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APPLICATION THE FUZZY TOPSIS AND FUZZY ELECTRE IN THE SERIOUS GAMES EVALUATION TOOL

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ABSTRACT

The evaluation of serious games is generally a complicated process because there is usually more than one dimension to be evaluated. In our Serious Games evaluation tool, we have four dimensions in each one we have a several well-defined evaluation criteria's.

So we intend to use a fuzzy multi-criteria decision-making method (FMCDM) which has been integrated in order to validate the selection of the different alternatives and the weighting of the multiple criteria involved in our tool.

However, even if all methods have the capacity to take into account the imprecision and uncertainty of human judgments, each method has its advantages and disadvantages depending on the context in which it is used. This makes it very difficult to choose one method over another. Moreover, there is no consensus in the scientific community on any particular method.

In this paper, we present the use of the fuzzy TOPSIS and fuzzy ELECTRE methods for ranking the evaluation dimensions / alternatives used in our Serious Games evaluation model in which the fuzzy AHP method was used.

These three chosen methods, which adapt perfectly to our context, given its discrete aspect, represent respectively the three categories of FMADM (fuzzy multi-attribute decision-making methods): fuzzy pairwise comparison methods, fuzzy distance based methods and fuzzy outranking methods.

The results obtained from the application of these fuzzy methods converge towards the same ranking of dimensions / alternatives.

Keywords: *Serious Game, FMADM, fuzzy AHP, fuzzy TOPSIS, fuzzy ELECTRE.*

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1. INTRODUCTION

The integration of multi-criteria decision-making methods (MCDM) in several areas such as logistics [1, 2, 3], health [4, 5] and education [6, 7, 8, 9] is no longer to be confirmed.

Depending on the space in which they operate, continuous or discrete, these methods have been classified into two main categories: multi-objective decision methods (MODM), which are based on techniques such as GP (Goal Programming) [10] or GA (Genetic Algorithm) [11,12] and multi-attribute decision making methods (MADM) which use an intra- and inter-attribute comparison process with the involvement of human judgment.

These have been classified into three types (Figure 1):

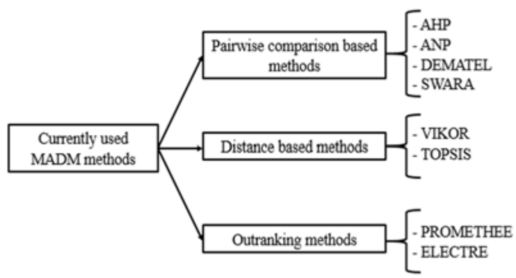

Figure 1: Classification of currently used MADM methods.

- ✓ Pairwise comparison based methods: allow the comparison of criteria with each other using a rating scale to calculate the relative importance values for each criterion. (AHP [13], ANP [14], DEMATEL [15], SWARA [16]).
- ✓ Distance based methods: use an aggregation function representing the proximity to the ideal solution. (TOPSIS [17], Vikor [18]).
- ✓ Outranking methods: carry out comparisons of actions in pairs in order to establish an outranking relationship (ELECTRE [19], PROMETHEE [20]).

Each of these methods has been combined with the fuzzy logic proposed by Zadeh [21], in order to represent the imprecision and ambiguity of data relating to certain problems encountered in human decision-making.

These fuzzy methods have been used in several applications in different fields such as technology [22,23,24], environment [25,26,27], logistics [28,29,30,31,32], renewable energy [33,34] and education [35,36,37].

However, we note that there is no one method better than the other, but some are better suited to particular decision-making problems than others.

Thus, despite the fact that all methods have the capacity to take account of imprecision and uncertainty in human judgments in real problems, each method has its advantages and disadvantages according to the context in which it is applied.

This paper presents the use, in turn, of the fuzzy TOPSIS and fuzzy ELECTRE methods will be done in the context of the realization of a SG evaluation model proposed in [38] and having already used the fuzzy AHP method in the weighting of the evaluation criteria.

This paper is divided into 5 sections. The first section presents the general context of our study. The use of the fuzzy TOPSIS method is introduced in section 2. As for the use of the fuzzy ELECTRE method is presented in section 3. A discussion of the results is presented in section 4 and finally, a conclusion is proposed in the last section.

2. GENERAL CONTEXT

The use, in turn, of the fuzzy TOPSIS and fuzzy ELECTRE methods will be made in the context of the realization of a SG evaluation model proposed in [38], where we proposed the use of the fuzzy AHP method for the weighting of the evaluation criteria.

