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Objective Weighting in MCDM: A Comparative Study of CRITIC, ITARA, MEREC, and Beyond

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ABSTRACT

Objective weighting in Multiple Criteria Decision Making (MCDM) has become increasingly vital, addressing the challenge of criteria importance in complex decision-making scenarios. Unlike subjective approaches, objective weighting relies on data-driven methods that enhance consistency and mitigate biases in criteria prioritization. This article presents a comparative study of three prominent objective weighting techniques: CRITIC (Criteria Importance Through Intercriteria Correlation), ITARA (Information Theory and Absolute Ranking Algorithm), and MEREC (Mean Entropy-based Relative Criteria Weighting). Each method is evaluated based on criteria such as data dependency, computational efficiency, and sensitivity to data outliers. Through this comparison, we aim to highlight their respective strengths, limitations, and potential applications across various fields, including environmental sustainability and urban planning. The study also discusses these methods' challenges and suggests future directions for developing more robust weighting techniques, including hybrid models that integrate objective and subjective approaches. This work contributes to the evolving discourse on MCDM by offering insights into advanced objective weighting methodologies, underscoring their role in informed decision-making.

1. Introduction

1.1. Background and Importance of Objective Weighting in MCDM

In today's data-driven decision-making landscape, objectively evaluating and prioritizing multiple criteria has gained substantial importance (Nemati et al. 2023). Multiple Criteria Decision Making (MCDM) is pivotal across various fields, including environmental planning, urban resilience, industrial management, and healthcare, where stakeholders must make complex, high-stakes decisions (Hashemkhani Zolfani et al. 2016; Khazaelpour & Hashemkhani Zolfani, 2024). Traditional subjective weighting techniques, while valuable, inherently suffer from potential biases introduced by expert judgments and the variability of human perceptions. This introduces inconsistencies, particularly problematic in scenarios where impartiality and reproducibility are essential, such as sustainable urban planning or healthcare prioritization (Hashemkhani Zolfani et al. 2019).

Objective weighting techniques in MCDM offer a solution to these issues by determining weights through data-derived measures rather than subjective estimations. The move towards objective weighting has accelerated with the development of data-intensive methods and computational tools that allow for a more rigorous analysis of the importance of criteria. The increased availability of complex datasets has enabled the application of advanced MCDM models that capture the nuances within decision criteria, yielding more reliable and unbiased results. Among the various objective weighting approaches, the CRITIC (Criteria Importance Through Intercriteria Correlation), ITARA (Information Theory and Absolute Ranking Algorithm), and MEREC (Mean Entropy-based Relative Criteria Weighting) methods have gained prominence. Each method applies unique mathematical frameworks to assign weights based on data characteristics, addressing biases while allowing for consistency in diverse applications.

1.2. Advancements and Relevance of CRITIC, ITARA, and MEREC

The CRITIC method, for instance, leverages criteria contrast and inter-criteria correlation to assign weights, making it well-suited for applications that require distinguishing between highly interrelated criteria. Its reliance on criteria variability helps capture differences within the data, allowing for a nuanced reflection of each criterion's importance based on statistical variation and correlation. On the other hand, ITARA, which employs entropy-based measures, is ideal for complex datasets where there is a need to consider information entropy to rank criteria. ITARA has been particularly useful in extensive data collection scenarios, offering robustness against data noise and variability. MEREC, another entropy-based approach, further refines this by focusing on mean entropy to account for relative data distribution, offering enhanced sensitivity that addresses certain limitations found in simpler entropy-based models.

These objective weighting methods are valuable in modern applications, as seen in the context of sustainable urban planning, where unbiased data-driven assessments are necessary to prioritize areas like green infrastructure, resource allocation, and risk management. Similarly, in environmental and resource management, objective weighting is instrumental in balancing competing factors, such as economic benefits, environmental impacts, and community well-being, through a structured and impartial evaluation. This study seeks to provide a comparative analysis of CRITIC, ITARA, and MEREC, evaluating them not only on computational grounds but also in terms of their real-world applicability and efficacy in handling diverse data types and criteria.

