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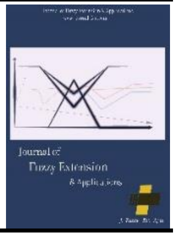

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Prediction of Human Behavior with TOPSIS

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Abstract

The present paper proposes a new application of the prediction of human behavior using TOPSIS as an appropriate tool for data optimization. Our hypothesis was that the analysis of the candidates with this method was influenced by the change of their behavior. We found that the behavior change could occur in more than one time span when the behavior of two candidates changed simultaneously. One of the advantages of this study is that the pattern of the behavior change with time is predicted with this method. Another advantage is that the modifications in the TOPSIS algorithm have made the predictions independent from the need of changing the fuzzy membership degrees of the candidates. This is the first time that these modifications in this technique with a new application including the numerical analysis of cognitive date are reported. Our results can be used in cognitive science, experimental psychology, cognitive informatics and artificial intelligence.

Keywords: TOPSIS analysis, MCDMA, Behavior change, Classification, Artificial intelligence.

1 | Introduction

Making decision is an important aspect for data optimization that includes some issues such as prediction of the best alternative and ranking of candidates. Multiple Criteria Decision-Making Algorithms (MCDMA) are the decision-making methods that involve quantitative and qualitative factors. Several MCDMAs have been used during recent years in order to choose the probable optimal alternatives. In these methods, the ratings of alternatives versus criteria, and the importance weights of all criteria, are assessed in linguistic values represented by different numbers [1]-[3]. TOPSIS is a multi-criteria approach that was developed by Hwang and Yoon in order to determine solutions from a finite set of alternatives [4]-[5]. In a study, this method was used for the prediction of human behavior according to the analysis of body posture and movement [6]. The prediction of behavior resistance to organizational change is another aspect of human behavior that has been analyzed with TOPSIS [7].

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1.1 | Contents of This Paper

This paper includes the presentation of the TOPSIS algorithm, two modifications that we have made in its algorithm and our results with the unmodified and modified algorithms for the prediction of human behavior in different time spans. Our current work is presented in fours sections. The Section 1 presented here concerns the introduction of the paper. The Section 2 includes the preliminaries. We have preformed two modifications in the TOPSIS algorithm. The Section 3 of this work presents our results with the unmodified and modified algorithms and discussion on the obtained results. The Section 4 includes the conclusion of the current work.

1.2 | Motivations and Research Outline

Several motivations have initiated the research and analysis work in the current paper. It was interesting to determine which kinds of cognitive factors or criteria that affect the human behavior were not analyzed with TOPSIS, yet. Secondly, as no previous study on the chosen criteria with TOPSIS was carried out, it was interesting to perform the presented analysis on these alternatives and criteria in different time spans. Thirdly, we were interested to perform some modifications in this algorithm to make it autonomous for changing the fuzzy membership degrees of candidates. Finaly, we were interested to get the numerical results in order to determine the rankings of alternatives according to the data, their weights and criteria types in the prediction of human behavior in different time spans.

The objectives of the current study have been to use TOPSIS for the prediction of human behavior in different time spans and determine how the modifications in the algorithm of this method can help make it independent of any need of change of data and fuzzy membership degrees of candidates so that the algorithm could make these changes itself without the need of human involvement for these changes.

Human behavior is an important aspect of personality that can be characterised by a change in behavior patterns over a short time. The modelling of temporal behavior is done over a time series, where time explains the behavior of the relevant variable [8]-[9]. The prediction of human characteristics with TOPSIS has been focused on the analysis of social aspects of human life such as energy consumption, stock price development, determination of urban surface temperatures, etc. [10]-[12]. The human characteristics can be analyzed according to their differences based on the values of their fuzzy degrees of membership [13]-[14].

Acting successfully is complex because the events on which we react are not always fully predictable and itis required to know which warning signals precede critical events. Learning helps to anticipate the onset of critical events in order to adjust behavior to react adequately. Thus, to understand how humans excel in different skills, we need to understand their behavior is adapted in time [15]. Time is an integral part of cognitive phenomena. It is built into most behavioral and cognitive processes [16]. Change over time is the basic foundation of developmental cognition. However, few theoretical models of human behavior focus almost exclusively on the passage of time [16]. Although the events in which human behavior is involved are not fully predictable, the change in the human characteristics having impact on them can be analyzed. Therefore, there is a real need in predicting the change of human behavior with time.

