SELECCIÓN DE UN PROYECTO DE INNOVACIÓN TECNOLÓGICA MEDIANTE LA TÉCNICA TOPSIS DIFUSO INTUICIONISTA

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SELECTION OF A TECHNOLOGICAL INNOVATION PROJECT THROUGH THE INTUITIONISTIC FUZZY TOPSIS TECHNIQUE

ABSTRACT:

This article presents the evaluation of Technological Projects (TP) of innovation in a transnational company of the automotive industry located in Cd Juarez -Mexico with de purpose of selection the best project through the intuitionistic fuzzy TOPSIS technique. The alternatives are the projects in the production areas of tube bending (A_1), tube flaring (A_2) and riveting of tube (A_3) in the line of plastic harnesses /vacuum line used in the transmission of the car. Therefore, experts are integrated into a work team and express their opinions in linguistic terms represented by intuitionistic fuzzy numbers. The criteria established for the evaluation are: the initial investment (x_1), the increase in production (x_2), the period of recovery of the investment (x_3), the execution capacity (x_4), the ecological impact (x_5) and the experience of the suppliers (x_6). The technique based on the six established criteria, shows that the project A_2 tube flared is the best option for the company to carry out the technological innovation project.

Keywords: Intuitionistic Fuzzy TOPSIS, technological project.

RESUMEN:

Este artículo presenta la evaluación de proyectos tecnológicos (PT) de innovación en una empresa transnacional del giro automotriz ubicada en Cd Juárez, México, para seleccionar el mejor proyecto mediante la técnica de TOPSIS difuso intuicionista. Las alternativas son los proyectos en las áreas de producción de doblado de tubo (A_1), abocinado de tubo (A_2) y remachado de tubo (A_3) en la línea de arneses de plástico /línea de vacío utilizado en la transmisión del automóvil. Para la evaluación se integra un equipo con personal interdepartamental y expreso sus opiniones en términos lingüísticos representados por números difusos intuicionistas. Los criterios establecidos para la evaluación son: la inversión inicial (x_1), el incremento en la producción (x_2), el periodo de recuperación de la inversión (x_3), la capacidad de ejecución (x_4), el impacto ecológico (x_5) y la experiencia de los proveedores (x_6). La técnica con base a los seis criterios establecidos, indica que el proyecto A_2 abocinado de tubo es la mejor opción para que la empresa invierta en el proyecto de innovación.

Palabras clave: TOPSIS difuso intuicionista, proyecto tecnológico

1– INTRODUCTION

Technology innovation is a process joining a market opportunity or a necessity to a technological equipment, product or process, with the purpose is its production and commercialization, a new business [1]. The new businesses based on technology projects have high scientific knowledge contents and are devoted to the improvement of technologies, in order to enhance the companies' competitiveness, in México, the innovation policy is based on the support to this type of projects [2].The Mexican government through the National Council for Science and Technology, (CONACYT) deploys the Program for Innovation Boost (PEI), promoting the development of innovation projects, as a strategy for the enhancement of competitiveness. Specifically, through joint investments for industrial research, innovation and technology improve the national economy [3].

To obtain government funding, projects have to present four characteristics, technical quality, market potential, implementation feasibility and linkage of company with suppliers, higher education institutions and research centres [3]. For the purpose of this project, the criteria considered for the analysis is taken form the literature. Regarding the technical quality, it is evaluated by the investment [4, 5, 6], the relevance, the innovative contents and the innovation merit [7], the consistency activities-cost [5], the strategic alignment [8]. Regarding market potential, it may be evaluated by three criteria, commercial strategy [4], the project impacts [5,8] and intellectual property [7]; the feasibility can be evaluated by the profitability [4,6], and risk by [5]; while the execution capacity is measured by [8,9]; Budget [6]; the development of human resources [3]; the environmental impact [8,9] and regarding extension, the relationship with research centres [3,8], with HEI's, [3] and to suppliers, [8].

The projects are evaluated by the Multi-Criteria Decision Making model, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), selecting the best of the alternative projects, designated as A^* from the set $A = \{A_1, A_2, \ldots A_n\}$, which intrinsic logic is that the best alternative, A^* must have the smaller geometric distance to the ideal, hypothetical alternative, A^+ and at the same time, the biggest geometric distance to the anti-ideal, also hypothetical, A^-, [9].

