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Sustainability Impact of Online Consumption Behavior from the Perspective of Digital Empowerment: IndetermSoft Set with Application

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Abstract: This study uses decision-making methods for the Sustainability Evaluation of Online Consumption Behavior from the Perspective of Digital Empowerment. Two methods are used such as the CRITIC method to compute the criteria weights and the MULTIMOORA method to rank the alternatives. We use the IndetermSoft Set to deal with the indeterminacy of criteria and their values. This study uses six criteria and seven alternatives. The fifth criterion has two different sub-criteria, so the IndetermSoft Set is used to deal with this indeterminacy. The ranks of alternatives are obtained in three cases. The case study is applied to show the validation of the proposed two decision-making methods.

Keywords: Sustainability; Consumption Behavior; Digital Empowerment; MCDM Methodology; IndetermSoft Set.

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1. Introduction

The rapid advancement of digital technologies has transformed consumer behavior, enabling individuals to make more informed and sustainable purchasing decisions. As online consumption continues to rise, there is a growing need to evaluate its sustainability impact, particularly from the perspective of digital empowerment[1], [2]. Digital tools, including AI-driven recommendations, blockchain for supply chain transparency, and e-commerce sustainability ratings, provide consumers with greater access to information about ethical and eco-friendly products. This shift has encouraged businesses to adopt greener digital practices, such as offering carbon-neutral shipping, digital receipts, and sustainable packaging options. However, assessing the sustainability of online consumption behavior requires a structured evaluation framework that integrates environmental awareness, digital literacy, and ethical decision-making[3], [4]. Digital empowerment plays a crucial role in fostering responsible consumerism by equipping individuals with the knowledge and tools needed to make eco-conscious choices. Consumers with higher digital literacy can analyze product sustainability claims, compare ethical brand certifications, and engage in circular economic practices, such as buying second-hand goods or renting instead of purchasing. Moreover, the rise of subscription-based digital services, such as streaming platforms and cloud storage, has reduced the demand for physical products, leading to lower carbon footprints. However, the effectiveness of these sustainable digital behaviors depends on consumers' trust in online sustainability information, as misinformation and greenwashing can undermine responsible purchasing decisions.

Despite its advantages, the sustainability of online consumption is challenged by issues such as e-waste generation, energy-intensive digital activities, and fast fashion e-commerce expansion. The growing reliance on digital platforms has increased electricity consumption in data centers, and frequent device upgrades contribute to electronic waste[5], [6]. Additionally, while online shopping provides convenience, the rise of fast delivery services and single-use packaging has led to a surge in carbon emissions. To address these challenges, businesses must implement sustainable digital solutions, such as optimizing AI-driven logistics for lower emissions, promoting recyclable packaging, and encouraging responsible product disposal programs. Evaluating the sustainability of online consumption behavior from a digital empowerment perspective requires a multi-criteria decision-making (MCDM) approach that balances environmental, economic, and social factors[7], [8]. By assessing key criteria such as environmental awareness, ethical consumption behavior, and digital literacy, researchers and policymakers can develop strategies to enhance sustainable consumption practices. As digital platforms continue to evolve, their role in shaping sustainable consumer behavior will become even more significant, making it essential to integrate technology-driven solutions with responsible purchasing habits. By fostering greater digital empowerment, individuals and businesses can collectively contribute to a more sustainable and eco-friendly digital economy[9], [10]. One important characteristic shared by nearly all the above discussed approaches is the moderate to high complexity of their mathematical models. These methods appear to be challenging to use and call very sophisticated mathematical understanding. Consequently, decision makers may find that an undemanding MCDM approach is a true boon. The mathematics behind Brauers and Zavadskas' multi-objective optimization based on ratio analysis (MOORA) approach is straightforward. As a result, it may be used for material selection with ease and effectiveness. A more thorough version of the MOORA methodology is the MULTIMOORA method. The findings of the MULTIMOORA methodology can be more reliable than those of typical MCDM techniques, which provide a single rank, because the final rank is produced by integrating three subordinate values[11], [12].

This study proposes a MCDM approach for the Sustainability Evaluation of Online Consumption Behavior from the Perspective of Digital Empowerment with the IndetermSoft set to deal with indeterminacy in the values of the criteria. Two MCDM methods are used in this study such as the CRITIC method to compute the criteria weights and the MULTIMOORA method to rank the alternatives.