Some previous studies have been made on the prediction of human behavior with TOPSIS concerning other cognitive aspects. A study has been made on the ergonomic behavior of humans, which required their body movement in order to select the best work shift group in the industry using this algorithm. This study showed that a significant percentage of the worker's behavior were unergonomic [17]. Another study has been made with an enhanced fuzzy delphi method in forecasting and decision-making in order to transform the subjective data to quasi-objective ones. The authors have explained that a forecasted success requires various steps of operations including the critical path method that is more efficient for forecasting in such cases [18]. In another study, a fuzzy multi-objective assignment was

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proposed with the advantage of dealing situations realistically. The authors investigated the stability of their method without differentiability that corresponds to the obtained solution [19]. These mthods can be considered when the data for the prediction of human behavior are investigated.

1.3 | Contributions of This Paper

The prediction of human behavior based on the change of human characteristics in different time spans is a novel application of TOPSIS, which can improve the applications of this approach in cognitive informatics and artificial intelligence. To our knowledge, this is the first time that this application is reported for the prediction of human behavior with different time spans. Our results in this paper show that we have achieved our objectives with the two modifications of TOPSIS that we present here for the prediction of human behavior.

This prediction with this method can be applied to several fields such as cognitive science, artificial intelligence, cognitive informatics, etc. The combination of our results reported in this paper with those of other researchers can help improve these fields.

2 | Preliminaries

2.1 | TOPSIS Method

A version of TOPSIS in python was developed by Chakravorty in 2016, with the code available on the GitHub website (https://github.com/Glitchfix/TOPSIS-Python/blob/master/topsis.py) that we used for our analysis.

Apart from positive characteristics that have positive influence in the output of human work, negative characteristics should also be considered for a temporal prediction of human behavior. To perform this numerical analysis with TOPSIS, the first and second groups of characteristics are considered as profit criteria and cost criteria, respectively.

As in TOPSIS, the calculations are made on the fuzzy degrees of membership of the entry data, it is necessary to present the definitions of these concepts of the fuzzy logic.

Definition 1. Fuzzy degree of membership. The fuzzy degree of membership is a parameter that determines the membership of an element to a set. This parameter is represented with μ. For example, $\mu=0$ and $\mu=1$ mean that the considered element doest not belong or belongs to the set. According to the description of this parameter, the values between 0 and 1 can also be considered for the degree of membership that determine some percentage of membership ot the element to the set [14].

Definition 2. Universe of speech. The universe of speech is a set of references that is used for the determination of the values of the elements of a set. In other words, all the values that the degrees of membership can have are found in the universe of speech [14].

Definition 3. Fuzzy set. A fuzzy set is a set that contains some elements according to an extentional definition, the properties of elements or the function of their membership. The elements are attributed to the fuzzy set according to their degrees of membership [14].

In TOPSIS, the members or elements of the fuzzy set are the alternatives and their properties are the criteria. This method includes the steps below [20]-[21]:

I. Create a normalized decision matrix.

The normalized R decision matrix is created according to the formula below:

$$r_{ij} = X_{ij} / \sum \sqrt{i = X_{ij}^2}.$$

II. Create a weighted normalized decision matrix.

This matrix is created according to the formula below:

$$v_{ij} = w_i . x_{ij}.$$

III. Determine the positive ideal solution A^+ and the negative ideal solution A^-.

The positive ideal solution A+ is the maximum value of the data and the negative ideal solution A- is the minimum value of the data for profit criteria, whereas the positive ideal solution A+ is the minimum value of the data and the negative ideal solution A- is the maximum value of the data for cost criteria, respectively.

IV. Calculate the separation distance from the positive ideal solution S^+ and the other distance from the negative ideal solution S^- for each alternative.

These distances are calculated according to the formulas below:

$$D^*_j = \sqrt{\Sigma_{i=1}^n \left(v_{ij} - v_i^*\right)^2}, \quad j = 1, \ldots, J.$$

$$D^-_j = \sqrt{\Sigma_{i=1}^n \left(v_{ij} - v_i^-\right)^2}, \quad j = 1, \ldots, J.$$

V. Calculate the similarity coefficients according to the proximity relative to the positive ideal solution.

The similarity coefficients for alternatives are calculated according to the formula below:

$$C^*_j = D^-_j / D^+_j + D^-_j, \quad j = 1, \ldots, J.$$

This formula is used in TOPSIS for performing the ranking of alternatives according to their preference order. The alternative has a good performance if it has large value of closeness coefficient (C_j^*). The alternative with the greatest relative closeness to the ideal solution is the best one [21].