This model has been designed on the basis of four dimensions deemed necessary that a SG must have in order to fulfill the task for which it was developed. These pedagogical, technological, ludic and behavioural dimensions will be measured according to several well-defined criteria represented in table 1 below:

Table 1: Dimensions and metrics

Dimension	Metrics
Pedagogical (PD)	Targeted skills (Ts) Pedagogical consideration (Pc) Learning result (Lr) Error Management (Em)
Technological (TD)	Game design (Gd) Performance (P) User Interface's (Ui) Usability (U)
Ludic (LD)	Challenge (C) Fun (F) Gameplay (G) Immersion (I)
Behavioural (BD)	Motivation (M) Engagement (E) User experience (Ue)

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We have chosen the pedagogical dimension, since a SG must, above all, meet one or more of the pedagogical objectives for which it was designed.

Similarly, a SG must be very attractive and benefit in its design from the technological advances in game development tools.

As for the ludic dimension, its presence is primordial in a SG to guarantee learning in fun and immersive situations in order to arouse the students' interest and maintain their attention during the SG.

Finally, the behavioural dimension makes it possible to test the correct insertion of the SG in the context of its use according to motivation, commitment and the user's experience.

The importance of one dimension in relation to another depends on the context in which the SG is used.

For example, if the SG is used in a purely formative context, the pedagogical dimension will be considered dominant over the other dimensions.

Therefore, depending on the context in which the SG is used, it is essential to validate this selection of the four dimensions and the weighting of their multiple criteria using a mathematical method of multi-criteria analysis.

In [38] the method based on pairwise comparison of the criteria, fuzzy AHP was used.

This method has imposed a two-level hierarchy of criteria: dimension {PD, TD, LD, and BD} and criteria by each dimension.

In this paper we exploit, in the same context, the two other types of fuzzy multi-attribute decision-making methods, namely the distance-based method (fuzzy TOPSIS) and the outranking methods (fuzzy ELECTRE).

3. RANKING OF ALTERNATIVES BY FUZZY TOPSIS

The TOPSIS method (The technique for order of preference by similarity to the ideal solution) is based on finding the best alternative A_i closest to the positive ideal solution point noted A^+ and furthest away from the negative ideal solution point noted A^-. (Figure 2)

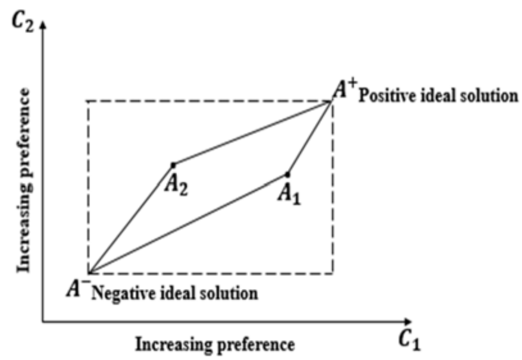

Figure 2: Basic concept of the TOPSIS method (A^+: positive ideal solution, A^-: negative ideal solution).

The hierarchy of dimensions imposed by fuzzy AHP in [38] is no longer adequate in the fuzzy TOPSIS environment, so we consider the dimensions PD, TD, BD, LD as alternatives to be ranked by fuzzy TOPSIS according to all the criteria involved.

The process used, presented by Chen [39], begins with the choice of the evaluation criteria weights and the establishment of the fuzzy decision matrix by the evaluator in order to proceed with the necessary calculation to obtain the closeness coefficient CC_i. (Figure 3)

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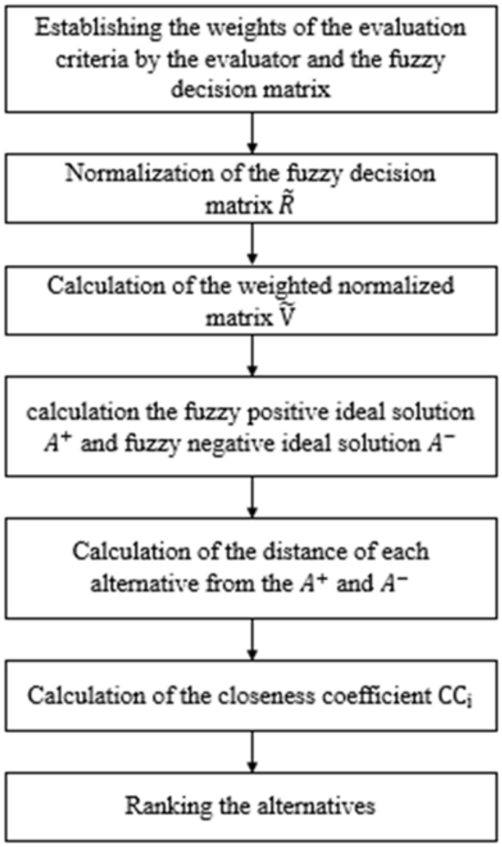

Figure 3: Process of ranking SG alternatives using the fuzzy TOPSIS method

The evaluation context of the SG is purely formative. Biology students at the Ben M'Sik Faculty of Science - Hassan II University Casablanca, use it.

