with the goal of urban renewal project selection. Papers in [23-30] introduce the hybridization of methods and techniques of MCDM within the framework of neutrosophy, obtaining more complete models than those based on fuzzy logic theory because uncertainty in decision-making also incorporates indeterminacy.

In addition that the hybridization of MCDM methods seems to be an inexhaustible source of creating new models for project selection, the model proposed in this paper differs from the rest of the similar ones. This is specifically designed to select information technology projects, which is why the Balanced Scorecard is included to guide the managers on which aspects to test in decision-making. BSC is so far infrequent in the published papers on hybridization. The AHP technique avoids bias in decision making due to the use of the consistency index. zero-one linear programming is the tool used to make the final decision, while neutrosophy is used to model the indeterminacy that decision makers might have. Another advantage of the model is that it allows decision makers to rate based on linguistic terms. To the best of the authors' knowledge, this seems to be the first model for selecting information technology projects by using the hybridization of Balanced Scorecard, neutrosophic AHP and zero-one linear programming, where a scale of linguistic terms serves to evaluate.

This paper is distributed as follows; section 2 contains the main theories used as the basis of this document. The proposed mathematical model is developed in section 3. In section 4 the application of the model is illustrated with an example. Section 5 states the conclusions.

2 Preliminaries

This section exposes the theories used to design the model. It is started with part of the theory of the project portfolio. Further, the authors summarize the AHP technique and neutrosophic set theory. Finally, the main concepts of zero-one linear programming are written.

2.1 Approaches to Portfolio IT Project

An important part of IT projects is related to software development. The difference of software development projects with respect to other engineerings, e.g., electronic engineering, is that the former one imposes additional challenges to project management, mainly due to the particular characteristics of software [30] and these characteristics are the following:

- The software is an intangible product.
- The standard software processes do not exist.
- The uniqueness of the large scale projects of software developments.

When a computer product will be developed, or an information system, or any other modifications, in that case, the elaboration of an innovative project is needed for planning and executing the introduction of this product inside the company. Technological innovation projects are elaborated to introduce scientific results obtained from scientific creation. This is related to applied researches, technological developments; and the commercialization of novel technologies, products, systems and processes. This is the final stage in the cycle of science-technology-production [31].

Literature had paid attention to project selection, see [2, 21-34], especially for research and development projects (R&D), see [35, 36]. One main difference exists between IT and (R&D) projects, it is that projects interdependence in the former has elevated importance [1, 3, 4]. Moreover, two IT projects can share identical code sections or hardware.

The project selection process in general, including IT projects, is a very complex process that is influenced by several factors. One key aspect of IT control is the prioritization of investments. Projects have to be assessed as an investment viewpoint, by having as a goal to analyze the project capacity for maximizing the company's value [32].

One of the criteria to approve the start of one project would be to determine its possibility of success and impact; evidently, most companies cannot start simultaneously every project. The project assessment consists of gathering pertinent information in the end to facilitate the project selection process and to determine the value of every project [8, 37]. The closing phases assessment allows us to build a base of knowledge that shall be communicated during the organization's continuous learning

[6].

One of the goals in portfolio management is to maximize the portfolio value, by carefully assessing those projects and programs which could be included in the portfolio and also to opportunely exclude those of them which do not fulfill the portfolio strategic objectives [38]. IT portfolio management is basically a selection process to locate resources to develop/maintain those projects that better satisfy strategic objectives [39].

There exist a number of difficulties in evaluating projects. Rebaza points out, referring to computer projects that in most cases the projects are evaluated according to cost-benefit criteria [40]. The task of evaluating projects is not simple and involves many difficulties, some of them are methodological. These difficulties include the following:

- Lack of information availability,
- Lack of qualified staff for evaluation,
- Lack of evaluation processes in the company.
- Use of limited criteria for evaluation.

Project selection methods are used to determine which project the organization will select. Generally, these methods are divided into four major categories according to Bonham, see [5]:

A. Mathematical programming—Integer programming, linear programming, nonlinear programming, goal programming and dynamic programming
B. Economic models—IRR, NPV, PB period, ROI, cost-benefit analysis, option pricing theory, the average rate of return and profitability index;
C. Decision analysis—Multiattribute utility theory, decision trees, risk analysis, analytic hierarchy process, unweighted 0–1 factor model, unweighted (1 – n) factor scoring model and weighted factor scoring model;
D. Interactive comparative models—Delphi, Q-sort, behavioral decision aids and decentralized hierarchical modeling.

A relatively recent trend in the information technology area is value-based software engineering (VBSE) [41]. VBSE is considered as part of the life cycle of software engineering management activities such as the development of the Business Case, project evaluation, project planning etc, which have so far been considered peripheral. The VBSE aims to guide proposals and solutions based on the maximization of the value provided.

Any decision to construct (or re-engineering) a software system should be guided by its "value" ([42]). Thus, a system brings more "value" to their users if it provides greater benefits, either in terms of return on investment (ROI), social benefits, reduced management costs, strategic advantages, or any other aspect. As can be assumed, the quantification of all these types of benefits is complex [42].

Sometimes intangible benefits, such as learning and opportunity for growth, are the fundamental sources of value. As a result, other indicators to be taken into consideration for investment have emerged. An example of this is the social return on investment [42], which seeks to capture social values by translating social goals into financial and non-financial measures. Kendal and Rolling ([8]) claim that the more projects that are initiated with insufficient resources, the fewer projects that are completed and the longer each project takes to complete. Surveys indicate that companies with the highest number of project selection criteria are associated with better performance ([6]).