2.2 | Modifications of TOPSIS

We performed two modifications in the TOPSIS code in Python in order to make it capable of giving the same outputs without needing to modify the average values of the fuzzy membership degrees of candidates 1 and 5.

Modification 1. We added these lines to the first step of the code:

```
evaluation_matrix[row_size-5][column_size-1] = evaluation_matrix[row_size-5][column_size-1] + 1.0

evaluation_matrix[row_size-5][column_size-2] = evaluation_matrix[row_size-5][column_size-2] + 1.0
```

This modification added the value of 1.0 to the fuzzy membership degrees of the first candidate in the two last columns of the entry matrix. Therefore, this increased the value of the cost criteria of this candidate. The same output was obtained as the one that we observed for the behavior change of candidate 1 for the time span of Y-25-Y30 according to *Table 2*.

Modification 2. We added these lines to the first step of the code in another analysis:

```
evaluation_matrix[row_size-5][column_size-1] = evaluation_matrix[row_size-5][column_size-1] +1.0

evaluation_matrix[row_size-5][column_size-2] = evaluation_matrix[row_size-5][column_size-2] +1.0
```

evaluation_matrix[row_size-1][column_size-1] = evaluation_matrix[row_size-1][column_size-1] -0.3

evaluation_matrix[row_size-1][column_size-2] = evaluation_matrix[row_size-1][column_size-2] - 0.6

This modification added the value of 1.0 to the fuzzy membership degrees of the first candidate in the two last columns of the entry matrix. Therefore, this increased the value of the cost criteria of this candidate. Moreover, it subtracted the values of 0.3 and 0.6 from the fuzzy membership degrees of the last candidate in the last column and in the before last column, respectively. Therefore, this reduced the values of the cost criteria of this candidate.

The same output was obtained as the one that we observed for the behavior change of candidates 1 and 5 for the time span of Y-25-Y30 according to *Tables 2* and *3*.

3 | Results and Discussion

Choosing the best behavior change is required for the prediction of human behavior according to an analyzable pattern. The characteristics that are analyzed in the example in this paper include the profit and cost criteria that can change with time. Therefore, this study will discuss the method that is expected to help determine the best candidate according to his characteristic change.

3.1 | Results with Unmodified TOPSIS

TOPSIS is the method that is used in making this best selection of human candidates. This study includes these steps using TOPSIS method:

I. Determine the TOPSIS criteria and candidates in the decision matrix.

In this study, the human characteristics as the criteria for the selection of human candidates are shown in *Table 1*. The information about five candidates, C-1, C-2, C-3, C-4 and C-5, with their different characteristics during 30 years in different time spans is presented in the table. The first four characteristics, createive, attentive, perseverant and productive, have a positive effect on the output of the candidates' work as they increase the efficiency of their work. Therefore, these characteristics are considered as profit criteria.

The two other ones, lazy and unmotivated, have a negative effect on this output as they reduce the efficie-ncy of their work. So, they are considered as cost criteria. The values of fuzzy membership degrees of the candidates' characteristics that vary between 0.0 and 1.0 are indicated in the *Table 1*.

Table 1. Fuzzy membership degrees of the characteristics of five candidates in the first time span in the decision matrix.

Candidates/Criteria	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
C-1	1.0,1.0,1.0	1.0,1.0,1.0	1.0,1.0,1.0	1.0,1.0,1.0	0.0,0.0,0.0	0.0,0.0,0.0
C-2	1.0,1.0,1.0	1.0,1.0,1.0	1.0,1.0,1.0	0.6,0.7,0.8	0.8,0.9,1.0	0.1,0.2,0.3
C-3	1.0,1.0,1.0	0.5,0.6,0.7	0.8,0.9,1.0	0.8,0.9,1.0	0.1,0.2,0.3	0.3,0.4,0.5
C-4	1.0,1.0,1.0	0.7,0.8,0.9	1.0,1.0,1.0	0.7,0.8,0.9	0.4,0.5,0.6	0.4,0.5,0.6
C-5	0.6,0.7,0.8	0.7,0.8,0.9	0.3,0.4,0.5	0.5,0.6,0.7	0.5,0.6,0.7	0.2,0.3,0.4

In order to determine the effect of the change in the behavior of candidate 1 according to the change of his characteristics when the behaviors of the other candidates do not change and their characteristics do not reveal any change too, we considered different types of changes in the values of the degrees of membership of candidate 1 with no change in those of other candidates.