2. IndetermSoft Set

It was introduced by Smarandache in 2022. Let U be a universe of discourse, $\mathrm{P}(H)$ be the powerset of H, and H be a non-empty subset of U. Assume that A is a collection of the values of an attribute, a.

Then, an IndetermSoft is defined as F: A→ P(H). Set if: i) the set A contains some indeterminacy; ii) the set P(H) contains some indeterminacy; iii) at least one attribute-value v∈A exists such that F(v) = indeterminate (unclear, incomplete, conflicting, or not unique); iv) any two or all three of the previously specified conditions.

The NeutroFunction, described in 2014-2015, is a function that is only partially well-defined (inner-defined), partially indeterminate, and partially outer-defined because of its degree of indeterminacy. The IndetermSoft Set is a particular instance of this function. The NeutroFunction is a fully specified extension of the classical function[13], [14], [15].

IndetermSoft Set, an extension of the classical (determinate) Soft Set, handles indeterminate data since certain sources cannot provide accurate or thorough information on the sets A, H, or P(H), as well as on the function F. We did not invent indeterminacy; we found it in the actual world. We still must deal with these types of situations since many sources offer information that is imprecise, confusing, incomplete, and conflicting rather than accurate like in the Soft Set.

3. MCDM Model

We use two MCDM methods to evaluate the Sustainability Evaluation of Online Consumption Behavior from the Perspective of Digital Empowerment. This section shows the steps of two MCDM methods.

CRITIC Method

This part shows the steps of the CRITIC method to compute the criteria weights.

Create the decision matrix.

$$R = \begin{bmatrix} r_{11} & r_{21} & r_{31} & \cdots & r_{1n} \\ r_{21} & r_{22} & r_{32} & \cdots & r_{2n} \\ r_{31} & & & & r_{3n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} & \cdots & \vdots & r_{mn} \end{bmatrix}_{m \times n} ; i = 1, \dots, m; j = 1, \dots, n \quad (1)$$

Normalize the decision matrix

We can normalize the decision matrix for beneficial and non-beneficial criteria such as:

$$y_{ij} = \frac{r_{ij}-r_i^-}{r_i^+-r_i^-}; i = 1, \dots, m; j = 1, \dots, n \quad (2)$$

$$y_{ij} = \frac{r_{ij}-r_i^+}{r_i^--r_i^+}; i = 1, \dots, m; j = 1, \dots, n \quad (3)$$

$$r_i^- = \min(x_{ij}) \quad (4)$$

$$r_i^+ = \max(x_{ij}) \quad (5)$$

Obtain the correlation coefficient

We can obtain the correlation matrix between the criteria and the alternatives.

Obtain the standard deviation.

Compute the index c

$$C_j = \sigma_j \sum_{k=1}^{n} (1 - U_{jk}) \quad (6)$$

Where U_{jk} refers to the value of the correlation coefficient and σ_j refers to the standard deviation.

Compute the criteria weights.

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j} \quad (7)$$

MULTIMOORA Method

We use this method to rank the alternatives.

Normalize the decision matrix

$$r_{ij}^* = \frac{r_{ij}}{\left(\sum_{i=1}^{m} r_{ij}^2\right)^{0.5}} \quad (8)$$

Compute the value of ratio system

$$q_i = \sum_{j=1}^{g} w_j r_{ij}^* - \sum_{j=g+1}^{n} w_j r_{ij}^* \quad (9)$$

We rank the alternative by the max value in the q_i

Then we rank the alternatives based on the reference point as:

$$z_i = \max_j \left| w_j p_j - w_j r_{ij}^* \right| \quad (10)$$

We rank the alternatives based on the min value of z_i

$$p_j = \begin{cases} \max_i \ r_{ij}^* \ for\ positive\ criteria \\ \min_i \ r_{ij}^* \qquad for\ cost\ criteria \end{cases} \quad (11)$$

Then we rank the alternatives based on the full multiplicative form

We obtain the values of full multiplicative such as:

$$D_i = \frac{\prod_{j=1}^{g}\left(r_{ij}^{*}\right)^{w_j}}{\prod_{j=g+1}^{n}\left(r_{ij}^{*}\right)^{w_j}} \tag{12}$$

The rank of alternatives is obtained by the max value of D_i. Then we apply the dominance theory to obtain the final ranks.

