# Simulation-based comparison of objective weighting methods

Üzeyir Fidan[1], Musab T. Akpınar[2]

[1] Uşak University, İzmir Yolu, Atatürk Blv. 8. Km, Uşak, Turkey
[2] Ankara Yıldırım Beyazıt University, Cinnah Cd. No:16, Ankara, Turkey

**Abstract**
Management information systems help decision-makers understand the consequences of their decisions. The increasing number of criteria in decision problems complicates the solution process of the problem at the same rate. This situation increases the interest in objective weighting methods that can reduce the transaction costs of decision-makers. This study focuses on comparing the results of objective criterion weighting methods, which have a very important place in multi-criteria decision-making methods. Thus, it is aimed to support the researchers' criteria weight determination and method selection process. To compare the methods, experiments were carried out by creating data sets suitable for normal distribution. The similarities/dissimilarities of the criterion weights obtained by different methods are discussed by evaluating the correlation coefficient and distance measure.

**Keywords**
Management information systems, DSS, objective weighting, decision, entropy, CRITIC, MEREC, similarity

## 1. Introduction

Developing information technologies and rapidly increasing competition increase the importance of computer-based decision-making systems. It is very difficult to make a decision based on many criteria in real-life problems without using a computer. Transferring decision problems to a computer environment reduces transaction and time costs for decision-makers.

Where decision-making involves individuals as well as society, management information systems facilitate social collaborative decision-making. Management information systems help decision-makers understand the consequences of their decisions [1]. Systems are designed to allow decision-makers to quickly identify trends that they cannot easily see. Management information systems help to make valid decisions by providing characteristics of information and providing analytical functions. It should be ensured that the management information system to be selected can work with the information formats available within the business and have the features it needs. Appropriate management information systems can structure key data from company operations and record it in reports to guide decisions [2].

When the decision management process is based on data from management information systems, they reflect the information that companies generate at the operational level. Management information systems take the data produced by the system and organize it into useful formats. Management information systems typically include sales figures, expenses, investments, and workforce data [3]. For example, if a company needs to know how much profit the company has made each year over the past five years to make a decision, management information systems can provide accurate reports that give this information.

The ability to run scenarios is an important decision-making tool [4]. Some management information systems have this feature built-in, while others may provide the information needed

IVUS 2022: 27th International Conference on Information Technology, May 12, 2022, Kaunas, Lithuania
EMAIL: uzeyir.fidan@usak.edu.tr (Ü. Fidan); musabtakpinar@gmail.com (M. T. Akpınar)
ORCID: 0000-0003-3451-4344 (Ü. Fidan); 0000-0003-4651-7788 (M. T. Akpınar)

to run scenarios in other applications, such as spreadsheets. Decisions are affected by what would happen if they were decided in a certain way [5]. What-if scenarios show how different variables change when a decision is made [6]. Any decision made will result in changes in projected company results and changes in business strategies and overall goals may be required. Management information systems either have a built-in trend analysis or can provide information that allows such analysis to take place [7]. Typical business strategies include projections for all key business outcomes.

The most important step in the decision-making process is determining the criteria' weight since they directly affect the result [8]. The criterion weights are also an indication of how important the relevant criterion is for the solution of the decision problem. The proposed methods for determining criterion weights are handled in three categories: objective weighting methods, subjective weighting methods, and hybrid weighting methods obtained by using these two together. Subjective weighting methods come to the fore as the approaches that the decision-maker can reflect all his experiences. On the other hand, as the number of criteria increases, the transaction costs that arise make it difficult to use these methods [9].

In objective weighting methods, which are also in and the focus of this study, decision-makers have no role in criterion weighting [8, 10]. Thus, a decision-making process can be realized depending on the internal dynamics of the data.

If the decision-maker wants to solve the problem by weighting according to the internal dynamics of the data without outside intervention, "Which objective weighting method should be used?" should answer the question. This study seeks to answer this question. Thus, it aims to help determine whether there is a difference between the objective weighting methods or the ideal objective weighting method.

## 2. Objective weighting methods

In the decision-making process, first of all, a decision matrix with alternatives and criteria is created. In the decision matrix, the rows show the alternatives and the columns show the criteria:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \qquad (1)$$

In Eq. 1, the decision matrix consisting of n alternatives and m criteria is represented.