Table 2 shows the changes in the values of fuzzy membership degrees for candidate 1 during several time spans. The first, second, third, fourth, fifth and sixth time spans include 5 years, 2 years, 3 years, 5 years, 4 years and 6 years, respectively.

We considered that the behaviors of candidates 1 and 6 changes with time.

We consider that the behavior of candidate 5 changes in the last time span.

Table 3 shows the change in the values of fuzzy membership degrees for candidate 5 during the first and last time spans.

Table 2. The change in the values of fuzzy membership degress for candidate 1 during 30 years in several time spans.

Time Spans/ Characteristics	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
Y1-Y5	1.0,1.0,1.0	1.0,1.0,1.0	1.0,1.0,1.0	1.0,1.0,1.0	0.0,0.0,0.0	0.0,0.0,0.0
Y6-Y7	1.0,1.0,1.0	1.0,1.0,1.0	1.0,1.0,1.0	0.6,0.7,0.8	0.1,0.2,0.3	0.1,0.2,0.3
Y11-Y13	0.6,0.7,0.8	0.7,0.8,0.9	0.3,0.4,0.5	0.5,0.6,0.7	0.1,0.2,0.3	0.1,0.2,0.3
Y16-Y20	0.6,0.7,0.8	0.7,0.8,0.9	0.3,0.4,0.5	0.5,0.6,0.7	0.2,0.3,0.4	0.2,0.3,0.4
Y21-Y24	0.6,0.7,0.8	0.7,0.8,0.9	0.3,0.4,0.5	0.5,0.6,0.7	0.5,0.6,0.7	0.5,0.6,0.7
Y25-Y30	1.0,1.0,1.0	1.0,1.0,1.0	1.0,1.0,1.0	1.0,1.0,1.0	1.0,1.0,1.0	1.0,1.0,1.0

Table 3. The change in the values of fuzzy membership degrees for candidate 5 during the first and last time spans.

Time Spans/ Characteristics	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
Y1-Y5	0.6,0.7,0.8	0.7,0.8,0.9	0.3,0.4,0.5	0.5,0.6,0.7	0.5,0.6,0.7	0.2,0.3,0.4
Y25-Y30	0.6,0.7,0.8	0.7,0.8,0.9	0.3,0.4,0.5	0.5,0.6,0.7	0.0,0.0,0.0	0.0,0.0,0.0

Tables 4, 5 and *6* represent the mean values of the fuzzy data presented in *Tables 1, 2* and *3*, respectively.

Table 4. Mean values of fuzzy membership degrees of the characteristics of five candidates in the first time span in the decision matrix.

Candidates/Criteria	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
C-1	1.0	1.0	1.0	1.0	0.0	0.0
C-2	1.0	1.0	1.0	0.7	0.0	0.2
C-3	1.0	0.6	0.9	0.9	0.2	0.4
C-4	1.0	0.8	1.0	0.8	0.5	0.5
C-5	0.7	0.8	0.4	0.6	0.6	0.3

Table 5. The change in the mean values of fuzzy membership degrees for candidate 1 during 30 years in several time spans.

Time Spans/ Characteristics	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
Y1-Y5	1.0	1.0	1.0	1.0	0.0	0.0
Y6-Y7	1.0	1.0	1.0	1.0	0.2	0.2
Y11-Y13	0.7	0.8	0.4	0.6	0.2	0.2
Y16-Y20	0.7	0.8	0.4	0.6	0.3	0.3
Y21-Y24	0.7	0.8	0.4	0.6	0.6	0.6
Y25-Y30	1.0	1.0	1.0	1.0	1.0	1.0

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Table 6. The change in the mean values of fuzzy membership degrees for candidate 5 during the first and last time spans.

Time Spans/ Characteristics	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
Y1-Y5	0.7	0.8	0.4	0.6	0.6	0.3
Y25-Y30	0.7	0.8	0.4	0.6	0.0	0.0

II. Determine the weights of each alternative for each criterion.

Table 7 shows the weights of alternatives for each criterion.

Table 7. Weights of alternatives for each criterion.

Alternatives/Values	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
C1-C5	0.5	0.5	0.5	0.5	0.5	0.5

The same weight values are chosen for different criteria in order to make them have the same influence on human behavior.

III. Determine the criteria matrix.

The next step is the determination of the criteria matrix. *Table 8* shows the criteria matrix indicating True for the profit criteria and false for the cost criteria, respectively.

Table 8. Criteria matrix.