Regarding the quality of the information, quantitative data, such as costs, time, investment recovery, sales are commeasurable in currency units. The literature is wide in quantitative models [17, 18]. Qualitative information is difficult to measure and might be non-commeasurable, for instance, strategic impact, long term benefits, robustness, flexibility or maintainability are difficult to measure objectively and surely are non-commeasurable. Besides, measurements depend on the theoretical background, the knowledge of the analysts and their function-position, it will be very hard to obtain objective agreements or consensus among a group of people from production, quality, marketing and finances. This imprecisions can be managed with Fuzzy Logic [11]. This theory explains, objectivizes the ambiguity and fuzziness associated to qualitative information and produce satisfactory evaluations [12, 13].

An intuitionistic fuzzy set (IFS) is one whose elements have a certain level of membership, $\mu_{(x)}$, and another of non-membership $v_{(x)}$, this concept has been used profusely and effectively, in the modelling of a wide diversity of problems, soft technologies such as suppliers and portfolio selection [15, 16] and hard technologies, such as photographic cameras, trains and washing machines control.

This article has five sections, section 2 presents a brief explanation regarding IFS's, section 3 describes the technique TOPSIS in fuzzy environments, section 4 is the application of the model in a multi-national company from Ciudad Juarez maquiladora industry, finally, section 5 presents discussion and conclusions.

2. INTUITIONISTIC FUZZY SET –IFS-

Atanassov [14] introduced the IFS concept, this is defined as:
Given a universe E, an IFS A in E is given by:

$$A = (\langle x, \mu_A(x), \nu_A(x) \rangle | x \in E), \quad (1)$$

Where $\mu_A(x) \in [0,1]$ y $\nu_A(x) \in [0,1]$ satisfying $0 \le \mu_A(x) + \nu_A(x) \le 1, \forall x \in E$, y $\mu_A(x), \nu_A(x)$

Are, respectively designated as the degree of membership, and the degree of non-membership of the element x ϵ E in *A*.

Also, $\pi_A(x) = 1 - \left(\mu_A(x) + \nu_A(x)\right)$ is named the degree of indecision of *x* towards *A*, which also represents a degree of uncertainty or indecisiveness.

Each pair $\left(\mu_A(x) + \nu_A(x)\right)$ in *A* is an intuitionistic fuzzy number (IFN), and is denoted by: $\alpha = (\mu_\alpha, \nu_\alpha)$.

Between three IFN's $\alpha = (\mu_\alpha, \nu_\alpha), \alpha_1 = (\mu_{\alpha_1}, \nu_{\alpha_1})$, and $\alpha_2 = (\mu_{\alpha_2}, \nu_{\alpha_2})$, and *n* a scalar, several mathematical operations can be made:

$$\alpha_1 \oplus \alpha_2 = \left(1 - (1 - \mu_{\alpha_1}) \cdot (1 - \mu_{\alpha_2}), \nu_{\alpha_1} \cdot \nu_{\alpha_2}\right). \quad (2)$$

$$\alpha_1 \otimes \alpha_2 = \left(\mu_{\alpha_1} \cdot \mu_{\alpha_2}, 1 - (1 - \nu_{\alpha_1}) \cdot (1 - \nu_{\alpha_2})\right). \quad (3)$$

$$\lambda\alpha = \left(1 - (1 - \mu_\alpha)^\lambda, {\nu_\alpha}^\lambda\right), \lambda > 0. \quad (4)$$

$$\alpha^\lambda = \left({\mu_\alpha}^\lambda, 1 - (1 - \nu_\alpha)^\lambda\right), \lambda > 0. \quad (5)$$

$$\frac{\alpha_1}{\alpha_2} = \left(\frac{\mu_{\alpha_1}(x)}{\mu_{\alpha_2}(x)}, \frac{\nu_{\alpha_1}(x) - \nu_{\alpha_2}(x)}{1 - \nu_{\alpha_2}(x)}\right). \quad (6)$$