The normalization operations given in Eq. 2 are applied to the criteria in the data matrix, based on whether their effects on the problem are benefit-based ($\mathcal{B}$) or non-benefit-based ($\mathcal{B}'$).

$$n_{ij} = \begin{cases} \dfrac{x_{ij}}{\max\limits_{k} x_{kj}} & if \quad j \in \mathcal{B} \\ \dfrac{\min\limits_{k} x_{kj}}{x_{ij}} & if \quad j \in \mathcal{B}' \end{cases} \qquad (2)$$

Thus, N normalized data matrix is obtained with the same size as the data matrix. Finally, the objective weights of the criteria can be calculated by applying mathematical operations for the normalized data matrix.

### 2.1. Equal weighting method

Although it is not dependent on the internal dynamics of the data, the equal weight method can also be shown as one of the objective weight methods, since it is determined without the intervention of the decision-maker.

The equal weight method is easily calculated by dividing the total weight by the number of criteria.

$$w_j = \frac{1}{m} \qquad (3)$$

In Eq. 3, $m$ represents the number of criteria in the decision matrix, and $w_j$ represents the weight of the j.criterion.

### 2.2. Entropy-based weighting method

The entropy-based criterion weighting method, which is frequently used in objective evaluation methods, is based on the use of information about the criteria in the decision matrix and their interactions [11, 12]. In the Entropy method, first of all, a probabilistic standardization is required for the criterion values in the normalized matrix. For this process:

$$P_{ij} = \frac{n_{ij}}{\sum_{i=1}^{n} n_{ij}} \qquad (4)$$

Entropy ($E_j$) value calculated with $P_{ij}$ value;

$$E_j = -\frac{\sum_{i=1}^{n} P_{ij}.\ln P_{ij}}{\ln n} \quad (5)$$

After the entropy value is calculated, the weight values of the criteria are easily calculated as in Eq. 6.

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{m}(1 - E_j)} \quad (6)$$

## 2.3. CRITIC

CRITIC (CRiteria Importance Through Inter-criteria Correlation) is an objective criterion weighting method that allows determining the relative importance of criteria [13]. First, the correlation between the criteria in the normalized matrix should be calculated. Pearson correlation as the data is produced according to the normal distribution:

$$\rho_{jk} = \frac{\sum_{i=1}^{m}\left(n_{ij} - \overline{n_j}\right).\left(n_{ik} - \overline{n_k}\right)}{\sqrt{\sum_{i=1}^{m}\left(n_{ij} - \overline{n_j}\right)^2 . \sum_{i=1}^{m}\left(n_{ik} - \overline{n_k}\right)^2}} \quad (7)$$

The information value ($C_j$) is calculated with the obtained correlation values.

$$C_j = \sigma_j . \sum_{k=1}^{n}(1 - \rho_{jk}) \quad (8)$$

Using the information values obtained for the criteria, the weights are calculated as in Eq. 9.

$$w_j = \frac{C_j}{\sum_{k=1}^{n} C_k} \quad (9)$$

## 2.4. Standard deviations-based weighting method

In the process of calculating weight with standard deviation, first of all, the standard deviation of each criterion must be calculated.

$$\sigma_j = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(n_i - \bar{n}_j)^2} \quad (10)$$

The calculated standard deviation values are converted to the weights of the criteria with the help of Eq. 11.

$$w_j = \frac{\sigma_j}{\sum_{j=1}^{m} \sigma_j} \quad (11)$$

## 2.5. MEREC

MEREC (Method based on the Removal Effects of Criteria) is an objective weighting method that uses a decision matrix to determine criterion weights [8, 14]. In the MEREC method, firstly the overall performance of the alternatives is calculated ($S_i$).

$$S_i = \ln(1 + (\frac{1}{m}\sum_{j} |\ln n_{ij}|)) \quad (12)$$

Then, the removal effect obtained by ignoring each criterion is calculated (Eq. 13).

$$S'_{ij} = \ln(1 + (\frac{1}{m}\sum_{k,k\neq j} |\ln n_{ik}|)) \quad (13)$$

The sum of the absolute deviations that occur with the removal effect is calculated with the help of Eq. 14.

$$E_j = \sum_{j} |S'_{ij} - S_i| \quad (14)$$

The criteria weights ($w_j$) are calculated using the removal effects ($E_j$).

$$w_j = \frac{E_j}{\sum_k E_k} \quad (15)$$

# 3. Numerical example

With the data obtained, the steps of forming the decision matrix and forming the normalized matrix are applied in common in all methods. After these steps, it was continued to determine the weights with different objective methods, to compare the correlations [15-17] and similarity values [18] of the weights obtained with these methods.

## 3.1. Data

In this section, a random data set consisting of 10 alternatives and 10 criteria was created, with a standard deviation of 1 and a mean of 10. This process was repeated 1000 times to avoid bias, and the data set was formed from the average data (see Table 1).