We thought it wise to give priority to pedagogical evaluation criteria over other criteria.

And given that the target population is of university level and therefore familiar with the new information technologies, we have given the technological evaluation criteria an advantage over the behavioural and ludic evaluation criteria.

Similarly, since the SG to be evaluated is used in a pedagogical activity, we privileged behavioural evaluation criteria over ludic evaluation criteria.

3.1 Step 1: selection of the weightings of the evaluation criteria by the evaluator and establishment of the fuzzy decision matrix.

In this step, as evaluator we chose fuzzy weights ($\widetilde{W}$) for each criterion according to a fuzzy language scale, transformed into fuzzy numbers (Table 2).

Table 2: Fuzzy weights of the metrics $\widetilde{W}$

Metrics	Fuzzy weights ($\widetilde{W}$)
Targeted skills (Ts)	(0.7,0.9,1)
Pedagogical consideration (Pc)	(0.7,0.9,1)
Learning result (Lr)	(0.7,0.9,1)
Error Management (Em)	(0.7,0.9,1)
Game design (Gd)	(0.5,0.7,0.9)
Performance (P)	(0.5,0.7,0.9)
User Interface's (Ui)	(0.5,0.7,0.9)
Usability (U)	(0.5,0.7,0.9)
Challenge (C)	(0.1,0.3,0.5)
Fun (F)	(0.1,0.3,0.5)
Gameplay (G)	(0.1,0.3,0.5)
Immersion (I)	(0.1,0.3,0.5)
Motivation (M)	(0.3,0.5,0.7)
Engagement (E)	(0.3,0.5,0.7)
User experience (Ue)	(0.3,0.5,0.7)

And the fuzzy decision matrix ($\widetilde{D}$) chosen is shown in Table 3.

In order to normalize the fuzzy decision matrix ($\widetilde{D}$) we used the linear scale transformation according to formulas (2) and (3).

The normalized fuzzy decision matrix ($\tilde{R}$) is given by the formula (1):

$$\tilde{R} = [\tilde{r}_{ij}]_{m\times n} \quad i = 1,2,\dots,m; j = 1,2,\dots,n. \quad (1)$$

In our context, the criteria {Ts, Pc, Lr, Em, C, F, G, I, M, E, Ue} have been chosen as benefit criteria, their normalized value $\tilde{r}_{ij}$ is calculated as follows :

$$\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+}\right) \text{ where } u_j^+ = \max_i u_{ij} \quad (2)$$

Similarly, the criteria {Gd, P, Ui, U} have been chosen as cost criteria, their normalized value $\tilde{r}_{ij}$ is calculated as follows :

$$\tilde{r}_{ij} = \left(\frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}}\right) \text{ where } l_j^- = \min_i l_{ij} \quad (3)$$

The normalized fuzzy decision matrix ($\tilde{R}$) is shown in Table 4.

3.2 Calculation of the closeness coefficient CC_i :

For the calculation of the closeness coefficient CC_i, we have calculated the weighted normalized matrix ($\tilde{V}$) in order to determine the distances of each alternative from the deduced reference points (A^+ and A^-) from this matrix according to the formulas. (4) and (5)

The fuzzy positive ideal solution A^+ is defined as follows:

$$A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \dots, \tilde{v}_n^+) \quad (4)$$

where $\tilde{v}_j^+ = \max_i\{v_{ij3}\}$ $i = 1,2,\dots,m;$ $j = 1,2,\dots,n.$

The fuzzy negative ideal solution A^- is defined as follows:

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots, \tilde{v}_n^-) \quad (5)$$

where $\tilde{v}_j^- = \min_i\{v_{ij1}\}$ $i = 1,2,\dots,m;$ $j = 1,2,\dots,n.$

The weighted normalized matrix $\tilde{V}$ is calculated by multiplying the weights $\tilde{w}$ of the evaluation criteria by the normalized fuzzy decision matrix $\tilde{r}_{ij}$, this is expressed by the formula (6) below, the result is shown in table 5.