Bonham [5] proposes a model for project selection based on three phases, viz., strategic analysis, individual project analysis (maximization) and portfolio selection (balance). He also noted the importance of analyzing the interdependence between projects.

Bergman and Mark ([2]) present a way to issue the problem of project selection using the requirement analysis to better inform each project option. As a project option develops through the selection process, its specification of requirements is detailed and refined. Project requirements provide a better technical, economic and organizational understanding of each project.

Value Measuring Methodology (VMM) ([4]) is a methodology for evaluating and selecting initiatives that offer the greatest benefits. Moreover, Rapid Economic Justification ([39]) is a framework developed by Microsoft to decide the value of investments in information technology.

Wibowo notes that existing approaches present the following limitations, see [43]:

- The inability to deal with the subjectivity and the imprecision of the evaluation processes and the selection of information systems projects.
- Failure to properly manage the multidimensional nature of the problem.
- It is very cognitively demanding for the decision-maker.

The model proposed in this paper overcomes all the difficulties specified above, as can be further seen.

2.2 AHP Technique

AHP consists first in designing a hierarchical structure, where the upper elements are more generic than those situated below. The layer on top contains a single leaf, representing the decision goal, the second layer that connected with the goal emerges as a set of leaves representing the criteria and the followed third layer is containing subcriteria and so on. The last bottom layer of this tree contains leaves representing the alternatives. See, Fig. 2.

Consequently, square matrices represent the expert or experts' decision, containing the pair-wise comparison of criteria, subcriteria or alternatives assessment. Aczél et al. in [16] proposed the scale that they considered is the better to evaluate decisions, as can be seen in Tab. 1.

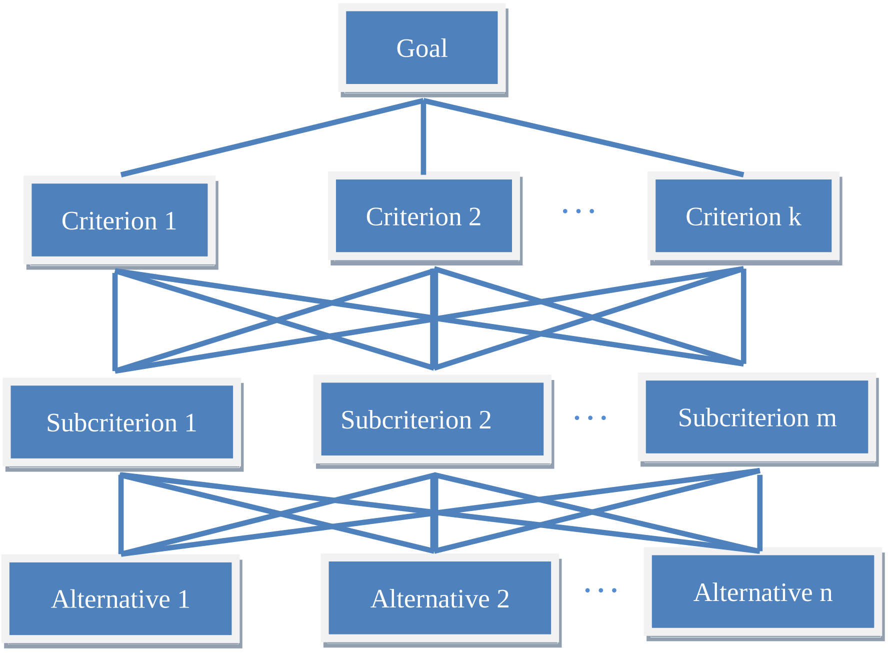

Figure 2: Scheme of a generic tree representing an Analytic Hierarchy Process

Table 1: Intensity of importance according to the classical AHP

The intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment moderately favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	Activity is strongly favored and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments.	When comprise is needed
Reciprocals	If activity *i* has one of the above numbers assigned to it when compared with activity *j*, i.e., number $a \in \{1,2,\cdots,9\}$, then *j* has the reciprocal value when compared with *i*, i.e., value $1/a$.	

On the other hand, Aczél et al. established that the *Consistency Index* (CI) should depend on λ_{max}, the maximum eigenvalue of the matrix. They defined the equation $CI = \frac{\lambda_{max}-n}{n-1}$, where n is the order of the matrix. Additionally, they defined the *Consistency Ratio* (CR) with equation CR = CI/RI, where the Random Index or RI is given in Tab. 2.

Table 2: RI associated with every order.

Order (n)	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Each RI value is an average random consistency index computed for $n \leq 10$ for very large samples. Randomly generated reciprocal matrices were created using the scale 1/9, 1/8, …,1/2, …, 8, 9 and the average of their eigenvalues were calculated. This average is used to form the RI.

If CR≤10% it is considered that experts' evaluation is consistent enough and hence, proceed to use AHP.

AHP aims to score criteria, subcriteria and alternatives and to rank every alternative according to these scores.