Alternatives/Values	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
C1-C5	True	True	True	True	False	False

The steps below correspond to the results obtained in our software with TOPSIS for the first time span, which concerns the first five years in *Table 2*.

IV. Normalization of fuzzy membership degrees and weights.

The vector normalization of the fuzzy membership degrees of the characteristics of five candidates as well as the normalization of their weights is followed by their multiplication, which results in the weighted normalization matrix. *Tables 9* and *10* show the results of the normalized decision matrix and weighted normalized decision matrix, respectively.

Table 9. Results of the normalized decision matrix.

Candidates/Criteria	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
C-1	0.47192918	0.52414242	0.55048188	0.55048188	0.00000000	0.00000000
C-2	0.47192918	0.52414242	0.38533732	0.38533732	0.00000000	0.00000000
C-3	0.47192918	0.31448545	0.49543369	0.49543369	0.24806947	0.54433105
C-4	0.47192918	0.41931393	0.440.38551	0.44038551	0.62017367	0.68041382
C-5	0.33035042	0.41931393	0.33028913	0.33028913	0.74420841	0.40824829

Table 10. Results of the weighted normalized decision matrix.

Candidates/Criteria	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
C-1	0.07865486	0.08735707	0.0836476	0.09174698	0.00000000	0.00000000
C-2	0.07865486	0.08735707	0.0836476	0.06422289	0.00000000	0.04536092
C-3	0.07865486	0.05241424	0.07528284	0.08257228	0.04134491	0.09072184
C-4	0.07865486	0.06988566	0.0836476	0.07339758	0.10336228	0.1134023
C-5	0.0550584	0.06988566	0.03345904	0.05504819	0.12403473	0.06804138

V. Determine the best alternative and the worst alternative.

Table 11 shows the results of the best alternative and the worst alternative.

Table 11. The results of the best alternative (A^+) and the worst alternative (A^-).

Candidates/Criteria	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
A^+	0.07865486	0.08735707	0.0836476	0.09174698	0.00000000	0.00000000
A^-	0.0550584	0.055241424	0.03345904	0.05504819	0.12403473	0.1134023

VI. Determine the distances from the best alternative (d_i^*) and the worst alternative (d_i^-).

Table 12 shows the results of the distances from the best alternative (d_i^*) and the worst alternative (d_i^-) for the candidates.

VII. Determine the similarity coefficients of the candidates.

Table 13 shows the similarity coefficients and the rankings of the candidates according to the worst similarity for different time spans.

Table 12. The results of distances from the best alternative (di*) and the worst alternative (di-) for the candidates.

Candidates	di*	di-
C-1	0.00000000	0.18408744
C-2	0.05305835	0.15618933
C-3	0.10637199	0.10205689
C-4	0.15551782	0.06438156
C-5	0.15729584	0.04860929

As expected and shown in *Table 13*, the fuzzy membership degrees of the cost criteria were increased in the time span of Y6-Y7 in comparison with those of the first time span of Y1-Y5 for the first candidate, it lost its rank and was ranked in the second place. The reduction of the fuzzy membership degrees of the profit criteria for candidate 1 in the time span of Y11-Y13 made it lose again its place in the ranking and it was ranked in the third place. Moreover, the small increase in the fuzzy membership degrees of the cost criteria for candidate 1 in the time span of Y16-Y20 did not change its rank in comparison with the one in the time span of Y11-Y13. As expected, the increase of the fuzzy membership degrees of the cost criteria for candidate 1 made it lose its place in the ranking and it was ranked in the last place.

Then, we analyzed the maximum values of the fuzzy membership degrees for all the criteria of candidate 1. The maximum values of the cost criteria for candidate 1 made it be ranked in the last place in the time span of Y21-Y25. The behavior change of candidate 1 in these time spans in comparison with no behavior change of the other candidates confirmed the impacts of profit and cost criteria in their rankings.

We were also interested to analyze the behavior change of candidate 5 in order to observe the improvement of its place in the ranking. *Table 14* shows the similarity coefficients (CC_i) and the ranking of the candidates according to the worst similarity for the time span of Y25-Y30 with the behavior change of candidates 1 and 5.

The decrease in the fuzzy membership degrees of the cost criteria for candidate 5, made this candidate be ranked in the second place as candidate 1 kept its membership values as in the last analysis.

The change in the rankings of the candidates according to their behavior change revealed the importance of the improvement of the profit criteria and the reduction of the cost criteria. As the candidates lost

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their appropriate characteristics and increased their inappropriate characteristics, they lost their place in the rankings.

