Available online at
https://jcrinn.com/
https://crinn.conferencehunter.com/

e-ISSN : 2600-8793

Journal of Computing Research and Innovation 9(1) 2024

Journal of Computing Research and Innovation

Innovative Time and Attendance System Software Selection for a Private Hospital: Leveraging the Entropy-TOPSIS Method

Norazean Nordin[1], Eaisya Nurfarhana Samat[2], Fairuz Noraainaa Adam[3], Nor Faradilah Mahad [4*]

[1,2,3,4] *College of Computing, Informatics and Mathematics, Universiti Teknologi MARA Negeri Sembilan Branch, Seremban Campus, Persiaran Seremban Tiga/1, Seremban 3, 70300 Seremban, Negeri Sembilan*

ARTICLE INFO

Article history:
Received: 31 January 2024
Revised: 13 February 2024
Accepted: 13 February 2024
Online first: 1 March 2024
Published 1 March 2024

Keywords:
MCDM
Entropy
TOPSIS
Time and Attendance Software

DOI:
10.24191/jcrinn.v9i1.425

ABSTRACT

Automated time and attendance systems offer the capability to track employee attendance, calculate working days, overtime hours, and late arrivals, and generate comprehensive attendance reports, thereby improving workforce productivity. Investing in suitable time and attendance system software is crucial for a company since many businesses are adopting digital time and attendance systems that automatically collect and analyse data to increase productivity and efficiency. This decision-making process considers numerous contradictory criteria. Thus, for this study, the Multi-Criteria Decision Making (MCDM) methods, namely Entropy and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), were used to choose the best time and attendance system software for a private hospital. There were six (6) criteria used to evaluate the time and attendance system software. The criteria were categorised as cost $(D_1,\$)$, ease of use (D_2), being compatible with existing HR software and operating system (D_3), reporting capabilities (D_4), customer service (D_5), and scheduling capabilities (D_6). Meanwhile, the alternatives are labelled as S_1, S_2, S_3, S_4 and S_5. The outcomes showed that the ranking order for the criteria is $D_1 > D_6 > D_4 > D_2 > D_5 > D_3$ while the ranking order for the alternative is $S_5 > S_4 > S_2 > S_3 > S_1$, respectively. In conclusion, the Entropy-TOPSIS can be used to assess and rank the alternatives.

1.0 INTRODUCTION

An attendance record is used to determine the presence or absence of employees. Recorded information includes employees begin and end hours, as well as their respective departments (Tuş & Adalı, 2019). For all business organisations, employee attendance is a major factor because it has a direct impact on both the individual and the organisation's performance (Ebrahim et al., 2019). Only with adequate and reliable records and monitoring can we uncover the full extent of absenteeism (Tyagi, 2019). Therefore, it is crucial

[4*] Corresponding author. *E-mail address*: faradilah315@uitm.edu.my
https://doi.org/10.24191/jcrinn.v9i1

for companies to find an effective way to monitor employees' attendance. There are so many organisations that are going through technological advancements and process changes (Oloyede et al., 2013). According to Olagunju et al. (2018), an automated time and attendance system can monitor employees' presence, notifying them of their arrival and departure times. Additionally, it can calculate the employees' total working days, overtime hours, and instances of late arrival, and generate attendance reports. With technology, it is possible to increase productivity through time and attendance systems that monitor and compute data automatically (Oloyede et al., 2013). Therefore, to select the time and attendance system software, Multi-Criteria Decision Making (MCDM) methods were chosen in this study. The integrated Entropy-The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method is used to select the time and attendance system software problem of a private hospital.

A time and attendance system can be either manual or automated. However, manual systems are not effective at keeping employees updated with information and evaluating their performance or working hours (Oo et al., 2018). Traditional methods of staff attendance, such as having employees sign attendance sheets upon entering an organisation, contribute to the low productivity of the organisation, although different market sectors have different impacts on staff absenteeism and staff lateness (Adewole et al., 2014). It is evident that by introducing time and attendance systems software that automatically monitors and analyses data, buddy punching and absenteeism can be reduced, and a company's productivity can be increased. As part of the MCDM method, the Entropy-TOPSIS method is employed for complex decisions that require the consideration of multiple criteria. The TOPSIS method is one of the commonly used methods to solve the MCDM problem. However, this method has a drawback. The major weakness of TOPSIS can be seen since this method does not offer weight elicitation (Roszkowska, 2013). The TOPSIS method requires criterion weights to be known but provides no instructions for calculating them (Dwivedi & Sharma, 2023). Thus, the weighting method is required to solve the TOPSIS method problem, and the weighting method can be defined based on static analysis, and their findings typically only represent the intuition or perception of those making the decisions at the time of analysis (Tzeng et al., 1998).