4. Case Study

This section presents a case study on the Sustainability Evaluation of Online Consumption Behavior from the Perspective of Digital Empowerment to validate the proposed approach. Four experts, with experience in the Multi-Criteria Decision-Making (MCDM) field, assessed the criteria and alternatives using a scale ranging from 0.1 to 0.8. Their evaluations were based on their expertise and professional judgment.

The study examines six key criteria and seven alternatives, structured as follows:

- Criteria:
  - Trust in Digital Sustainability Information (High)
  - Environmental Awareness (High)
  - E-Waste Reduction Practices (Medium)
  - Ethical Consumption Behavior (Strong)
  - Digital Literacy (Advanced, Basic)
  - Preference for Green Digital Services (Strong)
- Alternatives:
  - Conscious Online Food Delivery Choices
  - Ethical Brand Loyalty
  - Digital Subscription Services
  - Green E-commerce Shopping
  - Smart Energy Consumption in Digital Activities
  - Responsible Use of Fast Fashion Online Platforms
  - Second-Hand and Circular Economy Participation

Results of the CRITIC Method

To assess the relationship between the criteria and alternatives, Equation (1) was used to construct the decision matrix. The four experts rated the criteria on a scale between 0.8 and 0.9. The process involved the following steps:

1. Normalization of the decision matrix using Equation (2) (illustrated in Figure 1).
2. Calculation of the correlation coefficient (shown in Figure 2).
3. Determination of the standard deviation.
4. Computation of the index (c) using Equation (6).
5. Derivation of criteria weights using Equation (7) (results displayed in Figure 3).

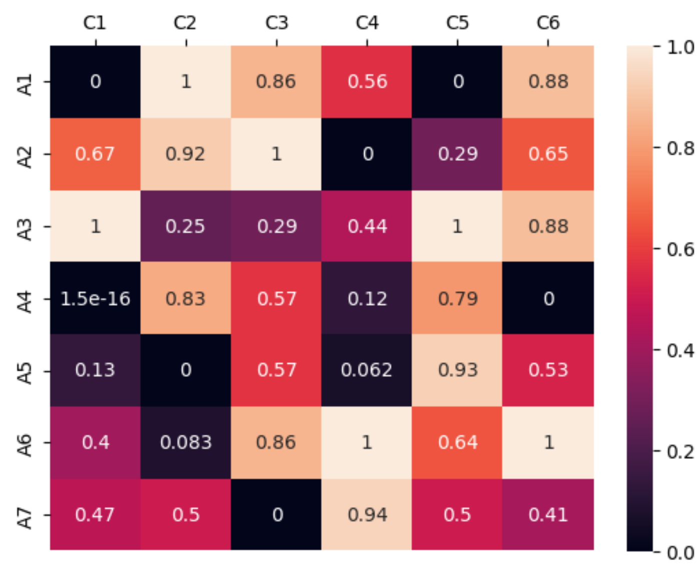

Fig 1. Normalization values by CRITIC method.

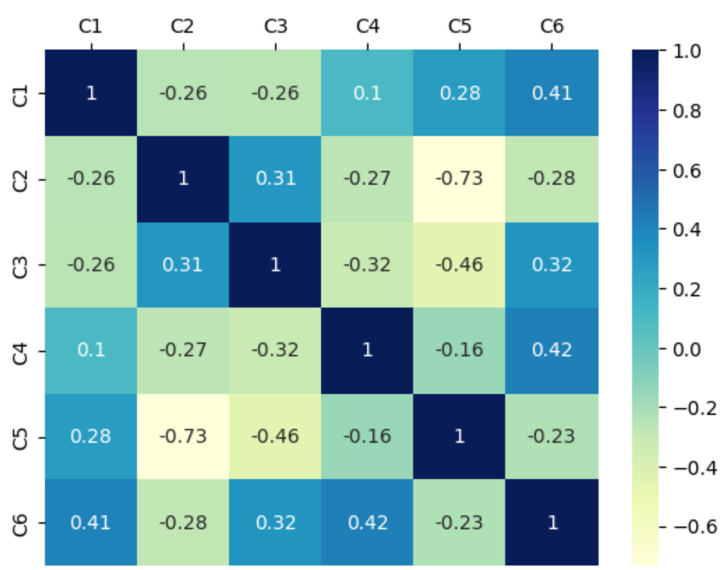

Fig 2. The correlation matrix.