In TOPSIS the weighted average and the Euclidian distance [19, 20] are given by:

$$\bar{\alpha} = IFWA(\alpha^1, \alpha^k, \ldots, \alpha^z), \quad = \lambda_1\alpha^1 \oplus \lambda_k\alpha^k \oplus \ldots \oplus \lambda_l\alpha^z, \quad = \left[1 - \prod_{k=1}^{z}\left(1 - \mu_\alpha^{(k)}\right)^{\lambda_k}, \prod_{k=1}^{z}\left(\nu_\alpha^{(k)}\right)^{\lambda_k}\right]. \quad (7)$$

$$d(\alpha_1, \alpha_2) = \sqrt{\sum_{i=1}^{n}\left(\mu_{\alpha_1}(x_i) - \mu_{\alpha_2}(x_i)\right)^2 + \left(\nu_{\alpha_1}(x_i) - \nu_{\alpha_2}(x_i)\right)^2 + \left(\pi_{\alpha_1}(x_i) - \pi_{\alpha_2}(x_i)\right)^2}. \quad (8)$$

3. INTUITIONISTIC FUZZY TOPSIS -IFT-

This section describes the IFT for Multi-Criteria Decision Making. Let $A = (A_1, A_2, \ldots An)$ be a set of alternatives to evaluate and $X = (x_1, x_2, \ldots x_m)$ the set of criteria considered. The evaluation process is given by the following steps:

Step 1. Organize a group of analysts, decision makers (DM's) and establish their relative expertise on the issues. The vector $DM = (dm_1, dm_2, \ldots dm_z)$ represents the importance $DM_k = (k = 1,2,\ldots z)$, which has a value given by a IFN assigned by a linguistic term. Table 1 presents the linguistic terms and the corresponding IFN.

Table 1. Linguistic terms and IFN's for the evaluation of the Decision Makers relative importance

Linguistic Term	IFN (μ,v)
Principiant (B) / Very Low Importance (VU)	(0.10, 0.90)
Practicant (Pr) / Low importance (U)	(0.35, 0.60)
Competent (Pt) / Regular Importance (M)	(0.50, 0.45)
Expert (E) / High Importance (I)	(0.75, 0.20)
Master (M) / Very High Importance (VI)	(0.90, 0.10)

Prepared with information provided by the company

The relative importance of the Decision Maker DM$_k$ = (μ_k, v_k, π_k) is given by eq. 9:

$$\lambda_k = \frac{\left(\mu_k+\pi_k\left(\frac{\mu_k}{\mu_k+v_k}\right)\right)}{\sum_{k=1}^{z}\left(\mu_k+\pi_k\left(\frac{\mu_k}{\mu_k+v_k}\right)\right)}, \quad (9)$$

where $\lambda_k > 0(k = 1, \dots, z), \sum_{k=1}^{z} \lambda_k = 1$.

Step 2. Determine the relative importance of the criteria, where W = (w_1,w_2,…w_m)is the vector containing the criteria weights w_j(j = 1,2,..m), its values are IFN's associated by linguistic terms. Table 1 gives the linguistic terms and the IFN's. The relative importance of the criteria w_j = (μ_j, v_j, π_j) is given by eq. 10:

$$w_j = \frac{\left(\mu_j+\pi_j\left(\frac{\mu_j}{\mu_j+v_j}\right)\right)}{\sum_{j=1}^{m}\left(\mu_j+\pi_j\left(\frac{\mu_j}{\mu_j+v_j}\right)\right)}, \quad (10)$$

where $w_j > 0(j = 1, \dots, m), \sum_{j=1}^{m} w_j = 1$.

Step 3. Build the final decision matrix representing the evaluation of the alternatives A_i (i = 1,2…n). The evaluation of the alternative A_i(i = 1,2…n) with the criteria x_j (j = 1,2,…m) may be represented by a precise number if the criteria x_j (j = 1,2,…l) is considered tangible. In the case x_j (j = l+1, …m) were intangible, tan, the evaluation is given by IFN associated by a linguistic term, as Table 2 presents.

Table 2. Linguistic terms used for the evaluation of the Alternatives

Linguistic Term	IFN (μ, v)
Extremely Bad (EB) / Extremely Low (EL)	(0.10, 0.90)
Very Bad (VB) / Very Low (VL)	(0.10, 0.75)
Bad (B) / Low (L)	(0.25, 0.60)
Medium Bad (MB) / Medium Low (ML)	(0.40, 0.50)
Medium (F) / Medium (M)	(0.50, 0.40)
Medium Good (MG) / Medium High (MH)	(0.60, 0.30)
Good (G) / High (H)	(0.70, 0.20)
Very Good (VG) / Very High (VH)	(0.80, 0.10)
Excelent (E) / Extremely High (EH)	(1.00, 0.00)

** Prepared with information provided by the company*

Results of this step might be a set of precise evaluations $a_j^i (i = 1, \ldots, n)(j = 1, \ldots, l)$ and a set of fuzzy evaluations $\alpha_j^i = (\mu_{\alpha_j^i}, v_{\alpha_j^i})(i = 1, \ldots, n)(j = l + 1, \ldots, m)$ for the same alternative $A_i (i = 1, \ldots, n)$.