Zhang et al. (2022) assert that TOPSIS and Entropy methods have numerous advantages. An important characteristic of the Entropy method is its ease of calculation. It is an objective weighting method that overcomes the disadvantages of subjective weighting and provides a more accurate assessment of the importance of each MCDM indicator. The concept of Entropy can be applied to the decision-making process effectively because it quantifies the disparities across data sets and clarifies the average intrinsic information that was conveyed to the decision-maker (Hafezalkotob & Hafezalkotob, 2015). As a result, combining both Entropy and TOPSIS would ensure unbiased, precise, and stable results (Goswami et al., 2022).

In conclusion, this study integrates the Entropy method with TOPSIS to select the most suitable time and attendance system software based on the multiple criteria that are often in conflict. This paper contains five (5) sections. The introduction is the first section, and the literature review follows. The next section is the methodology that presents the framework of the Entropy-TOPSIS method. Section four contains results and discussions. The conclusion and suggestions are presented in the final section.

2.0 LITERATURE REVIEW

A review of the literature and the background theory of the Entropy method and the TOPSIS method are included in this section.

2.1 Entropy Method

One of the objective fixed-weight methods that uses a significant amount of information to calculate the weight of criteria is the Entropy weight method, which Shannon introduced in 1948 (Li et al., 2011). Shannon (1948) created this approach, which uses a discrete probability distribution to assess the

https://doi.org/10.24191/jcrinn.v9i1

uncertainties associated with the source of information. In information theory, Entropy is a measure of uncertainty, where the smaller the information quantity, the higher the uncertainty, and the lower the Entropy (Zhang et al., 2022). According to Abdullah and Otheman (2013), the higher the Entropy value, the lower the Entropy weight, and the smaller the different alternatives in this specific attribute, the less information the specific attribute provides and the less important the specific attribute becomes. In a straightforward and simple manner, the Entropy approach is able to measure the sources of information about the importance of each criterion and determine the relative weights $(w_1, w_2, \ldots, w_m)$ (Srdjevic et al., 2004).

The weights of criteria are vital in addressing MCDM issues, and sometimes applying unreasonable weights will lead to impractical outcomes (Luo et al., 2019). The Entropy technique is used to calculate the criteria weights because it provides a data-driven and objective method for determining the relative importance of criteria, especially when explicit information or subjectivity is lacking in the decision-making process (Alamri et al., 2024). This approach is established as adequately consistent in identifying together the contrast, intensity, and divergence of responses in addition to figuring their weights suitably (Kumar et al., 2021). However, the Entropy method does not give scope to designers' preferences, and weights based solely on Entropy values would not appear sufficient without expert judgment (Zardari et al., 2015).

A review of previous studies using the Entropy approach to solve different MCDM methods is presented in Table 1. Goswami and Behera (2020) used Entropy – Additive Ratio Assessment (ARAS) method to choose the best material among seven alternatives for engineering applications based on six criteria: bending fatigue limit, core hardness, cost, surface hardness, ultimate tensile strength, and surface fatigue limit. Meanwhile, Fajdek-Bieda (2021) used Entropy – VIKOR method in chemical process optimisation. In this study, three parameters were tested, which were process temperature, catalyst concentration, and reaction time. On the other hand, Haq et al. (2023) proposed an innovative framework to handle objective and subjective criteria simultaneously with crisp inputs by combining Interval-Valued Neutrosophic Sets (IVNSs) and the Entropy – MAIRCA framework to select the best sustainable material.

Table 1. The application of the Entropy method

Author(s)	Methodologies	Application
Goswami and Behera (2020)	Entropy – Aras	Selection of best engineering materials.
Fajdek-Bieda (2021)	Entropy – VIKOR	Chemical processes optimization.
Haq et al. (2023)	Entropy – MAIRCA integrated with IVNSs	Sustainable material selection.