AHP can also be used in group assessment. In such a case, the final value is calculated by the weighted geometric mean, which satisfies the inverse requirements [44], see Eq. 1 and 2. The weights are utilized to measure the importance of each expert's criteria, where some factors are taken into consideration like expert's authority, knowledge, effort, among others

$$\bar{x} = \left(\prod_{i=1}^{n} x_i^{w_i}\right)^{1/\sum_{i=1}^{n} w_i} \quad (1)$$

If $\sum_{i=1}^{n} w_i = 1$, i.e., when expert's weights sum one, Eq. 1 transforms in Eq. 2,

$$\bar{x} = \prod_{i=1}^{n} x_i^{w_i} \quad (2)$$

2.3 Neutrosophic sets

Neutrosophic sets extend classical sets, fuzzy sets and intuitionistic fuzzy sets.. Fuzzy set models are based on the degree of membership of an element to a set. It has been applied in many areas of knowledge, including decision making.

Fuzzy set theory was introduced by Lotfi A. Zadeh for the first time at 1965. A fuzzy set consists of the following manners [45, 46]:

Given a Universe of Discourse U containing a set of objects and A being its subset, a membership function is a function T_A: U→[0, 1], defined for every $x \in U$, where $T_A(x)$ is the degree of truth for which x belongs to A.

The intuitionistic fuzzy set theory was introduced by Krassimir T. Atanassov at 1986. An intuitionistic fuzzy set is defined by two membership functions, T_A meaning that x belongs to U and F_A meaning that x does not belong to A. They must satisfy the restriction $T_A(x) + F_A(x) \leq 1$, [47].

On the other hand, Neutrosophic set includes a third membership function I_A, meaning indeterminacy. Thus, a neutrosophic set is a triple of membership functions, T_A, I_A and F_A with no restriction. The inclusion of indeterminacy is a contribution made by Florentin Smarandache [20], which agreed that neutrality and ignorance are also part of the uncertainty. Moreover, he accepts the possibility that truthfulness, indeterminacy and falseness can be simultaneously maximal. Also, he uses the idea of non-standard analysis of Abraham Robinson and he utilizes hyperreal numbers in calculations.

Let us define formally the concept of neutrosophic set.

Definition 2.3.1([20]): The neutrosophic set N is characterized by three membership functions, which are the truth-membership function T_A, indeterminacy-membership function I_A and falsity-membership function F_A, where U is the Universe of Discourse and $\forall x \in U$, $T_A(x), I_A(x), F_A(x) \subseteq]^-0, 1^+[$ and $^-0 \leq inf\ T_A(x) + inf\ I_A(x) + inf\ F_A(x) \leq sup\ T_A(x) + sup\ I_A(x) + sup\ F_A(x) \leq 3^+$.

See that according to the definition, $T_A(x)$, $I_A(x)$ and $F_A(x)$ are real standard or non-standard subsets of $]^-0, 1^+[$ and hence, $T_A(x)$, $I_A(x)$ and $F_A(x)$ can be subintervals of [0, 1]. $^-0$ and 1^+ belong to the set of hyperreal numbers.

Definition 2.3.2([20]): The Single Valued Neutrosophic Set (SVN) N over U is $A = \{< x, T_A(x), I_A(x), F_A(x) > : x \in U\}$, where T_A:U→[0, 1], I_A:U→[0, 1] and F_A:U→[0, 1]. $0 \leq T_A(x) + I_A(x) + F_A(x) \leq 3$.

The Single Valued Neutrosophic (SVN) number is symbolized by

N = (t, i, f), such that $0 \leq t, i, f \leq 1$ and $0 \leq t + i + f \leq 3$.

Definition 3.2.3 ([19, 48]): The single valued triangular neutrosophic number,

$\tilde{a} = \langle (a_1, a_2. a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on $\mathbb{R}$, whose truth, indeterminacy and falsity membership functions are defined as follows:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \leq x \leq a_2 \\ \alpha_{\tilde{a}}, & x = a_2 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_2 < x \leq a_3 \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \beta_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \leq x \leq a_2 \\ \beta_{\tilde{a}}, & x = a_2 \\ \frac{\left(x - a_2 + \beta_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \leq a_3 \\ 1, & \text{otherwise} \end{cases} \quad (4)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{\left(a_2 - x + \gamma_{\tilde{a}}(x - a_1)\right)}{a_2 - a_1}, & a_1 \le x \le a_2 \\ \gamma_{\tilde{a}}\ , & x = a_2 \\ \frac{\left(x - a_2 + \gamma_{\tilde{a}}(a_3 - x)\right)}{a_3 - a_2}, & a_2 < x \le a_3 \\ 1, & \text{otherwise} \end{cases} \quad (5)$$

Where $\alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \in [0, 1]$, $a_1, a_2, a_3 \in \mathbb{R}$ and $a_1 \le a_2 \le a_3$.

Definition 2.3.4 ([19, 48]): Given $\tilde{a} = \langle(a_1, a_2, a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}}\rangle$ and $\tilde{b} = \langle(b_1, b_2, b_3); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}}\rangle$ two single-valued triangular neutrosophic numbers and λ any non-null number in the real line. Then, the following operations are defined:

1. Addition: $\tilde{a} + \tilde{b} = \langle(a_1 + b_1, a_2 + b_2, a_3 + b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle$
2. Subtraction: $\tilde{a} - \tilde{b} = \langle(a_1 - b_3, a_2 - b_2, a_3 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle$
3. Inversion: $\tilde{a}^{-1} = \langle({a_3}^{-1}, {a_2}^{-1}, {a_1}^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}}\rangle$, where $a_1, a_2, a_3 \neq 0$.
4. Multiplication by a scalar number:
$$\lambda\tilde{a} = \begin{cases} \langle(\lambda a_1, \lambda a_2, \lambda a_3); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}}\rangle, & \lambda > 0 \\ \langle(\lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}}\rangle, & \lambda < 0 \end{cases}$$
5. Division of two triangular neutrosophic numbers:
$$\frac{\tilde{a}}{\tilde{b}} = \begin{cases} \langle\left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, a_3 > 0 \ and\ b_3 > 0 \\ \langle\left(\frac{a_3}{b_3}, \frac{a_2}{b_2}, \frac{a_1}{b_1}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, a_3 < 0 \ and\ b_3 > 0 \\ \langle\left(\frac{a_3}{b_1}, \frac{a_2}{b_2}, \frac{a_1}{b_3}\right); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, a_3 < 0 \ and\ b_3 < 0 \end{cases}$$
6. Multiplication of two triangular neutrosophic numbers:
$$\tilde{a}\tilde{b} = \begin{cases} \langle(a_1b_1, a_2b_2, a_3b_3); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_3 > 0 \ and\ b_3 > 0 \\ \langle(a_1b_3, a_2b_2, a_3b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_3 < 0 \ and\ b_3 > 0 \\ \langle(a_3b_3, a_2b_2, a_1b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}}\rangle, & a_3 < 0 \ and\ b_3 < 0 \end{cases}$$

Where $\wedge$ is a t-norm and $\vee$ is a t-conorm.

2.4 Zero-one linear programming

A zero-one linear programming theory solves problems like the following:

$$\begin{aligned} &\text{Max(Min) } f(\boldsymbol{x}) = c_1x_1 + c_2x_2 + \cdots + c_I x_I \\ &\text{Subject to: } x_i \in B \end{aligned} \quad (6)$$

Where, $\boldsymbol{x} = (x_1, x_2, \ldots, x_I)^T$, $x_i \in \{0, 1\}$ and $c_i \in \mathbb{R}$, i = 1, 2, …, I; B is the feasible set of solutions. B can be defined with equalities like $Ax = b$, inequalities like $Ax \le b$ or $Ax \ge b$, a combination of them, or simply an empty set. Where A is an mxI matrix and b is an m-column vector.

This theory solves decision problems, where only two alternatives exist, 1 represents to make the decision and 0 to not make the decision.

Zero-one linear programming problems are part of the Integer programming problems, when $x_i \in \mathbb{Z}$. Despite their seeming simplicity, these problems are NP-complete [49, 50], thus, a good universal algorithm cannot be found to solve them during a rational time of execution. This subject is out of the scope of this paper.

To solve the zero-one linear programming problem let us consider the following equivalent problem:

Max $f(\boldsymbol{x}) = c_1x_1 + c_2x_2 + \cdots + c_I x_I$

Subject to: $x_i \in B$

Where, $\boldsymbol{x} = (x_1, x_2, \ldots, x_I)^T$, $x_i \in \mathbb{Z}$, $x_i \le 1$ and $c_i \in \mathbb{R}$, i = 1, 2, …, I.

3 Neutrosophic model for IT project assessment

The model consists of three main processes, criteria selection, assessment and project portfolio selection. These processes are integrated by means of a Balanced Scorecard Model (BSC), a Neutrosophic Analytic Hierarchy Process (NAHP) and zero-one linear programming, see Fig. 3.

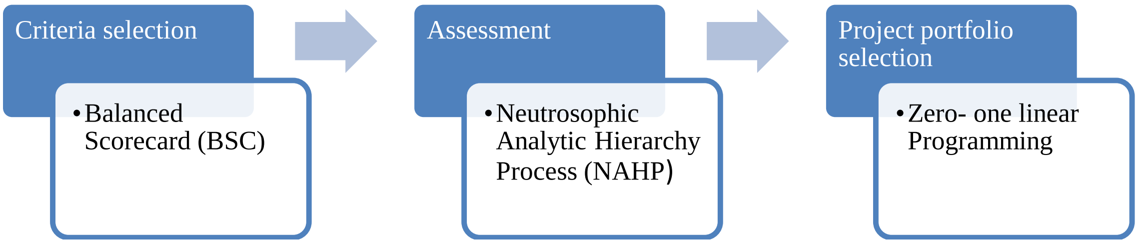

Figure 3: General structure of the model

The first step is to identify a potential group of projects. Next, a criteria selection is made. Some possible criteria are schematized in Fig. 4. This step is based on the BSC, which is an unusual tool for use in project selection. This tool could be incorporated because the proposed model is designed to solve the specific problem of information technology project selection. Fig. 4 can serve as a guide for decision makers on which aspects are the most important for evaluating information technology projects. The second stage of the model is to apply the NAHP. The proposed linguistic scale is based on triangular neutrosophic numbers summarized in Tab. 3, according to the scale defined in [19].

The hybridization of AHP with neutrosophic set theory was used in [19]. This is a more flexible approach to a model of uncertainty in decision making. The indeterminacy is an essential component to be assumed in real-world organizational decisions.

The neutrosophic pair-wise comparison matrix is defined in Eq. 7.

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \quad (7)$$

$\tilde{A}$ satisfies the condition $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$, according to the inversion operator defined in Def. 4.