The evaluations then are integrated to the final decision matrix. If the group of DM's give their evaluations, then, each will have the own final decision matrix. Then, the matrixes are combined, integrating all of them. This is made by eq. (7), taking into account the importance of each DM (from step 1). This is why the evaluations given by experienced DM's are more important, weigh more in the final decision. This process gives the final decision matrix A_{nxm} (11) containing qualitative and quantitative data:

$$A = ((a\alpha)_{ij})_{nxm} = \begin{bmatrix} a_1^1 & \cdots & a_l^1 & \alpha_{l+1}^1 & \cdots & \alpha_m^1 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ a_1^n & \cdots & a_l^n & \alpha_{l+1}^n & \cdots & \alpha_m^n \end{bmatrix}. \quad (11)$$

Step 4. Calculate the final normalized decision matrix, $\widetilde{A}_{nxm}$.

$$\widetilde{A} = ((\tilde{a}\tilde{\alpha})_{ij})_{nxm} = \begin{bmatrix} \tilde{a}_1^1 & \cdots & \tilde{a}_l^1 & \tilde{\alpha}_{l+1}^1 & \cdots & \tilde{\alpha}_m^1 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_1^n & \cdots & \tilde{a}_l^n & \tilde{\alpha}_{l+1}^n & \cdots & \tilde{\alpha}_m^n \end{bmatrix}_{nxm}. \quad (12)$$

where $\tilde{a}_j^i = \frac{a_j^i}{\sqrt{\sum_{i=1}^n {a^2}_j^i}} (i = 1, \ldots, n)(j = 1, \ldots, l)$ y $\tilde{\alpha}_j^i = \alpha_j^i (i = 1, \ldots, n)(j = l + 1, \ldots, m)$.

Step 5. Calculate the final weighted normalized matrix $\widehat{A}_{nxm}$.

$$\widehat{A} = ((\hat{a}\hat{\alpha})_{ij})_{nxm} = \begin{bmatrix} \hat{a}_1^1 & \cdots & \hat{a}_l^1 & \hat{\alpha}_{l+1}^1 & \cdots & \hat{\alpha}_m^1 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \hat{a}_1^n & \cdots & \hat{a}_l^n & \hat{\alpha}_{l+1}^n & \cdots & \hat{\alpha}_m^n \end{bmatrix}_{nxm}. \quad (13)$$

where $\hat{a}_j^i = w_j \tilde{a}_j^i (i = 1, \ldots, n)(j = 1, \ldots, l)$ y $\hat{\alpha}_j^i = w_j \tilde{\alpha}_j^i (i = 1, \ldots, n)(j = l + 1, \ldots, m)$.

Step 6. Determine the ideal alternative A^+ and the alternative anti-ideal A^-.

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$$A^+ = \left(\left(\max(\hat{a}_j^i) \mid j = 1, \ldots, l \in J^+\right), \left(\min(\hat{a}_j^i) \mid j = 1, \ldots, l \in J^-\right), \left(\max\left(\mu_{\hat{\alpha}_j^i}\right), \min\left(\nu_{\hat{\alpha}_j^i}\right) \mid j = l+1, \ldots, m \in J^+\right), \left(\min\left(\mu_{\hat{\alpha}_j^i}\right), \max\left(\nu_{\hat{\alpha}_j^i}\right) \mid j = l+1, \ldots, m \in J^-\right) \right) \quad (14)$$

and

$$A^- = \left(\left(\min(\hat{a}_j^i) \mid j = 1, \ldots, l \in J^+\right), \left(\max(\hat{a}_j^i) \mid j = 1, \ldots, l \in J^-\right), \left(\min\left(\mu_{\hat{\alpha}_j^i}\right), \max\left(\nu_{\hat{\alpha}_j^i}\right) \mid j = l+1, \ldots, m \in J^+\right), \left(\max\left(\mu_{\hat{\alpha}_j^i}\right), \min\left(\nu_{\hat{\alpha}_j^i}\right) \mid j = l+1, \ldots, m \in J^-\right) \right) \quad (15)$$

where J^+ is associated to the criteria with a positive impact, the beneficial ones, while J^- is related to the criteria with negative impact.