2.2 TOPSIS Method

The TOPSIS method was discovered by Hwang and Yoon (1981). This method will choose the alternative that has the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. According to Wang and Lee (2007), the positive ideal solution maximises benefit criteria and minimises cost criteria. In contrast, the negative ideal solution is the solution that maximises the cost criteria and minimises the benefit criteria. From here on, it is found that TOPSIS is an effective method for decision-making because of its efficiency and capacity to rank alternative priorities using ordinary mathematical logic, which has no requirement for pairwise comparisons or consistency tests (Elsayed et al., 2017).

In fact, the TOPSIS method is used due to its straightforward, easy-to-understand concept and ease of application (Zeleny, 2012). TOPSIS method is rational and relatively simple since the decision matrix is evaluated in several steps, starting with normalising columns, then multiplying values by the weighted criteria in each column (Triantaphyllou & Lin, 1996). In addition, it is important to note that this method is capable of rapidly identifying which alternative is the best among the available alternatives, is computationally efficient, and can measure the relative performance of each alternative in a simple

https://doi.org/10.24191/jcrinn.v9i1

mathematical form (Thakkar, 2021). Moreover, the TOPSIS method can assist decision-makers in organising issues to be solved and doing analysis, comparisons, and alternative ranking (Shih et al., 2007). As a result, an appropriate alternative(s) will be chosen that fits the goals and objectives.

Table 2 depicts a summary of the past research on the TOPSIS method in literature. These studies integrate TOPSIS with other methods. For instance, Wang and Chang (2007) used the fuzzy TOPSIS method to rank the optimal initial training aircraft. Meanwhile, Ramezani et al. (2011) applied the hybridisation method of Goal Programming-TOPSIS to optimise the concepts of non-dominated solutions and prediction intervals. Furthermore, Lan et al. (2023) proposed employing the Analytic Network Process (ANP)-TOPSIS model to address tourist destination selection issues in a temporal neutrosophic setting. The paper proposes the Temporal Complex Neutrosophic Set (TCNS)-ANP-TOPSIS model. The ANP method is used to determine the weights of the criteria based on the relationship between the requirements and the criteria group in the temporal complex neutrosophic environment and TOPSIS to rank alternatives collected from different time intervals. In addition, Yadav et al. (2023) employed the improved MEREC-TOPSIS method to choose the best network in 5G heterogeneous networks for the Internet of Things (IoT). The improved MEREC figures out the priority weight of handover decision attributes by removing the effect that each attribute has on the performance of the candidate network. TOPSIS then figures out the ranking of the available networks.

Table 2 contains multiple studies in which the TOPSIS methodology is used with various weighting methods to address MCDM issues. Thus, in this paper, TOPSIS is integrated with another weighting method, the Entropy method, to be used in the TOPSIS framework.

Table 2. Application of TOPSIS method

Author(s)	Methodologies	Application
Wang and Chang (2007)	Fuzzy TOPSIS	Selection of best engineering materials.
Ramezani et al. (2011)	A goal programming – TOPSIS	Sustainable material selection.
Lan et al. (2023)	TCNS – ANP – TOPSIS	Tourist destination
Yadav et al. (2023)	Improved MEREC – TOPSIS	Selecting the optimal network in 5G heterogeneous network for IoT.

3.0 METHODOLOGY

For this study, the weights of the criteria are calculated using the Entropy approach. As an objective weighting method, Entropy has higher reliability and accuracy than the subjective weighting method (Zhang et al., 2022). The following are the steps involved in applying the Entropy method (Huang, 2008):

Step 1: Set up a decision matrix, X as follows:

$$X = \begin{pmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{pmatrix}; \ i = 1, 2, \ldots, m \text{ alternatives}, j = 1, 2, \ldots, n \text{ criteria} \quad (1)$$

Step 2: Normalise the decision matrix by using Eq.(2) for both cost and benefit criteria.

$$t_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}}; \ i = 1, 2, \ldots, m \text{ alternatives}, j = 1, 2, \ldots, n \text{ criteria} \quad (2)$$

https://doi.org/10.24191/jcrinn.v9i1

Thus, a normalised decision matrix representing the relative performance of the alternatives is formed, as shown as follows:

$$T = \left(t_{ij}\right)_{m\times n};\ i = 1,2,\dots,m \text{ alternatives}, j = 1,2,\dots,n \text{ criteria} \tag{3}$$

Step 3: Calculate the Entropy value for the j^{th} criterion (E_j) by using:

$$E_j = -\frac{1}{\ln m}\sum_{i=1}^{m} t_{ij}\ln t_{ij};\ i = 1,2,\dots,m \text{ alternatives}, j = 1,2,\dots,n \text{ criteria} \tag{4}$$

where m is the number of alternatives.