$$\tilde{V} = [\tilde{v}_{ij}]_{m\times n}\ i = 1,2,\dots,m\,; j = 1,2,\dots,n. \quad (6)$$

$$\tilde{v}_{ij} = \tilde{r}_{ij} \times \tilde{w}_j\ \ i = 1,2,\dots,m; j = 1,2,\dots,n.$$

The distance values of each alternative from the reference points, calculated by the formulas (7) and (8).

$$d_i^+ = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^+)\ \ i = 1,2,\dots,m; j = 1,2,\dots,n. \quad (7)$$

$$d_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^-)\ i = 1,2,\dots,m; j = 1,2,\dots,n. \quad (8)$$

Where $d(\tilde{v}_a, \tilde{v}_b)$ represents the distance between two fuzzy triangular numbers, this is expressed by the formula (9) below.

$$d(\tilde{v}_a, \tilde{v}_b) = \sqrt{\frac{1}{3}[(l_a - l_b)^2 + (m_a - m_b)^2 + (u_a - u_b)^2]} \quad (9)$$

According to figure 4 below, the PD alternative has the shortest distance from the fuzzy positive ideal solution and the longest distance from the fuzzy negative ideal solution, in contrast to the LD alternative.

The alternative TD and BD are respectively positioned before the alternative LD and after the alternative PD.

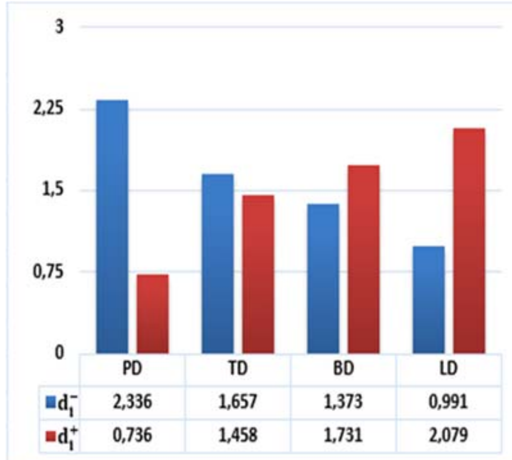

Figure 4: The distance of each alternative from the fuzzy positive ideal solution d_i^+ and fuzzy negative ideal solution d_i^-

In order to rank the alternatives, we calculate the closeness coefficient CC_i given by the formula (10), the results are represented in Table 6.

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+}\ \ i = 1,2,\dots,m. \quad (10)$$

Table 6: Closeness coefficient (CC_i)

Alternative	CC_i	Ranking
PD	0.760	1
TD	0.532	2
BD	0.442	3
LD	0.323	4

3.3. Conclusion

The ranking obtained by fuzzy TOPSIS shows that the PD alternative is better than the TD, BD and LD alternatives. This result reinforces that achieved by fuzzy AHP in [38].

4. SELECTION OF THE BEST ALTERNATIVE BY FUZZY ELECTRE

The Fuzzy ELECTRE method is based on the study of outranking relations, it uses the concordance index C_{pq} and the discordance index D_{pq} to analyse the outranking relations between the alternatives, these two indices can be considered measures of satisfaction and dissatisfaction of the evaluator.

The applied process, proposed by Sevkli [40], begins with the establishment of the normalized fuzzy weights for each evaluation criterion and the construction of the decision matrix in order to calculate the indices of concordance C_{pq} and discordance D_{pq}. (Figure 5)

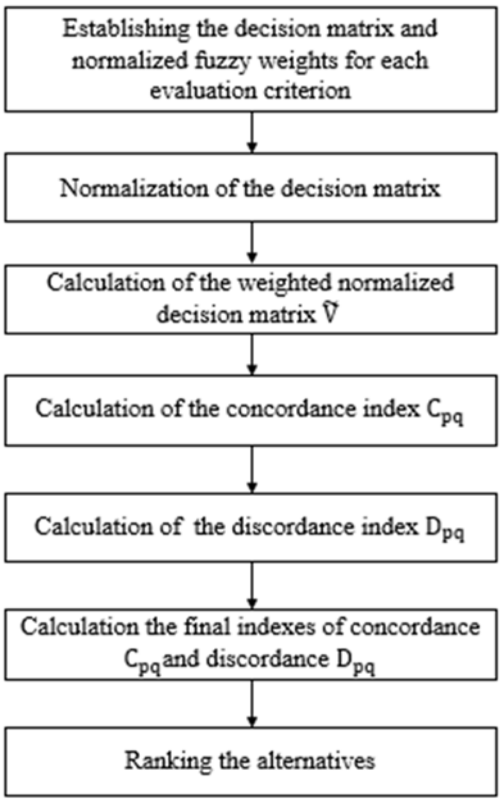

Figure 5: Process of ranking SG alternatives using the Fuzzy ELECTRE method

The same judgment was applied regarding the preferences of the evaluation criteria and alternatives applied in the fuzzy TOPSIS method.