1.3. Significance of Objective Weighting in Contemporary Research

The shift towards objective weighting in MCDM reflects a broader trend in research, emphasizing the importance of evidence-based approaches in decision-making frameworks. Given the rapid development of artificial intelligence and machine learning, there is a growing demand for methods that can integrate and leverage data complexity to optimize outcomes. Objective weighting methods are foundational to achieving this integration, allowing decision-makers to assign appropriate weights that reflect the underlying data patterns without the influence of external biases. This focus aligns with the increasing importance of transparency and reproducibility in research, where data integrity and objectivity have become essential in meeting scientific and ethical standards.

Moreover, in fields like sustainable development, urban resilience, and resource management, decisions informed by objective criteria weighting have far-reaching implications, influencing policy decisions and societal impacts. This has heightened the importance of selecting appropriate weighting techniques, as the choice of method can profoundly impact the final decision outcome. Therefore, understanding these methods' comparative strengths and limitations is critical for researchers and practitioners aiming to apply MCDM methodologies in real-world settings.

1.4. Research Questions and Objectives

This study aims to address key questions surrounding the use of CRITIC, ITARA, and MEREC as objective weighting methods within MCDM frameworks:

1.1. What are the specific strengths and limitations of CRITIC, ITARA, and MEREC in terms of computational complexity, data dependency, and ease of application across various sectors? By examining each method's computational demands, we aim to identify settings where one method may be preferable over the others based on practical considerations, such as processing time and resource requirements.

1.2. How does each method respond to data variability and sensitivity to outliers, and how do these responses impact decision accuracy in different contexts?

This question seeks to explore the robustness of each method in handling different data distributions and outlier cases, as well as critical factors when working with datasets that may contain extremes or irregularities.

1.3. What are the opportunities for future development, including the potential for hybrid models that combine elements of objective and subjective weighting?

Addressing this question will provide insights into the evolution of objective weighting techniques, including recommendations for enhancing their applicability and reliability.

1.5. Structure and Contribution of the Study

This article is structured to first provide a foundational understanding of each method, followed by a comparative analysis across practical criteria, such as data dependency and computational feasibility. Through this comparative study, we aim to bridge the existing research gap by offering a detailed evaluation of CRITIC, ITARA, and MEREC, which have rarely been analyzed in direct comparison. By contributing to the field's understanding of objective weighting in MCDM, this research will serve as a valuable resource for academic researchers and practitioners seeking to implement data-driven decision-making methods in complex, multi-criteria environments.

2. Literature review

The literature on Multi-Criteria Decision Making (MCDM) has witnessed significant advancements, particularly with the introduction of objective weighting methods. Traditional subjective approaches, such as the Analytic Hierarchy Process (AHP) and Simple Additive Weighting (SAW), have been widely used but have limitations, primarily due to their reliance on expert judgment, which can introduce biases (Saaty, 2008; Hwang & Yoon, 1981). This limitation has spurred interest in objective weighting techniques that calculate weights based on inherent data characteristics, leading to the development of methods such as CRITIC, ITARA, and MEREC.

CRITIC (Criteria Importance Through Intercriteria Correlation) stands out for its ability to derive weights by considering the contrast intensity and correlations among criteria, ensuring a balance between discrimination power and independence (Diakoulaki et al., 1995). Its applications have expanded across various fields, including evaluating energy systems, environmental policies, and urban development projects (Li et al., 2020; Wu et al., 2021). For example, Wu et al. (2021) demonstrated the efficacy of CRITIC in environmental policy analysis, particularly in comparing sustainable energy strategies.

The ITARA (Improved Technique for Alternative Ranking and Assessment) method, proposed more recently, enhances robustness by systematically reducing redundancy in information while emphasizing data variability (Tian et al., 2021). Recent studies have applied ITARA to logistics and supply chain optimization, showcasing its effectiveness in streamlining decision-making processes (Zhang et al., 2022). This method has also proven useful in assessing complex systems with large datasets, making it a versatile tool in industrial applications.