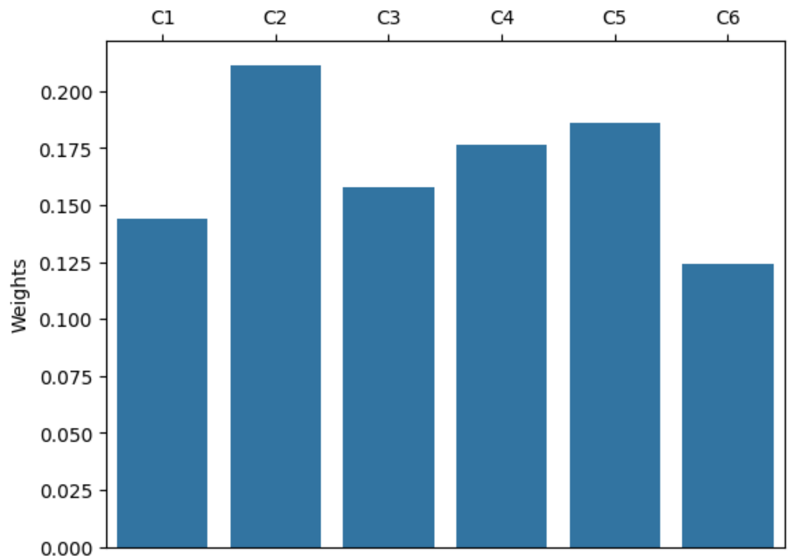

Fig 3. Criteria weights.

Results of the MULTIMOORA Method

When ranking the alternatives, we encountered indeterminacy in selecting the value for the fifth alternative, which had two possible values: basic and advanced. To handle this uncertainty, we applied the IndetermSoft Set, which allows for a flexible approach in dealing with indeterminate values. Consequently, we implemented the MULTIMOORA method under three different scenarios: one using the basic value, another using the advanced value, and a third that considers both values simultaneously.

In the first case, where the basic value was applied, we normalized the decision matrix using Equation (8), as illustrated in Figure 4. Following this, we computed the ratio system value using Equation (9) (see Figure 5). Next, we determined the reference point with the help of Equation (10), which is visualized in Figure 6. Finally, we obtained the full multiplicative values by applying Equation (12), as demonstrated in Figure 7.

A similar process was followed in the second case, where we substituted the basic value with the advanced value. In the third case, both basic and advanced values were considered simultaneously, allowing us to evaluate the effect of indeterminacy on the ranking process. By systematically applying the MULTIMOORA method in all three cases, we ensured a robust and comprehensive assessment of the alternatives.

Fig 4. Normalization matrix.

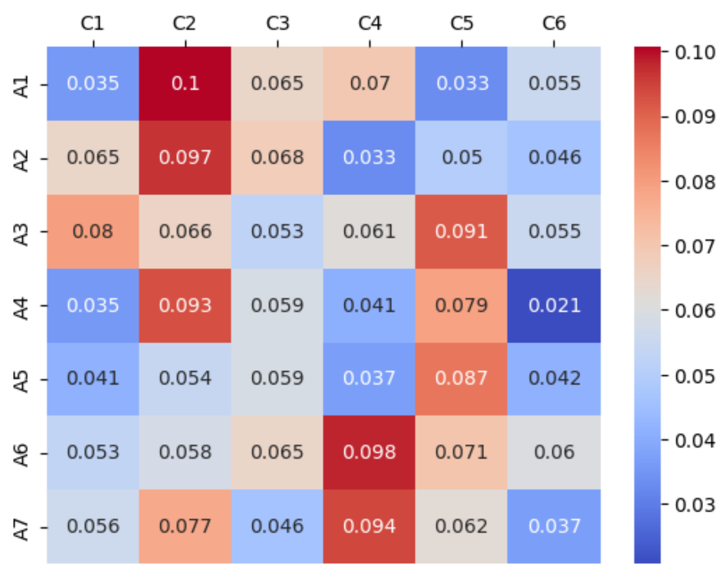

Fig 5. The ratio system values.