Step 4: Calculate the Entropy weight of the j^{th} criterion (w_j) by using:

$$w_j = \frac{1-E_j}{\sum_{j=1}^{n}\left(1-E_j\right)};\ j = 1,2,\dots,n \text{ criteria} \tag{5}$$

where $1-E_j$ refers to the degree of diversity of the information contained by each j^{th} criterion.

The weights determined by the Entropy method were further used as the input in the framework of TOPSIS in order to choose the best alternatives. The TOPSIS method can be implemented as follows (Jahanshahloo et al., 2006):

Step 1: Consider the decision matrix, X as shown in Eq. (1).

Step 2: Normalise the decision matrix by using Eq. (6) for both cost and benefit criteria.

$$t_{ij} = \frac{y_{ij}}{\sqrt{\sum_{i=1}^{m}\left(y_{ij}\right)^2}};\ i = 1,2,\dots,m \text{ alternatives}, j = 1,2,\dots,n \text{ criteria} \tag{6}$$

Thus, a normalised decision matrix,

$$N = \left(t_{ij}\right)_{m\times n};\ i = 1,2,\dots,m \text{ alternatives}, j = 1,2,\dots,n \text{ criteria} \tag{7}$$

is formed.

Step 3: The weighted normalised decision matrix, V is constructed as follows:

$$V = \left(v_{ij}\right)_{m\times n} = w_j t_{ij};\ i = 1,2,\dots,m \text{ alternatives}, j = 1,2,\dots,n \text{ criteria} \tag{8}$$

where w_j is the weight of the j^{th} criterion and $\sum_{j=1}^{n} w_j = 1.$

Step 4: Determine the positive ideal solution (PIS) and negative ideal solution (NIS), respectively, as follows:

$$A^+ = \left\{v_1^+,\dots,v_n^+\right\} = \left\{\left(\max_j v_{ij} \mid i \in I\right),\left(\min_j v_{ij} \mid i \in J\right)\right\} \tag{9}$$

https://doi.org/10.24191/jcrinn.v9i1

$$A^{-} = \left\{ v_1^{-}, \ldots, v_n^{-} \right\} = \left\{ \left(\min_j v_{ij} \mid i \in I \right), \left(\max_j v_{ij} \mid i \in J \right) \right\} \tag{10}$$

where I is associated with benefit criteria and J is associated with cost criteria.

Step 5: Calculate the separation measures using the n-dimensional Euclidean distance. The separation of each alternative from the PIS is given as Eq. (11), meanwhile the separation of each alternative from the NIS is given as eq. (12), respectively.

$$S_i^{+} = \left\{ \sum_{j=1}^{n} \left(v_{ij} - v_j^{+} \right)^2 \right\}^{\frac{1}{2}}; \; i = 1, 2, \ldots, m \text{ alternatives} \tag{11}$$

$$S_i^{-} = \left\{ \sum_{j=1}^{n} \left(v_{ij} - v_j^{-} \right)^2 \right\}^{\frac{1}{2}}; \; i = 1, 2, \ldots, m \text{ alternatives} \tag{12}$$

Step 6: Calculate the relative closeness coefficient for each alternative (CC_i) using:

$$CC_i = \frac{S_i^{-}}{S_i^{+} + S_i^{-}}; \; i = 1, 2, \ldots, m \text{ alternatives} \tag{13}$$

Step 7: Rank the alternatives.

In this study, the data about the selection of the suitable time and attendance system software for a private hospital in Türkiye (Tuş & Adalı, 2019) is used to implement the Entropy-TOPSIS method. A committee consisting of two employees from the Human Resources (HR) department and two employees from the information technology department was established to evaluate the alternative based on the criteria. The committee listed out all five (5) different time and attendance software, which were S_1, S_2, S_3, S_4 and S_5. Then, there were six (6) criteria that were evaluated to select the best time and attendance system software. The criteria considered were: cost $(D_1, \$)$, ease of use (D_2), being compatible with existing HR software and operating system (D_3), reporting capabilities (D_4), customer service (D_5) and scheduling capabilities (D_6). The criteria were separated into costs (inefficiency) and benefits (efficiency), so that D_1 was classified as cost criterion, while others were classified as benefit criteria. Since the last five criteria are qualitative, each alternative was evaluated using a 5-point scale (5: Excellent, 4: Very good, 3: Good, 2: Fair, 1: Poor) based on these criteria as the values can be seen in Table 3. Moreover, Microsoft Excel was used to analyse the data.