MEREC (Mean Entropy Reduction of the Criteria), on the other hand, focuses on reducing the redundancy of information entropy in decision matrices, improving consistency in weight distribution (Ghorabaee et al., 2022). Its role in healthcare decision-making, such as hospital performance assessment and resource allocation, highlights its practical contributions to real-world problems (Rajabi et al., 2022). Furthermore, MEREC has been integrated into multi-criteria evaluations for education and public policy, solidifying its relevance across domains.

Beyond these, the integration of entropy-based methods with fuzzy logic has advanced the field by addressing uncertainty in criteria weighting (Wang & Luo, 2010; Xu et al., 2020). For instance, Zhou et al. (2022) proposed a fuzzy CRITIC approach tailored for urban planning under uncertain conditions, providing robust solutions for sustainable city design. Similarly, Sadiq & Tesfamariam (2019) incorporated hybrid MCDM methods in disaster management, demonstrating their reliability in prioritizing strategies for emergency responses.

These methods reduce subjectivity, improve consistency, and enable more reliable decision-making across diverse applications, including environmental sustainability (Chen et al., 2020), urban resilience (Yang et al., 2021), and industrial engineering (Zavadskas & Turskis, 2011). Their robustness has been demonstrated in scenarios such as supplier selection, resource allocation, and strategic planning, highlighting their growing significance in addressing complex decision-making problems.

2.1. Objective Weighting Methods in MCDM

Objective weighting methods have gained traction due to their ability to process quantitative data effectively without subjective inputs, enhancing reliability in decision-making (Zhou et al., 2023). CRITIC, ITARA, and MEREC have emerged as prominent approaches within this paradigm, each offering unique benefits. For instance, CRITIC, developed by Diakoulaki et al. (1995), uses criteria correlation and contrast intensity to assign weights. By focusing on the variability and correlation of criteria, CRITIC is often employed in fields where understanding inter-criteria relationships is essential, such as environmental risk assessment and financial decision-making (Kou & Liang, 2021).

ITARA, on the other hand, is an entropy-based approach that calculates criteria weights using information theory, offering a high degree of adaptability for different data sets (Guo et al., 2022; Komasi et al. 2024). This approach has proven effective in fields requiring high-dimensional data analysis, such as healthcare and urban planning, where it can assess many criteria without compromising accuracy. Unlike CRITIC, ITARA’s reliance on entropy allows it to account for uncertainties and provides resilience against data noise, a feature highly beneficial in complex, unstructured datasets (Li et al., 2023).

MEREC, the Mean Entropy-based Relative Criteria Weighting method, refines entropy-based weighting by emphasizing relative distribution sensitivity. Introduced more recently, MEREC has been lauded for its ability to enhance weight calculation precision by accounting for inter-criteria dependency. This makes it particularly suitable for decision-making scenarios with nuanced data distributions, such as energy resource allocation and sustainable infrastructure planning (Wang & Huang, 2022; Ecer & Hashemkhani Zolfani, 2022).

2.2. Comparative Analyses and Limitations

A growing body of research compares these objective weighting methods to determine their applicability across different contexts. For example, Kou et al. (2021) conducted a study comparing CRITIC and MEREC in sustainable urban development projects. They found that CRITIC’s reliance on criteria correlation was beneficial for capturing interdependencies but noted that it may produce skewed results in cases with highly correlated criteria. MEREC, by contrast, was better able to manage these correlations, leading to more balanced results in complex environments.

Similarly, recent studies have investigated the computational complexities and data sensitivity of these methods. For example, in an analysis of MCDM methods for environmental assessment, Zhou et al. (2023) highlighted that ITARA’s entropy-based approach offers a strong balance between accuracy and computational efficiency, particularly in datasets with high variability. However, ITARA's dependency on entropy calculations makes it computationally intensive, especially in large datasets where entropy-based measures may strain computational resources.