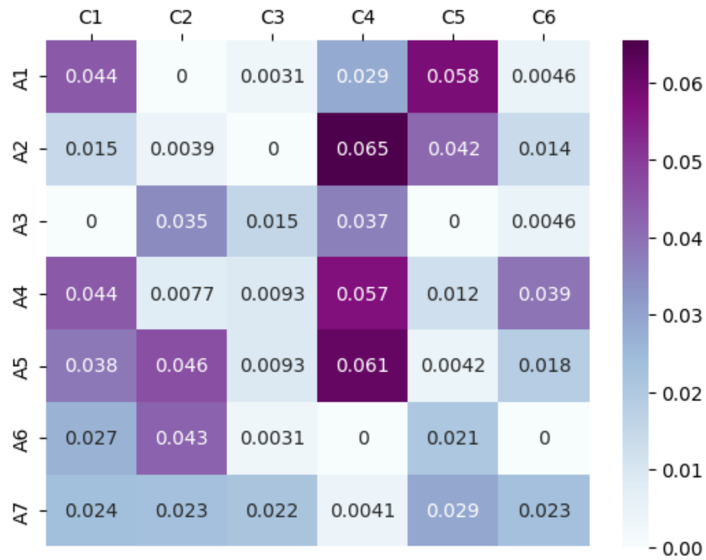

Fig 6. Reference point matrix.

Fig 7. Full multiplicative matrix.

Results for the Second and Third Cases

In the second case, where we applied the advanced value, the normalized decision matrix was generated, as shown in Figure 8. Subsequently, we calculated the ratio system values, which are illustrated in Figure 9. The reference point was determined and is displayed in Figure 10. Finally, we computed the full multiplicative values, as represented in Figure 11.

In the third case, which considered both basic and advanced values simultaneously, we followed the same procedure. The normalized decision matrix was obtained and shown in Figure 12. We then computed the ratio system values displayed in Figure 13. The reference point was determined and is presented in Figure 14. Lastly, the full multiplicative values were calculated and are illustrated in Figure 15.

To finalize the rankings, we applied the dominance theory across all three cases to establish a definitive ranking of the alternatives. The results, as shown in Figure 16, indicate that Alternative 3 emerged as the best choice, while Alternative 5 ranked the lowest.

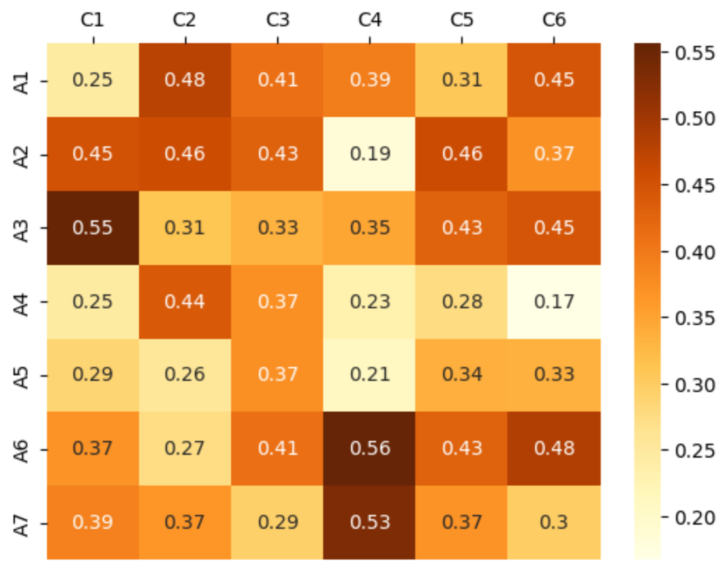

Fig 8. Normalization matrix.

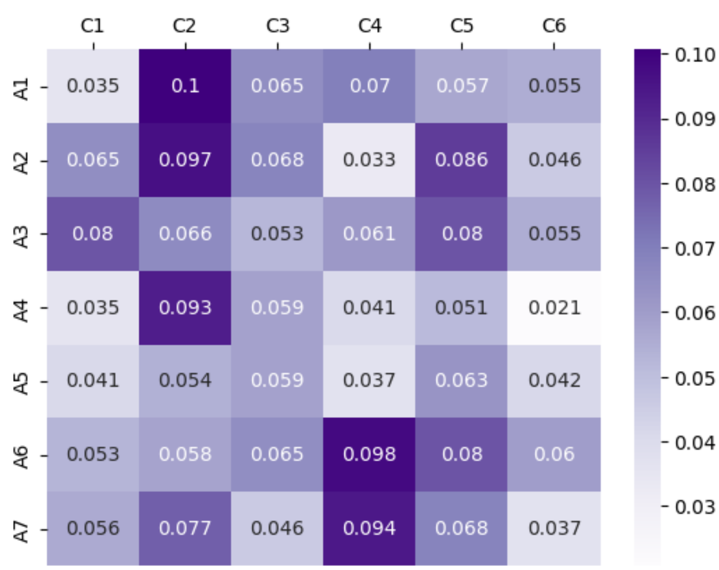

Fig 9. The ratio system values.