Step 8. Calculate the distance to the ideal alternative A^+ and the distance to the anti-ideal alternative by Euclidian distance, given by eqs. (16) and (17).

$$d(\hat{A}_i, A^+) = \sqrt{\sum_{j=1}^{m}\left(\hat{A}_i(x_j) - A^+(x_j)\right)^2 + \left(\mu_{\hat{A}_i}(x_j) - \mu_{A^+}(x_j)\right)^2 + \left(\nu_{\hat{A}_i}(x_j) - \nu_{A^+}(x_j)\right)^2 + \left(\pi_{\hat{A}_i}(x_j) - \pi_{A^+}(x_j)\right)^2}. \quad (16)$$

$$d(\hat{A}_i, A^-) = \sqrt{\sum_{j=1}^{m}\left(\hat{A}_i(x_j) - A^+(x_j)\right)^2 + \left(\mu_{\hat{A}_i}(x_j) - \mu_{A^+}(x_j)\right)^2 + \left(\nu_{\hat{A}_i}(x_j) - \nu_{A^+}(x_j)\right)^2 + \left(\pi_{\hat{A}_i}(x_j) - \pi_{A^+}(x_j)\right)^2}. \quad (17)$$

where $d(\hat{A}_i, A^+)$ is the distance from alternative $A_i (i = 1, \ldots, n)$ to the ideal alternative A^+, and $d(\hat{A}_i, A^-)$ represents the distance of alternative $A_i (i = 1, \ldots, n)$ to the anti-ideal alternative A^-.

Step 9. Calculate the similarity index to the ideal alternative IS_i.

$$IS_i = \frac{d(\hat{A}_i, A^-)}{d(\hat{A}_i, A^+) + d(\hat{A}_i, A^-)}. \quad (18)$$

where $0 \leq IS_i \leq 1 \ (i = 1, \ldots, n)$.

Step 10. List the alternatives $A_i (i = 1, \ldots, n)$ by the IS_i values in descending order.

4. CASE OF STUDY

The evaluation of several technology projects, for the selection of the best one is made in a large industrial plant dedicated to the manufacture of vacuum harnesses used in automotive transmissions, (Figure 1). Client complaints have been rising and paying thousands of dollars annually in penalty fees. Quality finds rejections in three processes, tube bending, flaring and riveting. Also have risen the solid and liquid discharges, to levels higher than accepted and only 20% of the plastic scrap is recuperated for remanufacturing.

Figure 1. Automotive Plastic Harness

The company is planning the automatization of manufacturing processes and quality inspection, seeking to improve productivity and quality, while reducing the complaints and levels of scrap. Because this represents a high investment, will be applying for financial support from CONACYT' PEI funds, expecting that if the project and the internal evaluation of alternative projects are made with extreme care, it might influence favourably the funding. The company used the common practices based on cost-benefit and recovery of investment to evaluate the alternatives, deciding for alternative 2, expending $ 75,000.00 dollars and with a recovery lapse of 36 months. This decision is compared against the solution given by the IFT model.

The company has three alternative projects in which to invest, one for tube bending (A_1), one for flaring (A_2) and another for riveting (A_3). A team is formed with a process engineer (DM_1), the production manager (DM_2) and the manager of finances (DM_3). The group decided to use the following six criteria:

- Initial investment, (x_1). It is a tangible cost criteria $x_1 \epsilon J^-$, quantitative, measured in Mexican pesos.
- Production increase, (x_2). It is a benefit criteria $x_2 \epsilon J^+$, quantitative, measured in the fraction daily rate increases, a percentage.
- Investment recovery, (x_3). It is a cost criteria $x_3 \epsilon J^-$, quantitative, measured in months.
- Execution capacity, (x_4). It's a benefit criteria $x_4 \epsilon J^+$, intangible, it is evaluated subjectively.
- Environmental impact, (x_5). It is a qualitative benefit criteria $x_5 \epsilon J^+$, it is evaluated subjectively.
- Experience with Suppliers, (x_6). This is a qualitative benefit criteria, $x_6 \epsilon J^+$, to be evaluated subjectively.