4.1 Step 1: Establishment of normalized fuzzy weights for the evaluation criteria and decision matrix construction.

As evaluator we have established a fuzzy weight ($\widetilde{w}_j$) for each criterion according to their importance, then these weights are normalized using the formula (11), the results are shown in Table 7.

$$w_{j1} = \frac{\frac{1}{w_{j1}}}{\sum_{j=1}^{n}\frac{1}{w_{j1}}}, w_{j2} = \frac{\frac{1}{w_{j2}}}{\sum_{j=1}^{n}\frac{1}{w_{j2}}}, w_{j3} = \frac{\frac{1}{w_{j3}}}{\sum_{j=1}^{n}\frac{1}{w_{j3}}} \quad (11)$$

Where $\widetilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$

Table 7: Normalization of aggregated fuzzy importance weights

Metrics	Normalized fuzzy weights ($\widetilde{w}_j$)
Targeted skills (Ts)	(0.022, 0.038, 0.048)
Pedagogical consideration (Pc)	(0.022, 0.038, 0.048)
Learning result (Lr)	(0.022, 0.038, 0.048)
Error Management (Em)	(0.022, 0.038, 0.048)
Game design (Gd)	(0.031, 0.048, 0.054)
Performance (P)	(0.031, 0.048, 0.054)
User Interface's (Ui)	(0.031, 0.048, 0.054)
Usability (U)	(0.031, 0.048, 0.054)
Challenge (C)	(0.157, 0.113, 0.096)
Fun (F)	(0.157, 0.113, 0.096)
Gameplay (G)	(0.157, 0.113, 0.096)
Immersion (I)	(0.157, 0.113, 0.096)
Motivation (M)	(0.052, 0.068, 0.069)
Engagement (E)	(0.052, 0.068, 0.069)
User experience (Ue)	(0.052, 0.068, 0.069)

The decision matrix is obtained from the evaluation of the alternatives to the criteria as shown in Table 8.

The normalized decision matrix is obtained by the formula (12) as shown in table 9.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad i = 1,2,\dots,m;\ j = 1,2,\dots,n. \quad (12)$$

Where x_{ij} is the evaluation value of alternative (i) in relation to criterion (j).

4.2 Calculation of indexes C_{pq} and D_{pq}

In order to calculate the concordance index C_{pq} and discordance index D_{pq}, we calculated the weighted normalized decision matrix $\tilde{V}$.

This weighted normalized matrix $\tilde{V}$ is calculated using formula (13), by multiplying the weights $\widetilde{w}_j$ of the evaluation criteria by the normalized decision matrix r_{ij} is shown in table 10.

$$\tilde{V} = [\tilde{v}_{ij}]_{m \times n} \text{where } i = 1,2,\dots,m;\ j = 1,2,\dots,n.$$

$$\tilde{v}_{ij} = r_{ij} \times \widetilde{w}_j \ \text{ where } i = 1,2,\dots,m;\ j = 1,2,\dots,n. \quad (13)$$

The calculation of the indexes C_{pq} and D_{pq} of each alternative are given by the formulas (14) and (15). The values obtained are represented respectively in table 11 and 12.

$$C_{pq}^1 = \sum_{j^*} w_j^l, C_{pq}^2 = \sum_{j^*} w_j^m, C_{pq}^3 = \sum_{j^*} w_j^u \quad (14)$$

Where j^* are the criteria contained in concordance set C_{pq}.

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$$D_{pq}^{1} = \frac{\sum_{j^+}\left|v_{pj^+}^{1} - v_{qj^+}^{1}\right|}{\sum_{j}\left|v_{pj}^{1} - v_{qj}^{1}\right|}, D_{pq}^{2} = \frac{\sum_{j^+}\left|v_{pj^+}^{2} - v_{qj^+}^{2}\right|}{\sum_{j}\left|v_{pj}^{2} - v_{qj}^{2}\right|}, D_{pq}^{3} = \frac{\sum_{j^+}\left|v_{pj^+}^{3} - v_{qj^+}^{3}\right|}{\sum_{j}\left|v_{pj}^{3} - v_{qj}^{3}\right|} \quad (15)$$

Where j^+ are the criteria contained in the discordance set D_{pq}.