Fig 10. Reference point matrix.

Fig 11. Full multiplicative matrix.

Fig 12. Normalization matrix.

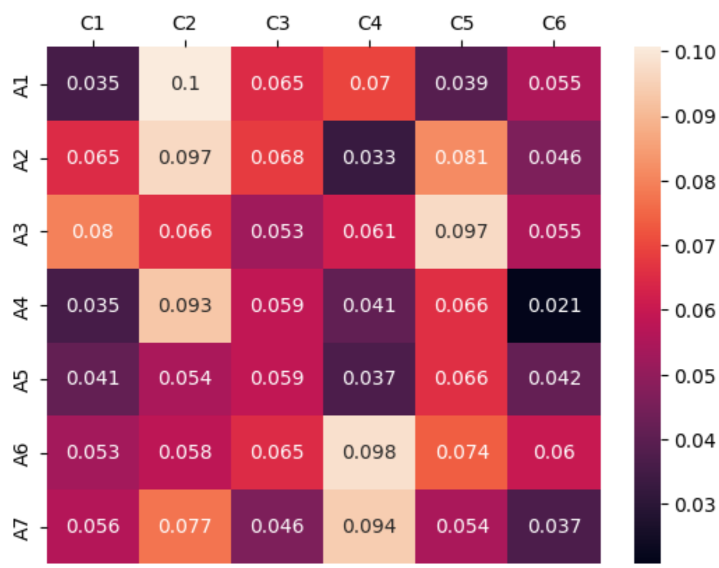

Fig 13. The ratio system values.

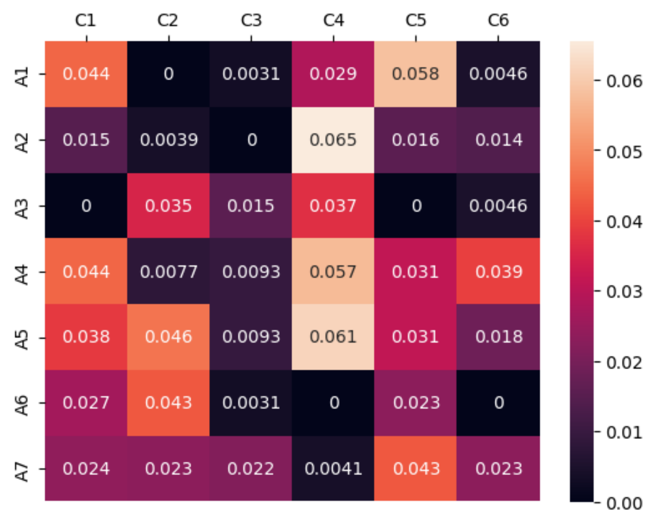

Fig 14. Reference point matrix.

Fig 15. Full multiplicative matrix.

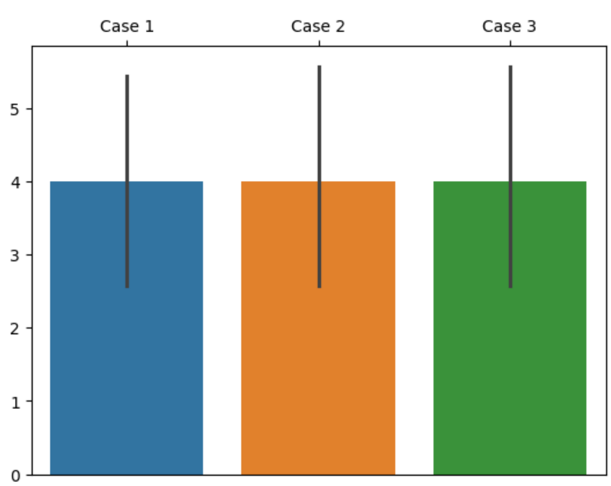

Fig 16. Final ranks of three cases.