**Table 1**
Sample data

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $A_1$ | 10,0049 | 9,9980 | 10,0033 | 10,0121 | 10,0404 | 9,9708 | 9,9777 | 9,9904 | 9,9950 | 10,0005 |
| $A_2$ | 9,9939 | 10,0215 | 9,9753 | 9,9752 | 9,9937 | 9,9469 | 9,9806 | 9,9719 | 10,0798 | 9,9834 |
| $A_3$ | 10,0389 | 9,9953 | 9,9850 | 9,9818 | 10,0223 | 10,0004 | 9,9344 | 9,9754 | 9,9889 | 10,0372 |
| $A_4$ | 9,9999 | 10,0379 | 9,9724 | 10,0163 | 10,0616 | 10,0104 | 10,0272 | 9,9542 | 9,9790 | 10,0304 |
| $A_5$ | 10,0170 | 9,9550 | 10,0353 | 9,9412 | 10,0077 | 10,0256 | 10,0745 | 10,0251 | 9,9745 | 9,9943 |
| $A_6$ | 9,9916 | 10,0131 | 10,0024 | 10,0259 | 10,0730 | 9,9753 | 9,9857 | 10,0019 | 10,0314 | 10,0153 |
| $A_7$ | 10,0184 | 9,9952 | 9,9776 | 9,9912 | 9,9550 | 10,0085 | 10,0070 | 10,0089 | 9,9593 | 9,9646 |
| $A_8$ | 10,0095 | 9,9830 | 9,9794 | 10,0164 | 10,0314 | 10,0111 | 9,9932 | 10,0067 | 10,0070 | 9,9177 |
| $A_9$ | 10,0034 | 10,0025 | 9,9478 | 9,9828 | 10,0005 | 9,9590 | 10,0363 | 9,9991 | 10,0023 | 10,0004 |
| $A_{10}$ | 10,0613 | 9,9799 | 9,9845 | 9,9903 | 9,9816 | 10,0397 | 10,0020 | 9,9558 | 9,9763 | 10,0437 |

The data can be normalized according to various methods, but in this study, the normalization process is applied according to the mathematical notation in Eq. 2. The normalized data matrix is presented in Table 2.

**Table 2**
Normalized data

| | $C_1$ | $C_2$ | $C_3$ | $C_4$ | $C_5$ | $C_6$ | $C_7$ | $C_8$ | $C_9$ | $C_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| $A_1$ | 0,9944 | 0,9960 | 0,9968 | 0,9986 | 0,9968 | 0,9931 | 0,9904 | 0,9965 | 0,9916 | 0,9957 |
| $A_2$ | 0,9933 | 0,9984 | 0,9940 | 0,9949 | 0,9921 | 0,9908 | 0,9907 | 0,9947 | 1,0000 | 0,9940 |
| $A_3$ | 0,9978 | 0,9958 | 0,9950 | 0,9956 | 0,9950 | 0,9961 | 0,9861 | 0,9950 | 0,9910 | 0,9994 |
| $A_4$ | 0,9939 | 1,0000 | 0,9937 | 0,9990 | 0,9989 | 0,9971 | 0,9953 | 0,9929 | 0,9900 | 0,9987 |
| $A_5$ | 0,9956 | 0,9917 | 1,0000 | 0,9916 | 0,9935 | 0,9986 | 1,0000 | 1,0000 | 0,9896 | 0,9951 |
| $A_6$ | 0,9931 | 0,9975 | 0,9967 | 1,0000 | 1,0000 | 0,9936 | 0,9912 | 0,9977 | 0,9952 | 0,9972 |
| $A_7$ | 0,9957 | 0,9957 | 0,9943 | 0,9965 | 0,9883 | 0,9969 | 0,9933 | 0,9984 | 0,9880 | 0,9921 |
| $A_8$ | 0,9949 | 0,9945 | 0,9944 | 0,9991 | 0,9959 | 0,9972 | 0,9919 | 0,9982 | 0,9928 | 0,9875 |
| $A_9$ | 0,9942 | 0,9965 | 0,9913 | 0,9957 | 0,9928 | 0,9920 | 0,9962 | 0,9974 | 0,9923 | 0,9957 |
| $A_{10}$ | 1,0000 | 0,9942 | 0,9949 | 0,9964 | 0,9909 | 1,0000 | 0,9928 | 0,9931 | 0,9897 | 1,0000 |

## 3.2. Calculation of criteria weights

In this subsection, the weights of the criteria in the sample data set were calculated and compared with the methods mentioned in the study (Equal weighting, Entropy, CRITIC, Standard deviation, and MEREC) in Table 3.