The result of the calculations for the concordance index C_{pq} is presented in Table 11.

Table 11: The concordance index

	C_{pq}^{1}	C_{pq}^{2}	C_{pq}^{3}
PD, TD	0.934	0.904	2.619
PD, BD	0.996	1	2.727
PD, LD	0.839	0.887	2.631
TD, PD	0.752	0.644	0.6
TD, BD	0.84	0.796	2.520
TD, LD	0.839	0.887	2.631
BD, PD	0.784	0.656	0.591
BD, TD	0.784	0.656	0.591
BD, LD	0.839	0.887	2.631
LD, PD	0.628	0.452	0.384
LD, TD	0.628	0.452	0.384
LD, BD	0.752	0.644	0.6

The result of the calculations for the discordance index D_{pq} is presented in Table 12.

Table 12: The discordance index

	D_{pq}^{1}	D_{pq}^{2}	D_{pq}^{3}
PD, TD	0.184	0.195	0.046
PD, BD	0.000	0.000	0.000
PD, LD	0.263	0.146	0.026
TD, PD	0.816	0.805	0.954
TD, BD	0.355	0.311	0.091
TD, LD	0.326	0.185	0.037
BD, PD	1.000	1.000	1.000
BD, TD	0.645	0.689	0.909
BD, LD	0.390	0.249	0.067
LD, PD	0.737	0.854	0.974
LD, TD	0.674	0.815	0.963
LD, BD	0.610	0.751	0.933

The final index of concordance (C_{pq}) and discordance (D_{pq}) are calculated using the formula (16) below:

$$C_{pq} = \sqrt[z]{\prod_{z=1}^{z} C_{pq}^{z}}\ , D_{pq} = \sqrt[z]{\prod_{z=1}^{z} D_{pq}^{z}} \quad (16)$$

where Z=3.

The figure below represents the final concordance and discordance indexes's between the pairs as they judged by the evaluator.

The concordance index C_{pq} represents the degree of confidence in the judgements between pairs.

The discordance index D_{pq} measures the disagreement degree's between pairs.

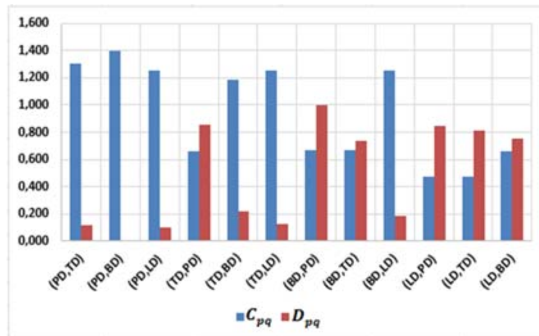

Figure 6: The final indexes of concordance and discordance

In order to determine the ranking of alternatives, the difference between the net indexes of concordance and discordance is calculated as shown in table 13.

Table 13: Result of the ranking

Alternative	Values	Ranking
PD	3.732	1
TD	1.902	2
BD	0.670	3
LD	-0.794	4

4.3 Conclusion

The result obtained by the Fuzzy ELECTRE method ranks the alternatives as follows PD>TD>BD>LD, which shows that PD is the best alternative, this result confirms the one obtained by Fuzzy AHP [38].

5. DISCUSSION AND RESULTS

In this study we presented the use of the multi-attribute decision-making methods Fuzzy ELECTERE and Fuzzy TOPSIS in the conception of our SG evaluator presented in [38].

The results obtained with these two methods (Fuzzy ELECTER and Fuzzy TOPSIS), validate those obtained with the Fuzzy AHP method previously used in our SG evaluator [38] as shown in table 14.

Namely that the Pedagogical dimension/alternative is the dominant one compared to the other dimensions/alternatives.

Table 14: Results of fuzzy multi-attribute decision-making methods

	Fuzzy AHP	Fuzzy TOPSIS	Fuzzy ELECTRE
PD	0.557	0.760	3.732
TD	0.267	0.532	1.902
BD	0.120	0.442	0.670
LD	0.056	0.323	-0.794

Even more, these results prove the same order of ranking of these dimensions/alternatives. Although there is a difference in the meaning of the values obtained for each method.