4.1 Theoretical Implications

This study contributes to the growing body of research on digital empowerment and sustainable online consumption by introducing a multi-criteria decision-making (MCDM) framework that incorporates IndetermSoft Sets. The proposed approach enhances traditional MCDM models by addressing indeterminacy and uncertainty in consumer behavior data, which is a critical challenge in evaluating sustainability initiatives.

By integrating CRITIC and MULTIMOORA methods, this research offers a structured methodology to assess the effectiveness of digital sustainability initiatives, such as green e-commerce, responsible digital consumption, and eco-conscious online behaviors. Furthermore, the application of the IndetermSoft Set in handling ambiguous consumer data introduces a novel computational tool for decision-making in sustainability studies.

The findings suggest that digital literacy and trust in online sustainability information play a significant role in influencing consumer behavior. This highlights the need for policymakers, businesses, and researchers to focus on improving transparency in online sustainability claims and promoting digital education programs to enhance eco-friendly consumer decision-making.

4.2 Practical Implications

The study's findings have several practical implications for businesses, policymakers, and consumers seeking to improve sustainability in digital commerce.

Companies can leverage the insights from this study to enhance their sustainability strategies, such as providing transparent sustainability ratings, integrating blockchain for supply chain traceability, and promoting carbon-neutral shipping. The findings also suggest that improving digital literacy among consumers can enhance their engagement with eco-friendly products, leading to higher brand loyalty and sustainable purchasing behaviors.

The results highlight the need for regulatory frameworks that ensure credible and verifiable sustainability claims in digital marketplaces. Governments can implement policies to promote responsible e-commerce practices, such as mandating standardized sustainability labels and encouraging tax incentives for green digital initiatives.

The study emphasizes the importance of digital empowerment in making informed purchasing decisions. By enhancing their understanding of sustainability metrics, environmental impact assessments, and ethical consumption choices, consumers can contribute to a more sustainable digital economy.

By applying the IndetermSoft Set approach, businesses and decision-makers can develop more flexible and data-driven strategies to support sustainable consumer behaviors in an increasingly digitalized world.

4.3 Limitations of the Study

Despite its contributions, this study has some limitations that should be considered in future research:

1. The reliance on expert evaluations introduces subjectivity in the weight assignment process. While the CRITIC method mitigates this to some extent, future studies could explore machine learning techniques for more objective weight determination.
2. The study's case analysis is based on a specific number of criteria and alternatives. Expanding the dataset to include more diverse consumer behaviors and industry sectors could strengthen the generalizability of the findings.
3. Although the IndetermSoft Set effectively manages uncertainty, its computational complexity may pose challenges for scalability in large datasets.

5. Conclusions

In this research, we applied the MULTIMOORA approach with the IndetermSoft Set to handle the Sustainability Evaluation of Online Consumption Behavior from the Perspective of Digital Empowerment problem by using CRITIC weight. The weighted and CRITIC-weighted MULTIMOORA techniques are the two scenarios that make up the extended model. The CRITIC method is used to compute the criteria weights and the MULTIMOORA method is used to rank the alternatives. Decision makers' opinions, which are based on their understanding and their experiences, are the direct source of subjective weight. However, the CRITIC concept is used to determine the objective weight. IndetermSoft Set is used to deal with indeterminacy in the sub criteria. The IndetermSoft Set is applied with three cases. The results show alternative 3 is the best and alternative 5 is the worst.

5.1 Future Research Directions

While this study provides valuable insights into the sustainability of online consumption behavior, several areas remain open for further investigation:

I. Future studies could incorporate additional sustainability criteria, such as carbon footprint analysis, water usage, and social sustainability metrics, to provide a more comprehensive evaluation.
II. The impact of digital empowerment on sustainable consumer behavior may vary across different regions and cultures. Future research can conduct comparative studies across multiple countries to assess regional variations in sustainable digital consumption.
III. With the rise of AI, blockchain, and IoT, future studies could explore how these technologies enhance transparency and trust in digital sustainability information.
IV. Since consumer behavior evolves over time, conducting long-term studies can provide deeper insights into how digital literacy and sustainability awareness change consumer preferences over extended periods.

V. Future research could collaborate with businesses, policymakers, and sustainability organizations to implement the proposed model in real-world settings and measure its practical impact on consumer decision-making.

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