Abdel-Basset et al. in [19] defined two indices to convert a neutrosophic triangular number in a crisp number. Eqs. 8 and 9 indicate the score and the accuracy respectively as follow:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (8)$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (9)$$

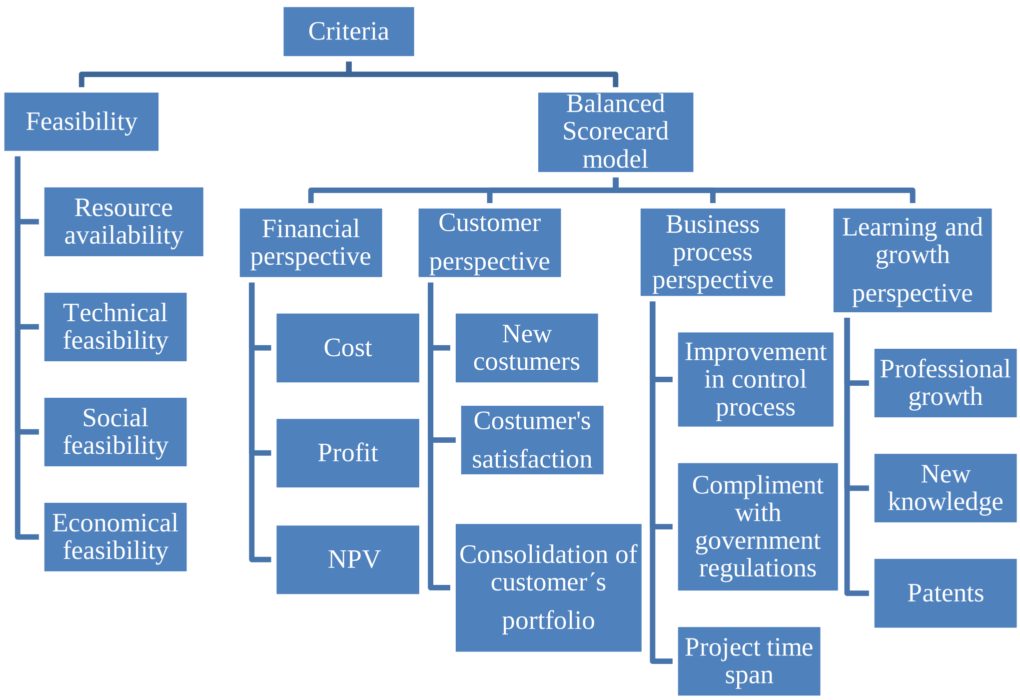

Figure 4: Example of possible project selection criteria

Table 3: Aczél et al.'s scale translated to a neutrosophic triangular scale.

Original scale	Definition	Neutrosophic Triangular Scale
1	Equally influential	$\tilde{1} = \langle(1, 1, 1); 0.50, 0.50, 0.50\rangle$
3	Slightly influential	$\tilde{3} = \langle(2, 3, 4); 0.30, 0.75, 0.70\rangle$
5	Strongly influential	$\tilde{5} = \langle(4, 5, 6); 0.80, 0.15, 0.20\rangle$
7	Very strongly influential	$\tilde{7} = \langle(6, 7, 8); 0.90, 0.10, 0.10\rangle$
9	Absolutely influential	$\tilde{9} = \langle(9, 9, 9); 1.00, 1.00, 1.00\rangle$
2, 4, 6, 8	Sporadic values between two close scales	$\tilde{2} = \langle(1, 2, 3); 0.40, 0.65, 0.60\rangle$ $\tilde{4} = \langle(3, 4, 5); 0.60, 0.35, 0.40\rangle$ $\tilde{6} = \langle(5, 6, 7); 0.70, 0.25, 0.30\rangle$ $\tilde{8} = \langle(7, 8, 9); 0.85, 0.10, 0.15\rangle$

Suppose that the criteria in Fig. 4 and the neutrosophic triangular scale in Table 3 are given, then the steps to apply the NAHP are as follow:

1. To design an AHP tree. This contains the selected criteria, subcriteria and alternatives from the first stage.
2. To create the matrices per level from the AHP tree, according to experts' criteria expressed in neutrosophic triangular scales and respecting the matrix scheme in Eq. 7.
3. To evaluate the consistency of these matrices. Abdel-Basset et al. make reference to Buckley, who demonstrated that if the crisp matrix $A = [a_{ij}]$ is consistent, then the neutrosophic matrix $\widetilde{A} = [\tilde{a}_{ij}]$ is consistent.
4. To follow the other steps of a classical AHP. Here, operations among neutrosophic triangular numbers substitute equivalent operations among crisp numbers in classical AHP.
5. The results obtained from step 4 are the project weights expressed in form of neutrosophic triangular numbers. Now, Eq. 8 is applied to convert, w_1, w_2, …,w_n to crisp weights.
6. If more than one expert make the assessment, then w_1, w_2, …,w_n are replaced by $\overline{w}_1, \overline{w}_2, \cdots, \overline{w}_n$, which are their corresponding weighted geometric mean values, see Eq.1. and Eq. 2.

The obtained weights are not necessarily expressed in normal form, accordingly, there exists the choice to calculate equivalent normalized weights $w'_1, w'_2, \cdots, w'_n$ or $\overline{w}'_1, \overline{w}'_2, \cdots, \overline{w}'_n$, such that $\sum_{i=1}^{n} w'_i = 1$ or $\sum_{i=1}^{n} \overline{w}'_i = 1$. The precedent algorithm can be seen in the form of a flow chart in Fig. 5.