Fuzzy TOPSIS ranks the alternatives under the principle of distance to the ideal, while fuzzy ELECTRE ranks them under the principle of concordance and discordance, while fuzzy AHP classifies them according to a pairwise comparison of each hierarchical level.

As a result of this study we note that the human factor, namely the evaluator, considerably influences the result obtained by these three methods by assigning a weight to a dimension / alternative that is more important than to another.

This suits us perfectly, as our SG evaluator should adapt to the different contexts in which it will be used: Purely pedagogical or technological or behavioural or ludic context.

6. CONCLUSION

The application of the three categories of fuzzy multi-attribute decision-making methods: distance-based methods (Fuzzy TOPSIS), outranking methods (Fuzzy ELECTRE) and pairwise comparison methods (Fuzzy AHP) in our proposed SG evaluator solved the problem of the choice of importance between the four evaluation dimensions/alternatives on which our evaluator relies.

The ranking of dimensions/alternatives obtained in this study was the same for the three fuzzy MADM methods applied.

In our future work, we suggest extending this study on the different extensions of fuzzy sets, namely the hesitant fuzzy sets, the intuitionist fuzzy sets and the Pythagorean fuzzy sets.

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Table 3: The Fuzzy Decision Matrix ($\tilde{D}$)

	Ts	Pc	Lr	Em	Gd	P	Ui	U	C	F	G	I	M	E	Ue
PD	(9,10,10)	(9,10,10)	(9,10,10)	(9,10,10)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)	(5,7,9)	(5,7,9)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)
TD	(5,7,9)	(5,7,9)	(7,9,10)	(9,10,10)	(9,10,10)	(9,10,10)	(9,10,10)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)
BD	(3,5,7)	(5,7,9)	(5,7,9)	(3,5,7)	(5,7,9)	(5,7,9)	(7,9,10)	(7,9,10)	(7,9,10)	(5,7,9)	(5,7,9)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)
LD	(1,3,5)	(3,5,7)	(3,5,7)	(1,3,5)	(5,7,9)	(3,5,7)	(7,9,10)	(5,7,9)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)	(7,9,10)	(5,7,9)	(5,7,9)

Table 4: The normalized fuzzy decision matrix ($\tilde{R}$)

	Ts	Pc	Lr	Em	Gd	P	Ui	U	C	F	G	I	M	E	Ue
PD	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.9,1,1)	(0.5,0.556,0.714)	(0.3,0.333,0.429)	(0.7,0.778,1)	(0.5,0.556,0.714)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
TD	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.7,0.9,1)	(0.9,1,1)	(0.5,0.5,0.556)	(0.3,0.3,0.333)	(0.7,0.7,0.778)	(0.5,0.556,0.714)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
BD	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.3,0.5,0.7)	(0.556,0.714,1)	(0.333,0.429,0.6)	(0.7,0.778,1)	(0.5,0.556,0.714)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)
LD	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.3,0.5,0.7)	(0.1,0.3,0.5)	(0.556,0.714,1)	(0.429,0.6,1)	(0.7,0.778,1)	(0.556,0.714,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.7,0.9,1)	(0.5,0.7,0.9)	(0.5,0.7,0.9)

Table 5: The weighted normalized matrix $\tilde{V}$

	Ts	Pc	Lr	Em	Gd	P	Ui	U	C	F	G	I	M	E	Ue
PD	(0.630,0.9,1)	(0.630,0.9,1)	(0.630,0.9,1)	(0.630,0.9,1)	(0.250,0.389,0.643)	(0.150,0.233,0.386)	(0.350,0.544,0.9)	(0.250,0.389,0.643)	(0.07,0.27,0.5)	(0.05,0.21,0.45)	(0.05,0.21,0.45)	(0.07,0.27,0.5)	(0.21,0.45,0.7)	(0.21,0.45,0.7)	(0.21,0.45,0.7)
TD	(0.350,0.630,0.9)	(0.350,0.630,0.9)	(0.490,0.810,1)	(0.630,0.9,1)	(0.250,0.350,0.5)	(0.150,0.210,0.3)	(0.350,0.49,0.7)	(0.250,0.389,0.643)	(0.07,0.27,0.5)	(0.07,0.27,0.5)	(0.07,0.270,0.5)	(0.07,0.27,0.5)	(0.21,0.45,0.7)	(0.21,0.45,0.7)	(0.21,0.45,0.7)
BD	(0.210,0.450,0.7)	(0.350,0.630,0.9)	(0.350,0.630,0.9)	(0.210,0.450,0.7)	(0.278,0.5,0.9)	(0.167,0.3,0.54)	(0.350,0.544,0.9)	(0.250,0.389,0.643)	(0.07,0.27,0.5)	(0.05,0.21,0.45)	(0.05,0.210,0.45)	(0.07,0.27,0.5)	(0.21,0.45,0.7)	(0.21,0.45,0.7)	(0.21,0.45,0.7)
LD	(0.07,0.270,0.5)	(0.210,0.450,0.7)	(0.210,0.450,0.7)	(0.07,0.270,0.5)	(0.278,0.5,0.9)	(0.214,0.420,0.9)	(0.350,0.544,0.9)	(0.278,0.5,0.9)	(0.07,0.27,0.5)	(0.07,0.27,0.5)	(0.07,0.27,0.5)	(0.07,0.27,0.5)	(0.21,0.45,0.7)	(0.15,0.35,0.63)	(0.15,0.35,0.63)