The 4,5 and 6 qualitative criteria were considered because of their impact, for instance, the fifth, environmental impact, is related to the size, type and quantity of solid, plastic residues. They are going to the dump or cooling liquids to their traps, vapours are minimal in re-work stations. Preliminarily, also were considered other six factors, the equipment's flexibilities, impact on competitiveness, the friendliness of interphase man-machine and training needs, those factors were not considered in the analysis because the alternate equipment are alike.

Step 1. Let $A = (A_1, A_2, A_3)$ be the set of alternatives to evaluate and $X = (x_1, \ldots, x_6)$ the set of criteria to consider for the evaluation. Organize the group of decision makers, $DM = (dm_1, dm_2, dm_3)$ and determine their relative importance.

$$DM = (M,E,P_t) = [(0.90, 0.10), (0.75, 0.20), (0.50, 0.45)] \quad (19)$$

The corresponding importance of the DM_k is given by eq. (9), obtaining:
$\lambda_1 = 0.4062$, $\lambda_2 = 0.3563$ y $\lambda_3 = 0.2375$, which satisfy $\lambda_k > 0(k = 1,2,3)$, $\sum_{k=1}^{3} \lambda_k = 1$.

Step 2. Determine the relative importance of the criteria. The evaluation of the set of criteria $X = (x_1, x_2, \ldots x_6)$ made by the decision makers is:

$$TD\_X = \begin{bmatrix} I & I & M & I & U & VI \\ VI & VI & I & VI & M & I \\ VI & M & VI & U & U & U \end{bmatrix} \quad (20)$$

The relative importance of the criteria w_j is given by eqs. (9) and (10), obtaining

$w_1 = 0.1945$, $w_2 = 0.1811$, $w_3 = 0.1700$, $w_4 = 0.1780$, $w_5 = 0.0965$ y $w_6 = 0.1798$

satisfying the condition $w_j > 0(j = 1, \ldots, 6)$, $\sum_{j=1}^{6} w_j = 1$
Step 3. Build the final decision matrix of the evaluation of the alternatives $\boldsymbol{A_i (i = 1,2,3)}$.

$$DM_{quantitative} = \begin{pmatrix} 110{,}000 & 20 & 48 \\ 75{,}000 & 30 & 36 \\ 140{,}000 & 25 & 40 \end{pmatrix} \quad (21)$$

The Table 3 presents the evaluations of the DM's for the qualitative criteria

Table 3. Qualitative criteria and evaluations

Decision Maker	**Project**	Execution Capacity	Environmental Impact	Experience w/Suppliers
dm_1	A_1	L	M	H
	A_2	H	H	H
	A_3	VH	H	L
dm_2	A_1	M	M	VH
	A_2	H	H	H
	A_3	VH	M	L
dm_3	A_1	H	H	H
	A_2	VH	H	VH
	A_3	VH	H	L

Table 4 presents are the final decision matrix, containing qualitative and quantitative evaluations.

Table 4. Final Decision Matrix

Project	Criteria					
	x_1	x_2	x_3	x_4	x_5	x_6
A_1	110,000	20	48	(0.4778,0.4000)	(0.5571,0.3393)	(0.7404,0.1562)
A_2	75,000	30	36	(0.7275,0.1696)	(0.7000,0.2000)	(0.7275,0.1696)
A_3	140,000	25	40	(0.8000,0.1000)	(0.6401,0.2560)	(0.2500,0.6000)

Step 4. Calculate the final normalized decision matrix $\widetilde{A}_{nxm}$, table 5 presents this matrix.

Table 5. Final Normalized Decision Matrix

Project	Criteria					
	x_1	x_2	x_3	x_4	x_5	x_6
A_1	0.5694	0.4558	0.6656	(0.4778,0.4000)	(0.5571,0.3393)	(0.7404,0.1562)
A_2	0.3882	0.6838	0.4992	(0.7275,0.1696)	(0.7000,0.2000)	(0.7275,0.1696)
A_3	0.7246	0.5698	0.5547	(0.8000,0.1000)	(0.6401,0.2560)	(0.2500,0.6000)

Step 5. Calculate the final normalized, weighted decision matrix $\widehat{A}_{nxm}$. Table 6 presents this matrix.