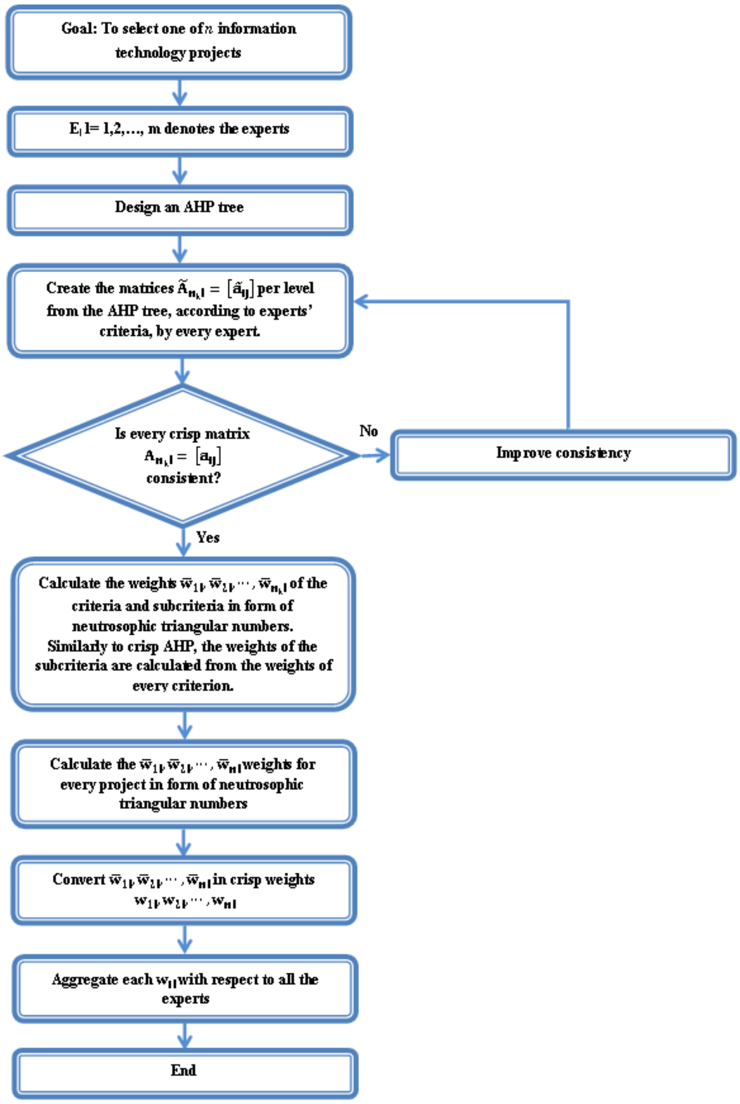

Figure 5: Flow chart of the NAHP algorithm.

Let us remark that in Abdel-Basset's method, $\tilde{A}$ is converted in A and later they continue applying classical AHP to A. In contrast, in the proposed model, data is converted to numeric value only in the last step. This way seems to be more acceptable because imprecision is kept throughout all the calculations.

The third stage consists of the application of a zero-one linear programming problem defined as follows:

$$\text{Max } f(\boldsymbol{x}) = w_1x_1 + w_2x_2 + \cdots + w_nx_n \qquad (10)$$
$$\text{Subject to: } x_i \in B$$

See that the problem defined in Eq. 10 is a particular case of that appeared in Eq. 6.

Where, $x_i = \begin{cases} 1 & \text{, if Project i is selected} \\ 0 & \text{, otherwise} \end{cases}$ and w_i are the weights per project obtained from stage 2.

The purpose of this stage is to select the best projects, which optimally satisfy the constraints imposed by B, considering the weights obtained from NAHP.

4 Application of the model to an example

This section contains an example to illustrate the application of the model to a particular case of project selection. The authors simplified this example significantly for the sake of facilitating readers' comprehension.

Once the BSC model and the first stage are concluded, suppose that two project assessment criteria have been chosen; they are financial perspectives and internal processes, see Fig. 6.

To apply the AHP technique in the second stage, the elements of the problem were hierarchically structured. The goal appears on top of the tree, criteria to evaluate the goal were situated in the intermediate level and alternatives to reach that goal are on the bottom. Where, the goal is to assess IT projects, the intermediate level contains three criteria, viz., cost, project time span and profit and the bottom contain the three potential projects, called Project 1, Project 2 and Project 3. The tree is depicted in Fig. 7.

The expert expresses its criteria by means of the linguistic terms summarized in Tab. 3. The criteria defined in the intermediate level are pair-wise linguistically compared to determine their relative importance to achieve the objective.

Later, neutrosophic evaluations in the third column of Tab. 3 substitute their equivalent linguistic terms. Experts' evaluations can be seen in Tab. 4.