Table 8: The decision matrix

	Ts	Pc	Lr	Em	Gd	P	Ui	U	C	F	G	I	M	E	Ue
PD	9	9	9	9	7	7	9	9	5	3	5	5	7	7	7
TD	7	7	7	7	9	9	9	9	5	3	5	5	5	5	5
BD	5	5	5	5	5	5	5	5	5	3	5	5	7	7	7
LD	3	3	3	3	5	5	5	5	5	5	5	5	3	3	3

Table 9: The normalized decision matrix

	Ts	Pc	Lr	Em	Gd	P	Ui	U	C	F	G	I	M	E	Ue
PD	0.703	0.703	0.703	0.703	0.522	0.522	0.618	0.618	0.500	0.416	0.500	0.050	0.609	0.609	0.609
TD	0.547	0.547	0.547	0.547	0.671	0.671	0.618	0.618	0.500	0.416	0.500	0.050	0.435	0.435	0.435
BD	0.390	0.390	0.390	0.390	0.373	0.373	0.343	0.343	0.500	0.416	0.500	0.050	0.609	0.609	0.609
LD	0.234	0.234	0.234	0.234	0.373	0.373	0.343	0.343	0.500	0.693	0.500	0.050	0.261	0.261	0.261

Table 10: The weighted normalized decision matrix $\tilde{V}$

	Ts	Pc	Lr	Em	Gd	P	Ui	U	C	F	G	I	M	E	Ue
PD	(0.015,0.027,0.337)	(0.015,0.027,0.337)	(0.015,0.027,0.337)	(0.015,0.027,0.337)	(0.016,0.025,0.028)	(0.016,0.025,0.028)	(0.019,0.030,0.033)	(0.019,0.030,0.033)	(0.079,0.057,0.048)	(0.065,0.047,0.040)	(0.079,0.057,0.048)	(0.079,0.057,0.048)	(0.032,0.041,0.042)	(0.032,0.041,0.042)	(0.032,0.041,0.042)
TD	(0.012,0.021,0.262)	(0.012,0.021,0.262)	(0.012,0.021,0.262)	(0.012,0.021,0.262)	(0.021,0.032,0.036)	(0.021,0.032,0.036)	(0.019,0.030,0.033)	(0.019,0.030,0.033)	(0.079,0.057,0.048)	(0.065,0.047,0.040)	(0.079,0.057,0.048)	(0.079,0.057,0.048)	(0.023,0.030,0.030)	(0.023,0.030,0.030)	(0.023,0.030,0.030)
BD	(0.009,0.015,0.187)	(0.009,0.015,0.187)	(0.009,0.015,0.187)	(0.009,0.015,0.187)	(0.012,0.018,0.020)	(0.012,0.018,0.020)	(0.011,0.016,0.019)	(0.011,0.016,0.019)	(0.079,0.057,0.048)	(0.065,0.047,0.040)	(0.079,0.057,0.048)	(0.079,0.057,0.048)	(0.032,0.041,0.042)	(0.032,0.041,0.042)	(0.032,0.041,0.042)
LD	(0.005,0.009,0.112)	(0.005,0.009,0.112)	(0.005,0.009,0.112)	(0.005,0.009,0.112)	(0.012,0.018,0.020)	(0.012,0.018,0.020)	(0.011,0.016,0.019)	(0.011,0.016,0.019)	(0.079,0.057,0.048)	(0.109,0.078,0.067)	(0.079,0.057,0.048)	(0.079,0.057,0.048)	(0.014,0.018,0.018)	(0.014,0.018,0.018)	(0.014,0.018,0.018)