**Table 3**
The criteria weights obtained as a result of the comparative analysis

| | Equal Weighting | Entropy | Critic | Standard Deviation | Merec |
|---|---|---|---|---|---|
| $w_1$ | 0,1000 | 0,0514 | 0,0791 | 0,0734 | 0,0939 |
| $w_2$ | 0,1000 | 0,0590 | 0,0827 | 0,0787 | 0,0789 |
| $w_3$ | 0,1000 | 0,0599 | 0,0733 | 0,0792 | 0,0973 |
| $w_4$ | 0,1000 | 0,0710 | 0,0846 | 0,0863 | 0,0647 |
| $w_5$ | 0,1000 | 0,1455 | 0,1087 | 0,1234 | 0,1114 |
| $w_6$ | 0,1000 | 0,1010 | 0,1006 | 0,1029 | 0,0892 |
| $w_7$ | 0,1000 | 0,1600 | 0,1319 | 0,1292 | 0,1440 |
| $w_8$ | 0,1000 | 0,0624 | 0,0876 | 0,0809 | 0,0719 |
| $w_9$ | 0,1000 | 0,1330 | 0,1291 | 0,1178 | 0,1594 |
| $w_{10}$ | 0,1000 | 0,1568 | 0,1225 | 0,1282 | 0,0893 |

The criteria weights of the methods other than the equal weight method show similar changes. The visualized form of criterion weights is presented in Fig. 1.

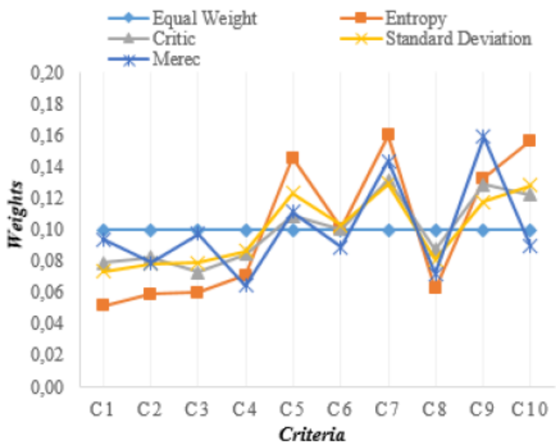


**Figure 1:** The weights of the comparative analysis

## 3.3. Comparison of objective weighting methods

In this subsection, the results of the criterion weighting operations performed on the data set consisting of 10 criteria and 10 alternatives produced by simulation are compared. Two methods were followed while making the comparison: the Pearson Correlation Coefficient (Eq. 17) and the dissimilarity values with the help of Euclidean Distances (Eq. 18).

$$W\rho_{jk} = \frac{\sum_{i=1}^{m}(w_{ij} - \bar{w}_j).(w_{ik} - \bar{w}_k)}{\sqrt{\sum_{i=1}^{m}(w_{ij} - \bar{w}_j)^2 . \sum_{i=1}^{m}(w_{ik} - \bar{w}_k)^2}} \quad (17)$$

$$D_{jk} = \sqrt{\sum_{i=1}^{n}(w_{ij} - w_{ik})^2} \quad (18)$$

Correlation values between objective criterion weighting methods are presented in Table 4.

**Table 4**
The correlation values of comparison in different methods

| | Equal Weight | Entropy | Critic | Standard Deviation |
|---|---|---|---|---|
| **Entropy** | 0,0000 | | | |
| **Critic** | 0,0000 | 0,9415 | | |
| **Standard Deviation** | 0,0000 | 0,9984 | 0,9435 | |
| **Merec** | 0,0000 | 0,8132 | 0,6565 | 0,8070 |

As can be seen in Fig. 1, although the equal weight method is included in the comparison process by being accepted among the objective weighting methods, it does not correlate with other weighting methods (Table 4).

Similar to the method used in the calculation of the correlations, the dissimilarities between the criterion weights obtained by different methods are calculated by Euclid Distance and presented in Table 5.

**Table 5**
The distance measure values of comparison in different methods

| | Equal Weight | Entropy | Critic | Standard Deviation |
|---|---|---|---|---|
| **Entropy** | 0,1340 | | | |
| **Critic** | 0,0655 | 0,0756 | | |
| **Standard Deviation** | 0,0682 | 0,0660 | 0,0226 | |
| **Merec** | 0,1061 | 0,0780 | 0,0802 | 0,0650 |

## 4. Conclusions

Determining the criterion weights in the multi-criteria decision-making process has a direct effect on the solution of the problem. Even if subjective weighting methods are claimed to be more successful in some decision situations where the number of criteria is low, objective weighting methods come to the fore due to both the low processing and time costs and the reliability of the characteristics of the data.