https://doi.org/10.24191/jcrinn.v9i1

Table 3. The decision matrix

Weightage	0.56239	0.07041	0.03539	0.13237	0.05521	0.14424
Alternatives	D_1	D_2	D_3	D_4	D_5	D_6
S_1	5000	3	3	4	3	2
S_2	680	5	3	2	2	1
S_3	2000	3	2	3	4	3
S_4	600	4	3	1	2	2
S_5	800	2	4	3	3	4

4.0 RESULTS AND DISCUSSION

This section includes the results and discussion of the weight and rank of the criteria and the rank of the alternatives.

4.1 Weightage and rank of criteria

Table 4. Weight and ranking for criteria by using the Entropy and CRITIC methods

Criteria		Entropy Weight, w_j		CRITIC Weight, w_j	
		Weight	Rank	Weight	Rank
D_1	Cost	0.56239	1	0.157	3
D_2	Ease of use	0.07041	4	0.249	1
D_3	Being compatible with existing HR software and operating system	0.03539	6	0.168	2
D_4	Reporting capabilities	0.13237	3	0.121	6
D_5	Customer services	0.05521	5	0.154	4
D_6	Scheduling capabilities	0.14424	2	0.151	5
Sum		1		1	

In this study, the Entropy method was applied to compute the weights of the criterion. The data used was about the time and attendance system software selection problem for a private hospital in Türkiye (Tuş & Adalı, 2019). This data has six (6) criteria considered in selecting the time and attendance system software, and all the weights of the criteria were determined by the authors using the CRITIC method.

Table 4 shows the weight of each criterion by using both the Entropy and CRITIC methods. Following the use of the Entropy approach to establish the weight of the criterion, the ranking order for criteria was $D_1 > D_6 > D_4 > D_2 > D_5 > D_3$. It can be observed that the cost (D_1) criterion has been chosen as the best criterion, and being compatible with existing HR software and operating system (D_3) criterion has the least weightage in the case of the Entropy method. Using the CRITIC method, the criteria were ranked in the order $D_2 > D_3 > D_1 > D_5 > D_6 > D_4$. Tuş and Adalı (2019) used the CRITIC method to compute the weight of each criterion. Notably, the best criteria selected for the CRITIC method is the ease of use (D_2) criterion and reporting capabilities (C_4) criterion is chosen as the least preferred criteria. Both techniques employed distinct mathematical models, therefore it is understandable that they will generate different results. The

https://doi.org/10.24191/jcrinn.v9i1

cost (C_1) criterion is the most preferred weight for the Entropy method and the ease of use (C_2) criterion is the most preferred weight for the CRITIC method.

4.2 The ranking of alternatives

Table 5 shows the ranking of alternatives for the Entropy-TOPSIS method and the CRITIC-WASPAS method. The ranking order of Entropy-TOPSIS method is $S_5 > S_4 > S_2 > S_3 > S_1$. However, in the case of the CRITIC-WASPAS method, there have been some slight changes in the ranking order where the positions of S_2 and S_4 have swapped with each other. Thus, the ranking order of the CRITIC-WASPAS method is $S_5 > S_2 > S_4 > S_3 > S_1$. The relative value of the alternatives for the CRITIC-WASPAS method depends on the value of the coefficient, when $\lambda = 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0$. It can be noted that the value of the coefficient λ does not affect the change in the rank of the alternative and retains the ranking. Moreover, in both methods, S_1 and S_3 seems to be the least preferred alternatives.