Table 13. The similarity coefficients (CCi) and the ranking of the candidates according to the worst similarity for different time spans.

Time Spans/ Candidates	CC_i Y1-Y5	Ranking	CC_i Y6-Y7	Ranking	CC_i Y11-Y13	Ranking
C-1	1.00000000	1	0.76138319	2	0.5624454	2
C-2	0.74643277	2	0.84690711	1	0.88363263	3
C-3	0.48964851	3	0.58800964	3	0.59477793	1
C-4	0.29277736	4	0.34374949	4	0.36702603	4
C-5	0.23607616	5	0.25136886	5	0.25100868	5
Time Spans/ Candidates	**CC_i Y16-Y20**	**Ranking**	**CC_i Y21-Y24**	**Ranking**	**CC_i Y25-Y30**	**Ranking**
C-1	0.43940569	2	0.11530851	2	0.30840767	2
C-2	0.88070026	3	0.87406436	3	0.86800327	3
C-3	0.59582695	1	0.61226684	4	0.7304002	4
C-4	0.37472539	4	0.41694505	5	0.58087955	5
C-5	0.2493377	5	0.31089593	1	0.50952421	1

Table 14. The similarity coefficients (CCi) and the ranking of the candidates according to the worst similarity for the time span of Y25-Y30 (with the behavior change of candidates 1 and 5).

Candidates	CC_i	Ranking
C-1	0.27135808	2
C-2	0.83347546	5
C-3	0.67909256	3
C-4	0.53124602	4
C-5	0.74649548	1

3.2 | Results with Modified TOPSIS

Table 15 shows the similarity coefficients (CCi) and the ranking of the candidates according to the worst similarity with the first and second modifications of TOPSIS in the two left and two right columns, respectively.

Table 15. The similarity coefficients (CCi) and the ranking of the candidates according to the worst similarity with the first and second modifications of TOPSIS in the two left and two right columns, respectively.

Candidates	CC_i	Ranking	CC_i	Ranking
C-1	0.3084767	2	0.27135808	2
C-2	0.86800327	3	0.83347546	5
C-3	0.7304002	4	0.67909256	3
C-4	0.58087955	5	0.53124602	4
C-5	0.50952421	1	0.74649548	1

The results in this table also showed that the first modification of TOPSIS using the fuzzy membership degrees of the first time span of Y1-Y5 for candidate 1 gave the same results as the ones that we obtained for this candidate in the time span of Y25-Y30 and showed in *Table 13*. Moreover, the first modification in TOPSIS was efficient in order to not need any change in the fuzzy membership degrees of candidate 1. Therefore, this modification was efficient for changing these values without any change in the data.

The second modification of TOPSIS using the fuzzy membership degrees of the time span of Y1-Y5 for both candidates 1 and 5 gave the same results as the ones presented in *Table 13*. The second modification in TOPSIS was efficient in order to not need any change in the fuzzy membership degrees of candidates

1 and 5. Therefore, this modification was also efficient for changing these values without needing to do any change in the data.

3.3 | Results with Sensitive Analysis

We performed the sensitive analysis on the data that we analyzed with the unmodified TOPSIS presented above in two steps. First, we analyzed the impact of the modification of data in the evaluation matrix on the ranking of candidates. Then, we determined how the ranking of the candidates could change with the changes of the weight values and those of the types of criteria.

Table 16 shows the new evaluation matrix. In this table, the data in the last column for the third candidate were changed from 0.4 to 1.0 in comparison with the weights presented in *Table 4*.

Table 16. The new evaluation matrix for the first sensitive analysis.

Candidates/Criteria	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
C-1	1.0	1.0	1.0	1.0	0.0	0.0
C-2	1.0	1.0	1.0	0.7	0.0	0.2
C-3	1.0	0.6	0.9	0.9	0.2	1.0
C-4	1.0	0.8	1.0	0.8	0.5	0.5
C-5	0.7	0.8	0.4	0.6	0.6	0.3

Table 17 shows the ranking of candidates with TOPSIS after this modification.

Table 17. The ranking of candidates with TOPSIS for the first sensitive analysis.

Candidates	CC_i	Ranking
C-1	0.79628707	2
C-2	0.86554283	1
C-3	0.43913286	4
C-4	0.4595051	3
C-5	0.41647469	5

Table 18 shows the new matrix of weights. In this table, the weights of the first four columns were changed from 0.5 to 0.1 in comparison with the weights presented in *Table 7*.