In this study, the relationship between the objective criterion weighting methods, which researchers frequently use in decision-making problems, was evaluated with the Pearson Correlation Coefficient, and the dissimilarity levels were evaluated with the Euclid Distance metric.

The first decision to focus on is the choice between the Equal Weighting Method and other methods [19]. Because the Equal Weighting Method can be thought of as not assigning a weight to any of the criteria. Comparison results in the study also support this idea. When the results of the correlation analysis are examined, the Equal Weighting Method has zero correlation with other methods.

Another situation that should be focused on is that the weight values obtained from the objective criterion weighting methods are different from each other. Therefore, although the decision process is tried to be managed objectively, the best possible scenario is to evaluate the weights obtained by different methods by experts.

## 5. References


[1] Shen, M., Carswell, M., Santhanam, R., & Bailey, K.. "Emergency management information systems: Could decision makers be supported in choosing display formats?," Decision Support Systems, 2012, 52(2), 318-330.

[2] Gurbaxani, V., & Whang, S. "The impact of information systems on organizations and markets," Communications of the ACM, 1991, 34(1), 59-73.

[3] Faccia, A., Mosteanu, N. R., Fahed, M., & Capitanio, F. "Accounting information systems and ERP in the UAE: an assessment of the current and future challenges to handle big data." 3rd International Conference on Cloud and Big Data Computing, 2019 (pp. 90-94).

[4] Thompson, B. P., & Bank, L. C. "Use of system dynamics as a decision-making tool in building design and operation," Building and Environment, 2010, 45(4), 1006-1015.

[5] Kahneman, D., Lovallo, D., & Sibony, O. "Before you make that big decision," 2011.

[6] Mittelstadt, B., Russell, C., & Wachter, S. "Explaining explanations in AI," In Proceedings of the conference on fairness, accountability, and transparency, 2019, (pp. 279-288).

[7] Urquhart, C., Lehmann, H., & Myers, M. D. "Putting the 'theory'back into grounded theory: guidelines for grounded theory studies," Information systems journal, 2010, 20(4), 357-381.

[8] Keshavarz-Ghorabaee, M., Amiri, M., Zavadskas, E. K., Turskis, Z., & Antucheviciene, J., "Determination of objective weights using a new method based on the removal effects of criteria (MEREC)," Symmetry, 2021, 13(4), 525.

[9] Alfares, H. K., & Duffuaa, S. O., "Simulation-based evaluation of criteria rank-weighting methods in multi-criteria decision-making," International Journal of Information Technology & Decision Making, 2016, 15(01), 43-61.

[10] Zardari, N. H., Ahmed, K., Shirazi, S. M., & Yusop, Z. B., "Weighting methods and their effects on multi-criteria decision-making model outcomes in water resources management," Springer, 2015.

[11] Odu, G. O., "Weighting methods for multi-criteria decision-making technique," Journal of Applied Sciences and Environmental Management, 2019, 23(8), 1449-1457.

[12] He, D., Xu, J., & Chen, X.," Information-theoretic-entropy based weight aggregation method in multiple-attribute group decision-making," Entropy, 2016, 18(6), 171.

[13] Diakoulaki, D., Mavrotas, G., & Papayannakis, L., "Determining objective weights in multiple criteria problems: The critic method," Computers & Operations Research, 1995, 22(7), 763-770.

[14] Rani, P., Mishra, A. R., Saha, A., Hezam, I. M., & Pamucar, D., "Fermatean fuzzy Heronian mean operators and MEREC-based additive ratio assessment method: An application to food waste treatment technology selection," International Journal of Intelligent Systems, 2022, 37(3), 2612-2647.

[15] Deng, H., Yeh, C. H., & Willis, R. J., "Inter-company comparison using modified TOPSIS with objective weights," Computers & Operations Research, 2000, 27(10), 963-973.

[16] Schmitt, N., "Comparison of subjective and objective weighting strategies in changing task situations," Organizational Behavior and Human Performance, 1978, 21(2), 171-188.

[17] Sałabun, W., Wątróbski, J., & Shekhovtsov, A., "Are MCDA methods benchmarkable? A comparative study of Topsis, Vikor, Copras, and Promethee II methods," Symmetry, 2020, 12(9), 1549.

[18] Fkih, F., "Similarity measures for Collaborative Filtering-based Recommender Systems: Review and experimental comparison," Journal of King Saud University-Computer and Information Sciences, 2021.

[19] Mukhametzyanov, I. "Specific character of objective methods for determining weights of criteria in MCDM problems: Entropy, CRITIC and SD," Decision Making: Applications in Management and Engineering, 2021, 4(2), 76-105.