Table 5. Ranking of alternatives by using the Entropy – TOPSIS method and the CRITIC – WASPAS method

S_i	Entropy-TOPSIS		CRITIC-WASPAS (Tuş & Adalı, 2019)
	CC_i	Rank	Rank
S_1	0.13343	5	5
S_2	0.83432	3	2
S_3	0.67941	4	4
S_4	0.84413	2	3
S_5	0.91500	1	1
Sum	3.40628		

This finding may be affected by the high cost of S_1 and S_3 specifically \$5000 and \$2000, respectively. Both methods have agreed that S_5 is the best software for the private hospital. This result might be a result of the alternative receiving a high score when compared to compatibility with existing HR software and operating systems (D_3) criterion and scheduling capabilities (D_6) criterion. Also, cost (D_1) criterion offered by S_5 makes it the third-lowest price among other alternatives. Therefore, by using the Entropy-TOPSIS method and the CRITIC-WASPAS method, S_5 was selected as the best time and attendance system software in a private hospital.

5.0 CONCLUSION AND RECOMMENDATIONS

This study used the Entropy-TOPSIS hybridisation method to solve a time and attendance system software selection problem for a private hospital in Türkiye. The Entropy method determined criteria weight, while TOPSIS ranked the software. Multiple alternatives were evaluated using qualitative and quantitative methodologies. Microsoft Excel was used for Entropy weight determination and TOPSIS evaluation. The combined method was found to be feasible and effective. From the results obtained, S_5 was the most favourable time and attendance system software and S_1 was the least favourable. This research proposes a hybrid decision-making model, the Entropy-TOPSIS method, to address complex time and attendance system software selection problems in a private hospital in Türkiye. The study emphasises the importance of effective evaluation methods in achieving quality decision-making, demonstrating the effectiveness of the Entropy-TOPSIS method.

https://doi.org/10.24191/jcrinn.v9i1

For future studies, it is recommended to adopt any weighting methods, such as the Analytic Hierarchy Process (AHP) for time and attendance system software selection. AHP uses paired comparisons for both discrete and continuous scales (Saaty, 1987), breaking the general method into easier-to-evaluate sub-problems (Alonso & Lamata, 2006). Consistency tests are conducted to ensure expert inputs are consistent. It is also recommended to assess the issues in a fuzzy environment. Fuzzy TOPSIS, developed upon TOPSIS, addresses MCDM problems in a fuzzy environment and balances uncertainty in human judgement data (Chen, 2000). It is simple and straightforward to use in solving MCDM problems with imprecise data (Rajak & Shaw, 2019). Therefore, Fuzzy TOPSIS should be considered for time and attendance software system selection.

6.0 ACKNOWLEDGEMENTS

The authors would like to thank Universiti Teknologi Mara (UiTM) Cawangan Negeri Sembilan, Kampus Seremban, for their facilities and support in completing this research.

7.0 CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts.

8.0 AUTHORS' CONTRIBUTIONS

Norazean, Eaisya Nurfarhana, and Fairuz Noraainaa designed the research framework, carried out the research, and wrote the article; Nor Faradilah oversaw the research process and reviewed and approved the article submission.

9.0 REFERENCES

Abdullah, L., & Otheman, A. (2013). A new entropy weight for sub-criteria in interval Type-2 Fuzzy TOPSIS and its application. *International Journal of Intelligent Systems and Applications*, *5*(2), 25–33. https://doi.org/10.5815/ijisa.2013.02.03

Adewole, K. S., Abdulsalam, S. O., Babatunde, R. S., Shittu, T. M., & Oloyede, M. O. (2014). Development of fingerprint biometric attendance system for non-academic staff in a tertiary institution. *Computer Engineering and Intelligent Systems*, *5*(2), 62–70.

Alamri, F. S., Saeed, M. H., & Saeed, M. (2024). A hybrid entropy-based economic evaluation of hydrogen generation techniques using Multi-Criteria Decision Making. *International Journal of Hydrogen Energy*, 49, 711-723.

Alonso, J. A., & Lamata, M. T. (2006). Consistency in the analytic hierarchy process: a new approach. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, *14*(4), 445–459.

Chen, C.-T. (2000). Extensions of the TOPSIS for group decision-making under fuzzy environment. *Fuzzy Sets and Systems*, *114*, 1–9. www.elsevier.com/locate/fss

Dwivedi, P. P., & Sharma, D. K. (2023). Evaluation and ranking of battery electric vehicles by Shannon's entropy and TOPSIS methods. *Mathematics and Computers in Simulation*, *212*, 457–474. https://doi.org/10.1016/j.matcom.2023.05.013

Ebrahim, M. A., Bader, J., & Sankar, J. P. (2019). Attendance management and employee performance among selected commercial banks in the Kingdom of Bahrain. *International Journal of Economics, Commerce and Management United Kingdom, VII*(12), 761–762.