Table 18. The matrix of weights for the second sensitive analysis.

Alternatives/Values	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
C1-C5	0.1	0.1	0.1	0.1	0.5	0.5

Table 19 shows the new matrix of criteria.

Table 19. The matrix of criteria for the second sensitive analysis.

Alternatives/Values	Creative	Attentive	Perseverant	Productive	Lazy	Unmotivated
C1-C5	True	True	False	False	False	False

In this table, the false values have been attributed to two criteria, perseverant and productive, which indicates that they are considered as cost criteria as their excess can make humans lose time and reduce their output.

Table 20 shows the ranking of candidates with TOPSIS after these modifications.

The results that we obtained with the sensitive analysis showed that the change in a data presented in the evaluation matrix or those in the values of weights or types of criteria could affect the output of TOPSIS. As expected, the rankings changed with these modifications. These results confirmed the robustness of this method that we used in this study.

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Table 20. The ranking of candidates with TOPSIS for the second sensitive analysis.

Candidates	CC_i	Ranking
C-1	0.93118765	1
C-2	0.75311467	2
C-3	0.46100335	3
C-4	0.12411629	5
C-5	0.24986587	4

Figs. 1 and *2* show the flowcharts of the unmodified and modified TOPSIS that we used in this study.

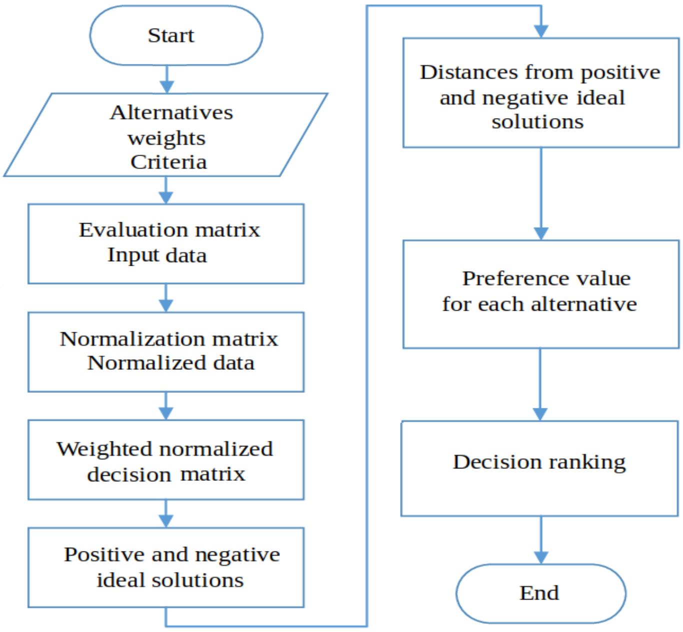

Fig. 1. Flowchart of the unmodified TOPSIS.

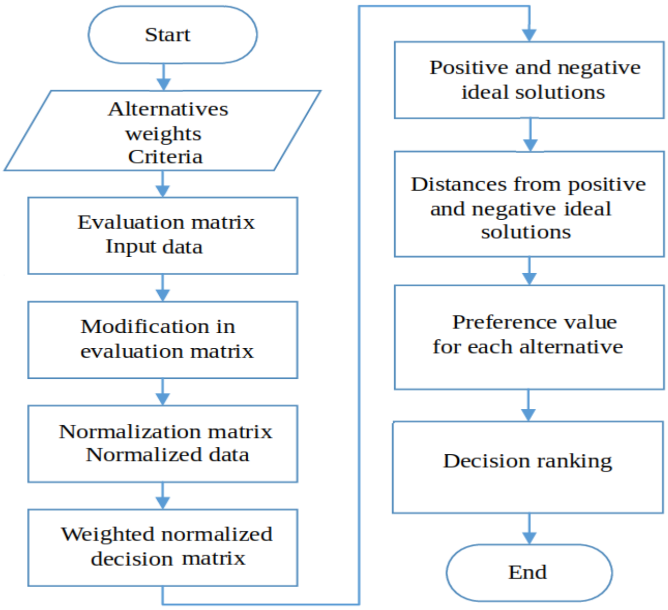

Fig. 2. Flowchart of the modified TOPSIS.