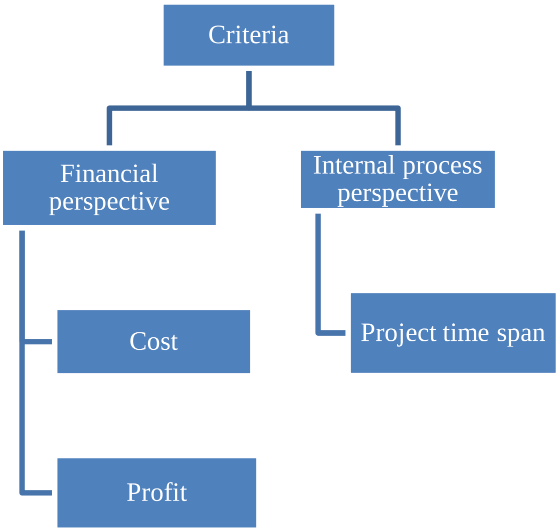

Figure 6: Selected criteria for the example

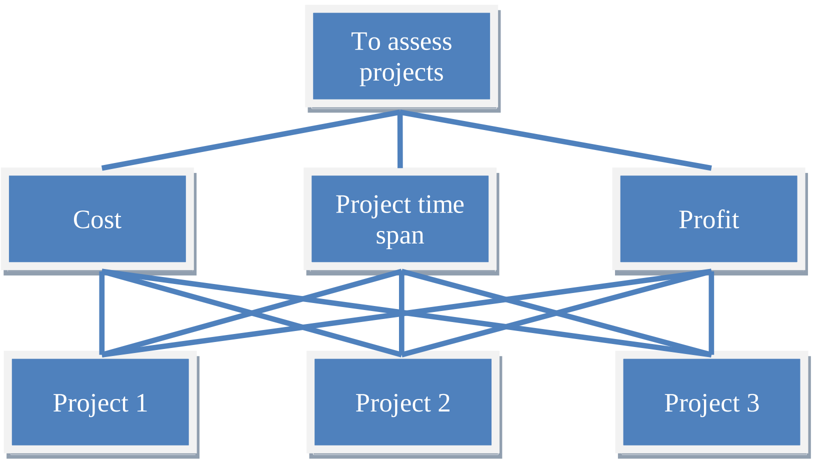

Figure 7: AHP tree of the example

Table 4: Reciprocal matrix corresponding to the second level

	Cost	Project Time span	Profit
Cost	$\tilde{1}$	$\tilde{2}$	$\tilde{5}^{-1}$
Project time span	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{4}^{-1}$
Profit	$\tilde{5}$	$\tilde{4}$	$\tilde{1}$

See that evaluations contain the uncertainty and imprecision proper of neutrosophic set theory and hence the results are more realistic than those obtained from the classical Aczél et. al.'s AHP technique, now experts can include the indeterminacy term. Also, let us observe that the inverse of the single-valued triangular neutrosophic numbers can be calculated by using the inversion operator defined in Def. 4.

In this example, Cost is assessed with a value between equally and slightly more influential than Project time span, Profit is strongly more influential than Cost and Profit is evaluated between slightly and strongly more influential than Project time span. When the last three criteria comparisons are analyzed, let us note a certain degree of inconsistency, where it is expected that Profit is at least strongly more influential than the Project time span.

To measure the neutrosophic reciprocal matrix consistency, it is sufficient to calculate the CI of the crisp matrix, where $\tilde{a}_{ij}$ is substituted by a_{ij}, according to the theorem proved in [9], which says that given a fuzzy reciprocal matrix of fuzzy numbers $\bar{a}_{ij} = (\alpha_{ij}/\beta_{ij}/\gamma_{ij}/\delta_{ij})$, when choosing $a_{ij} \in [\beta_{ij}, \gamma_{ij}]$, if the matrix $(a_{ij})_{ij}$ is consistent then $(\bar{a}_{ij})_{ij}$ is also consistent.

Now on, the *eig* function coded in Octave 4.2.1 shall be used for estimating λ_{max}, in this case, CI = 9.0404%<10%, i.e., the matrix is consistent.

The values per row are summed and the weights are calculated. The results were summarized in Tab. 5.

Table 5: Sum per row and neutrosophic triangular weights in the second level criteria

	Row sum	Weight
Cost	<(2.17, 3.20, 4.25); 0.40, 0.65, 0.60>	<(0.12, 0.21, 0.36); 0.40, 0.65, 0.60>
Project time span	<(1.53, 1.75, 2.33); 0.40, 0.65, 0.60>	<(0.08 , 0.12, 0.12); 0.40, 0.65, 0.60>
Profit	<(8.00, 10.0, 12.0); 0.50, 0.50, 0.50>	<(0.43, 0.67, 1.03); 0.40, 0.65, 0.60>
Total	<(11.70, 14.95, 18.58); 0.40, 0.65, 0.60>	<(0.63, 1.00, 1.59); 0.40, 0.65, 0.60>

Tabs. 6, 7 and 8 contain reciprocal matrices for the third level and their weights. Where, Tab. 6 is related to the Cost, Tab. 7 with Project time span and Tab. 8 with Profit. The CIs of these matrices are, 5.1558%, 0.53269% and 0.53269%, respectively.

Table 6: Reciprocal matrix of the third level related to Cost and their weights.

	Project 1	Project 2	Project3	Weight
Project 1	$\tilde{1}$	$\tilde{2}$	$\tilde{5}$	<(0.31, 0.50, 0.79); 0.40, 0.65, 0.60>
Project 2	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{5}$	<(0.27, 0.41, 0.63); 0.40, 0.65, 0.60>
Project 3	$\tilde{5}^{-1}$	$\tilde{5}^{-1}$	$\tilde{1}$	<(0.07, 0.09, 0.12); 0.40, 0.65, 0.60>

Table 7: Reciprocal matrix of the third level related to Project time span and their weights.