Elsayed, A. K., Dawood, A. S., & Karthikeyan, R. (2017). Evaluating alternatives through the application of TOPSIS method with entropy weight. *International Journal of Engineering Trends and Technology*, *46*, 60–66. https://doi.org/10.14445/22315381/IJETT-V46P211

Fajdek-Bieda, A. (2021). Using Entropy-VIKOR method in chemical processes optimization. *Procedia Computer Science*, *192*, 4208–4217. https://doi.org/10.1016/j.procs.2021.09.197

Goswami, S. S., & Behera, D. K. (2020). Implementation of ENTROPY-ARAS decision making methodology in the selection of best engineering materials. *Materials Today: Proceedings*, *38*, 2256–2262. https://doi.org/10.1016/j.matpr.2020.06.320

Goswami, S. S., Jena, S., & Behera, D. K. (2022). Selecting the best AISI steel grades and their proper heat treatment process by integrated entropy-TOPSIS decision making techniques. *Materials Today: Proceedings*, *60*, 1130–1139. https://doi.org/10.1016/j.matpr.2022.02.286

Hafezalkotob, A., & Hafezalkotob, A. (2015). Extended MULTIMOORA method based on Shannon entropy weight for materials selection. *Journal of Industrial Engineering International*, *12*(1), 1–13. https://doi.org/10.1007/s40092-015-0123-9

Haq, R. S. U., Saeed, M., Mateen, N., Siddiqui, F., & Ahmed, S. (2023). An interval-valued neutrosophic based MAIRCA method for sustainable material selection. *Engineering Applications of Artificial Intelligence*, *123*, 106177. https://doi.org/10.1016/j.engappai.2023.106177

Huang, J. (2008). Combining entropy weight and TOPSIS method for information system selection. *2008 IEEE Conference on Cybernetics and Intelligent Systems* (pp. 1281–1284). https://doi.org/10.1109/ICCIS.2008.4670971

Hwang, C.-L., & Yoon, K. (1981). Methods for Multiple Attribute Decision Making. In *Multiple Attribute Decision Making: Methods and Applications A State-of-the-Art Survey* (pp. 58–191). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-48318-9_3

Jahanshahloo, G. R., Lotfi, F. H., & Izadikhah, M. (2006). Extension of the TOPSIS method for decision-making problems with fuzzy data. *Applied Mathematics and Computation*, *181*(2), 1544–1551. https://doi.org/10.1016/j.amc.2006.02.057

Kumar, R., Singh, S., Bilga, P. S., Singh, J., Singh, S., Scutaru, M. L., & Pruncu, C. I. (2021). Revealing the benefits of entropy weights method for multi-objective optimization in machining operations: A critical review. *Journal of materials research and technology*, 10, 1471-1492.

Lan, L. T. H., Hien, D. T. T., Thong, N. T., Smarandache, F., & Giang, N. L. (2023). An ANP-TOPSIS model for tourist destination choice problems under Temporal Neutrosophic environment [Formula presented]. *Applied Soft Computing*, *136*. https://doi.org/10.1016/j.asoc.2023.110146

Li, X., Wang, K., Liuz, L., Xin, J., Yang, H., & Gao, C. (2011). Application of the entropy weight and TOPSIS method in safety evaluation of coal mines. *Procedia Engineering*, *26*, 2085–2091. https://doi.org/10.1016/j.proeng.2011.11.2410

https://doi.org/10.24191/jcrinn.v9i1

Luo, L., Zhang, C., & Liao, H. (2019). Distance-based intuitionistic multiplicative MULTIMOORA method integrating a novel weight-determining method for multiple criteria group decision making. *Computers and Industrial Engineering*, *131*, 82–98. https://doi.org/10.1016/j.cie.2019.03.038

Olagunju, M., Adeniyi, A. E., & Oladele, T. O. (2018). Staff attendance monitoring system using fingerprint biometrics general terms. *International Journal of Computer Applications*, *179*(21), 975–8887.

Oloyede, M. O., Adedoyin, A. O., & Adewole, K. S. (2013). Fingerprint biometric authentication for enhancing staff attendance system. *International Journal of Applied Information Systems*, *5*(3), 19–24. https://doi.org/10.5120/ijais12-450867

Oo, S. B., Oo, N. H. M., Chainan, S., Thongniam, A., & Chongdarakul, W. (2018). Cloud-based Web application with NFC for employee attendance management system. *2018 International Conference on Digital Arts, Media and Technology (ICDAMT)* (162–167).