The comparison of *Figs. 1* and *2* show the difference between the unmodified and modified TOPSIS algorithms that appears in the first step of the preparation of the evaluation matrix including the entry data, which are the degrees of membership of the criteria for the alternatives, and before the second steps for their normalization by the preparation of the normalized matrix. In fact, the additional code lines that we presented in the preliminaries for the modified TOPSIS are applied in the first step of TOPSIS as shown in *Fig. 2*.

Table 21 presents the comparative information about TOPSIS and other decision-making methods.

Table 21. Comparison of TOPSIS with other decision-making methods.

Method	Characteristics		
	Calculation Level	Features	Output Results
VIKOR	Medium	Considers the importance of the optimal distance to the best and worst case in calculating the distances of the options.	The closer the coefficients to zero, the more important
TOPSIS	Medium	Considers the shortwst distance from the ideal answer and the farthest distance from the counter-ideal answer for the selected option.	The closer the coefficients to one, the more important
Electre	Complex	Non-rank method parallel comparison of criterisons and elimination of defeated criterions.	The more wins and losses, the more priority
SAW	Easy	Scoring method Ranking after weighting the used variables.	The closer the coefficients to one, the more important

The comparison of TOPSIS with other decision-making methods in *Table 21* shows that the computational level of this first method is medium. Moreover, it is a ranking method in which the ranking of alternatives is based on the calculation of the distances from positive and negative optimal solutions and not the weights.

The prediction of human behavior with TOPSIS that we used in this study has important merits and limitations. One of the merits of this method is that it is able to determine the best alternative according to the ranking. In fact, it determines the distances of each candidate from its best and worst ideal solutions to obtain the best alternative. This is the specificity of this method as no other decision making method determines the best alternative according to the calculations of these distances. Another advantage of TOPSIS is that it is sensitive to the changes of the entry data, their weights or criteria types. This helps determine the effect of any of these changes on the output of the algorithm. However, the limitations of this method should also be considered. One of its limitations is that without the determination of the types of criteria it is not possible to perform the numerical analysis for the prediction of human behavior with this method. Therefore, first it is necessary to determine which characteristics are profit and cost criteria and then indicate them with the terms true and false in the matrix of criteria, respectively. Another limitation is that the addition or modification of alternatives can change their ranking in the output of TOPSIS. In the current work, we first determined the types of criteria as profit and cost criteria and then we performed the numerical analysis with this algorithm in order to overcome the first limitation of this technique. As the addition of further alternatives or their modification was not required, we did not encounter the second limitation of this method. The analysis results presented in this paper can have important perspectives in cognitive science [22]-[27]. Buying behavior [28]-[34], competitiveness [35]-[38], performance [39]-[44], user activity [45]-[46], satisfaction [47]-[50] and conflicting objectives such as quality, cost, and delivery time [51]-[57], are various commercial issues that can be analyzed with TOPSIS. The human characteristics that we analyzed in this paper can have an impact on these aspects of human behavior. Our results can also be used in other fields such as nanotechnology, microelectronics, pure sciences and engineering [58]-[62]. TOPSIS can be used for the prediction of the performance of materials [63]-[68] according to their characteristics. The tendency of humans to use these materials can be predicted with this approach. Our results can also be used in robotics for the development of robots that could distinguish and analyze the cognitive disorder of humans [69]-[71].

It has been shown that emotion and perception have important impacts in human behavior [72]-[78]. The statistical analysis of data with TOPSIS has been used in several studies [79]-[85]. We will investigate these aspects of human behavior with this method in our future work.

4 | Conclusion

This paper presented the analysis results of applying TOPSIS in the prediction of human behavior for data optimization. The change in the fuzzy membership degrees of the candidates' characteristics revealed the influence of the profit and cost criteria on the rankings. In light of the results obtained in this paper, it can be concluded that the modifications on TOPSIS can make an appropriate prediction of human behavior without needing the modification of data for different time spans. The changes in the human characteristics have been taken into account in order to determine which one of them has an influence on the rankings. Ranking comparisons using unmodified and modified TOPSIS methods were made in order to validate the proposed analysis. From the results, this study has shown the efficacy of this method in the prediction of human behavior. For our future work, we aim to determine the pattern of the human behavior change according to the analyzed time spans for the characterization of human cognition. For this purpose, we will investigate the factors that influence the human cognition such as emotion, reason, imagination, etc. and the prediction of their effects with TOPSIS. This future work will help us obtain supplementary results to those that we presented in this paper. Moreover, we will investigate the stability of the human behavior according to these cognitive factors. This second work will lead to a better understanding of the predictions of their stability will TOPSIS in relation with these last ones.

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