Table 6. Final Normalized Weighted Matrix

Project	Criteria					
	x_1	x_2	x_3	x_4	x_5	x_6
A_1	0.1108	0.0826	0.1132	(0.0851,0.0712)	(0.0538,0.0328)	(0.1331,0.0281)
A_2	0.0755	0.1238	0.0849	(0.1295,0.0302)	(0.0676,0.0193)	(0.1308,0.0305)
A_3	0.1410	0.1032	0.0943	(0.1424,0.0178)	(0.0618,0.0247)	(0.0449,0.1079)

Step 6. Determine the alternatives, the ideal A^+ and the anti-ideal A^-.

Criteria x_1 and x_3 are regarded as cost type, J^-; the rest are beneficial, J^+. Taking this into account, both solutions are:

$$A^+ = \big(0.0755,0.1238,0.0849,(0.1424,0.0178),(0.0676,0.0193),(0.1331,0.0281)\big)$$
$$A^- = \big(0.1410,0.0826,0.1132,(0.0851,0.0712),(0.0538,0.0328),(0.0449,0.1079)\big)$$

Step 8. Calculate the Euclidian distances to both alternatives by means of e1s. (16) and (17). Table 7 shows those distances.

Table 7. Distances to the Ideal and Anti-ideal Alternatives

Project	$d(\hat{A}_i, A^+)$	$d(\hat{A}_i, A^-)$
A_1	0.0103	0.0151
A_2	0.0003	0.0243
A_3	0.0191	0.0071

Step 9. Calculate the similarity index to the ideal alternative, IS_i. This is made by: $IS_{I0} = A = (A_1, A_2, A_3)$ in eq. (18):

$$IS_I = A = [(0.5939),(0.9865),(0.2705)] \quad (22)$$

Step 10. List the alternatives $A_i(i = 1, \dots, n)$ with respect to IS_i , in decreasing order. Bu doing so, the order is:

$$A_2 \succ A_1 \succ A_3.$$

In this case, the best alternative is A_2, the same decision as the one taken by the Company with just quantitative criteria, it is a mere coincidence. Now, the Company is preparing the Project accordingly to the operation rules of the PEI monetary fund.

5. DISCUSION AND CONCLUSIONS

The common industrial practice is the evaluation by means of quantitative information [21] because it is easy to gather the data, there are no doubts of the measurement, and it is objective. In this case, the alternative N. 2 is better in quantitative criteria and in the qualitative ones, it is the best in both criteria. The case pinpoints the adequateness of IFT for technology evaluation, also can be applied to substitution and replacement problems. The application also indicates that the use of fuzzy variables aids the analysis and decision making processes and that people learn its use rapidly. Although the criteria used is very dissimilar, the case shows that the inherent logic allows the understanding and provides a sense of security. Because the decision makers were from different functional areas and with distinct preparation, experience, and bachelor degrees, the unknown issues lead to questions and the discussions to answers and explanations. For instance, about execution capacity, the three agree in A_3, with a “VH”, in environmental impact, the three DM’s coincide in A_2, and regarding suppliers, the coincidence is through project A_3, with a level “L”. The question arises when for project A_1, DM1 evaluates it with an “L”, DM_2 gives an “M” and DM_3 assigns an “H”. Project A_1 can’t be, at the same time, easy and hard to implement. One of the problems with categorical order is the frontiers, they are sharp, exact, but the difference between the “L” and the “M” may be more attributed to the DM’s paradigms, and to a poor evaluation because of other type of factors such as political or animosities. But consider the following, suppose a fuzzy space between the two levels instead of a sharp border, or if two DM’s give an “M” and the other, whether and “L” or an “H”, most probably the correct evaluation is closer to M, because of the concordance of opinions. With this type of explanations DM’s understand the underlying logic. Discussion also allowed the comprehension of the importance of environmental issues and this basic understanding lead to agreements between them, even the relationship of these issues to competitiveness.

Although there is a wide offer of software for project evaluation, some of them based on discounted flow techniques, the traditional and common practice, internal return, present net value, equivalent uniform annual cost do not consider qualitative information and the analysis is made with a portion of the real problem, the reality complexity is omitted and one may get a good solution for a non-existent problem. Regarding the more complex ones such as ELECTRE, the cost, complexity leads to a poor application. Software of complex methodologies could be improved by means of expert systems.

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