Rajak, M., & Shaw, K. (2019). Evaluation and selection of mobile health (mHealth) applications using AHP and fuzzy TOPSIS. *Technology in Society*, *59*, 101186. https://doi.org/10.1016/j.techsoc.2019.101186

Ramezani, M., Bashiri, M., & Atkinson, A. C. (2011). A goal programming-TOPSIS approach to multiple response optimization using the concepts of non-dominated solutions and prediction intervals. *Expert Systems with Applications*, *38*(8), 9557–9563. https://doi.org/10.1016/j.eswa.2011.01.139

Roszkowska, E. (2013). Rank ordering criteria weighting methods – A comparative overview. *Optimum. Studia Ekonomiczne*, *5(65)*, 14–33. https://doi.org/10.15290/OSE.2013.05.65.02

Saaty, R. W. (1987). The analytic hierarchy process-what it is and how it is used. *Mathematical Modelling*, *9*(5), 161–176.

Shannon, C. E. (1948). A Mathematical theory of communication. *The Bell System Technical Journal*, 27, 623–656.

Shih, H. S., Shyur, H. J., & Lee, E. S. (2007). An extension of TOPSIS for group decision making. *Mathematical and Computer Modelling*, *45*(7–8), 801–813. https://doi.org/10.1016/J.MCM.2006.03.023

Srdjevic, B., Medeiros, Y. D. P., & Faria, A. S. (2004). An objective multi-criteria evaluation of water management scenarios. *Water Resources Management*, *18*, 35–54.

Thakkar, J. J. (2021). Technique for Order Preference and Similarity to Ideal Solution (TOPSIS). In *Multi-Criteria Decision Making* (pp. 83–91). Springer Singapore. https://doi.org/10.1007/978-981-33-4745-8_5

Triantaphyllou, E., & Lin, C.-T. (1996). *Development and Evaluation of Five Fuzzy Multiattribute Decision-Making Methods*.

Tuş, A., & Adalı, E. A. (2019). The new combination with CRITIC and WASPAS methods for the time and attendance software selection problem. *OPSEARCH*, *56*(2), 528–538. https://doi.org/10.1007/s12597-019-00371-6

https://doi.org/10.24191/jcrinn.v9i1

Tyagi, M. (2019). Effect of HR interventions based on Biometric Attendance System records to improve Employee Absenteeism. *Journal of the Academy of Hospital Administration*, *31*(2), 5–13.

Tzeng, G. H., Chen, T. Y., & Wang, J. C. (1998). A weight-assessing method with habitual domains. *European Journal of Operational Research*, *110*(2), 342–367. https://doi.org/https://doi.org/10.1016/S0377-2217(97)00246-4

Wang, T. C., & Chang, T. H. (2007). Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment. *Expert Systems with Applications*, *33*(4), 870–880. https://doi.org/10.1016/j.eswa.2006.07.003

Wang, Y. J., & Lee, H. S. (2007). Generalizing TOPSIS for fuzzy multiple-criteria group decision-making. *Computers and Mathematics with Applications*, *53*(11), 1762–1772. https://doi.org/10.1016/j.camwa.2006.08.037

Yadav, A. K., Singh, K., Srivastava, P. K., & Pandey, P. S. (2023). I-MEREC-T: Improved MEREC-TOPSIS scheme for optimal network selection in 5G heterogeneous network for IoT. *Internet of Things*, *22*, 100748. https://doi.org/10.1016/j.iot.2023.100748

Zardari, N. H., Ahmed, K., Shirazi, S. M., & Yusop, Z. Bin. (2015). *Weighting Methods and their Effects on Multi-Criteria Decision Making Model Outcomes in Water Resources Management*. Springer International Publishing. https://doi.org/10.1007/978-3-319-12586-2

Zeleny, M. (2012). *Multiple Criteria Decision Making Kyoto 1975*. Springer Science & Business Media.

Zhang, Y., Zhang, Y., Zhang, H., & Zhang, Y. (2022). Evaluation on new first-tier smart cities in China based on entropy method and TOPSIS. *Ecological Indicators*, *145*, 109616. https://doi.org/10.1016/j.ecolind.2022.109616