	Project 1	Project 2	Project3	Weight
Project 1	$\tilde{1}$	$\tilde{5}^{-1}$	$\tilde{2}^{-1}$	<(0.09, 0.13, 0.23); 0.40, 0.65, 0.60>
Project 2	$\tilde{5}$	$\tilde{1}$	$\tilde{2}$	<(0.35, 0.61, 1.02); 0.40, 0.65, 0.60>
Project 3	$\tilde{2}$	$\tilde{2}^{-1}$	$\tilde{1}$	<(0.14, 0.26, 0.51); 0.40, 0.65, 0.60>

Table 8 Reciprocal matrix of the third level related to Profit and their weights.

	Project 1	Project 2	Project3	Weight
Project 1	$\tilde{1}$	$\tilde{5}$	$\tilde{2}$	<(0.35, 0.61,1.02); 0.40, 0.65, 0.60>
Project 2	$\tilde{5}^{-1}$	$\tilde{1}$	$\tilde{2}^{-1}$	<(0.09, 0.13, 0.23); 0.40, 0.65, 0.60>
Project 3	$\tilde{2}^{-1}$	$\tilde{2}$	$\tilde{1}$	<(0.14, 0.26, 0.51); 0.40, 0.65, 0.60>

Table 9: Global weight matrix

	Costs	Project time span	Profits	Global Weight
Project 1	<(0.31, 0.50, 0.79); 0.40, 0.65, 0.60>	<(0.09, 0.13, 0.23); 0.40, 0.65, 0.60>	<(0.35, 0.61, 1.02); 0.40, 0.65, 0.60>	<(0.19, 0.53, 1.36); 0.40, 0.65, 0.60>
Project 2	<(0.27, 0.41, 0.63); 0.40, 0.65, 0.60>	<(0.35, 0.61, 1.02); 0.40, 0.65, 0.60>	<(0.09, 0.13, 0.23); 0.40, 0.65, 0.60>	<(0.10, 0.25, 0.59); 0.40, 0.65, 0.60>
Project 3	<(0.07, 0.09, 0.12); 0.40, 0.65, 0.60>	<(0.14, 0.26, 0.51); 0.40, 0.65, 0.60>	<(0.14, 0.26, 0.51); 0.40, 0.65, 0.60>	<(0.08, 0.22, 0.63); 0.40, 0.65, 0.60>
Criterion Weight	<(0.12, 0.21, 0.36); 0.40, 0.65, 0.60>	<(0.08, 0.12, 0.12); 0.40, 0.65, 0.60>	<(0.43, 0.67, 1.03); 0.40, 0.65, 0.60>	

Tab. 9 contains the global weight matrix, which is calculated similarly to the crisp case, where the algebra of crisp values is substituted by its equivalent neutrosophic one.

Now, let us calculate crisp global weights of projects applying Eq. 8 to elements in Tab. 9 and normalizing, they are 0.52658 for Project 1, 0.23797 for Project 2 and 0.23545 for Project 3.

Evidently, according to the obtained weights, the projects can be ranked in the following order, Project 1 $\succ$ Project 2 $\succ$ Project 3.

Additionally, in the third stage, if the decision-makers have to make the choice about what projects should be carried out, which satisfies some constraints, the precedent weights can be used as inputs in the optimization problem.

Suppose the manager counts on a total budget of \$9000. In case of approval, \$3000 must be spent in Project 1, \$3500 in Project 2 and \$5000 in Project 3. As well, the total possible number of man-hour is 1100 and it is known that Project 1 needs 1000, Project 2 needs 200 and Project 3 needs 700.

Then, none, one, two or all of the three projects can be selected, always that they satisfy the restrictions imposed on the problem. Our goal is to optimize this selection, i.e., the project or projects which can be simultaneously carried out have to be selected and then to maximize the benefits.

Formally, let us define three variables x_i, i = 1, 2, 3 as follows:

$$\mathrm{x_i} = \begin{cases} 1 & \text{, if Project i is selected} \\ 0 & \text{, otherwise} \end{cases}$$

Let us divide the data by their upper bounds for calculating with dimensionless magnitudes. Hence, the mathematical problem is the following:

Max $\mathrm{f}(\boldsymbol{x}) = w_1x_1 + w_2x_2 + w_3x_3$

Subject to:

$(3000/9000)x_1 + (3500/9000)x_2 + (5000/9000)x_3 \leq 1$ (Budget constraint)

$(1000/1100)x_1 + (200/1100)x_2 + (700/1100)x_3 \leq 1$ (Man-hour constraint)

w_1 = 0.52658, w_2 = 0.23797 and w_3 = 0.23545 are the previously calculated project weights.

This is a problem of zero-one linear programming. The best solution is **x** = (1, 0, 0), i.e., the best option is to only select Project 1.

Conclusion

To select appropriately an information technology project is generally a complex task and at the same time an unavoidable one because this kind of project is essential for many companies. One of the difficulties arisen by decision makers is the environmental uncertainty and limitations of the existent assessment systems. In this paper, the neutrosophy theory was chosen, which allows us to deal with uncertainty and imprecision for IT project selection. Analytic hierarchy process is the technique for making complex decisions. Then, the proposed model is based on a neutrosophic analytic hierarchy process. This technique was complemented with a balanced scorecard model for determining the IT selection criteria and zero-one linear programming to make the best feasible choice of projects. Finally, an example was used for illustrating the advantages that were obtained from integrating these four tools. It is necessary to emphasize that this model is unique to the set of information technology project selection models, as it was reviewed by the authors in the literature on that subject and it is particularly adjusted for solving the problem of IT project selection.

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Received: Oct 2, 2019. Accepted: Mar 17, 2020