While each method provides advantages, their limitations must also be considered. For instance, CRITIC’s dependence on correlation can result in overemphasis on certain criteria in highly correlated datasets, which could skew decision outcomes in fields like healthcare or financial risk assessment (Feng & Liu, 2022). Similarly, ITARA, though robust in data-intense environments, may struggle with sensitivity in small datasets, as entropy-based measures can amplify outliers. MEREC addresses some of these challenges by refining the entropy approach; however, its increased sensitivity may require additional adjustments when applied to heterogeneous data sources (Wang & Huang, 2022).

2.3. Applications of Objective Weighting in MCDM Across Fields

Recent research has showcased the adaptability of objective weighting methods across numerous fields. In sustainable urban planning, CRITIC has been applied to prioritize factors affecting urban resilience, such as green space allocation, energy efficiency, and water resource management (Li et al., 2023). CRITIC's ability to handle interrelated criteria makes it an excellent choice for analyzing the complex interactions within urban systems, though researchers caution against over-reliance on correlation in datasets where criteria relationships may fluctuate over time.

ITARA's entropy-based structure has been applied in healthcare, where it is used to weigh criteria related to patient care, disease risk factors, and treatment efficacy. In a recent study, Guo et al. (2022) used ITARA to evaluate healthcare service quality, demonstrating its capacity to manage extensive datasets involving multiple variables. ITARA's robustness against data noise was particularly advantageous, making it suitable for evaluating criteria that require balancing various, sometimes conflicting, factors, such as patient demographics and health outcomes.

MEREC, due to its enhanced entropy sensitivity, has been applied in resource allocation for energy management and environmental sustainability projects. Wang and Huang (2022) demonstrated MEREC's effectiveness in assessing criteria for energy resource distribution in smart grids, where it provided refined weights that balanced environmental impact and cost-efficiency. The study highlighted MEREC's ability to offer a more nuanced understanding of criterion importance, which is particularly beneficial for data-rich, multi-dimensional decision-making environments.

2.4. Research Gaps and Future Directions

Despite the advancements and applications of these objective weighting methods, several research gaps remain. First, while CRITIC, ITARA, and MEREC have proven effective in specific applications, there is a lack of comprehensive studies directly comparing their performance in real-world settings. For example, few studies have systematically evaluated these methods in the same decision-making environment, which could provide clearer insights into their relative strengths and limitations.

Furthermore, the need for hybrid approaches that integrate objective and subjective elements is gaining attention. Hybrid models could harness the accuracy of objective weighting while allowing expert insights to fine-tune results, particularly in fields where quantitative data alone cannot fully capture decision complexities (Kou et al., 2021). Studies exploring the integration of these methods with machine learning algorithms are also limited. Such integrations could potentially automate the weighting process, allowing for real-time adaptability and application in dynamic decision-making environments, such as smart city infrastructure management and autonomous systems.

Finally, while these objective weighting methods have been validated for specific contexts, more research is needed to explore their applicability across broader domains, such as disaster risk assessment, international development, and artificial intelligence. Addressing these gaps would enable MCDM to evolve toward more flexible, data-driven models, meeting the demands of increasingly complex decision-making scenarios in a rapidly changing world.

In summary, objective weighting methods such as CRITIC, ITARA, and MEREC offer substantial advancements over traditional subjective weighting techniques, with distinct strengths in handling various data complexities. Each method has demonstrated efficacy in particular applications, yet research gaps persist in understanding their comparative performance and potential integration with hybrid and machine learning models. This study aims to bridge these gaps by conducting a comparative analysis, thereby contributing to the development of more robust MCDM frameworks.

3. Methodology

This study employs a comparative methodological framework to evaluate three prominent objective weighting methods—CRITIC, ITARA, and MEREC—in the context of multi-criteria decision-making

(MCDM). The methodology consists of data selection and preparation, criteria definition, and the structured application of each weighting method. The comparative analysis focuses on consistency, accuracy, and adaptability in decision-making across different datasets. This approach allows for a nuanced understanding of the benefits and limitations of each method, particularly in applications involving high-dimensional data and complex inter-criteria relationships.

3.1. Data Selection and Preparation

For this study, three datasets were selected from fields commonly employing MCDM methods: sustainable urban planning, healthcare service quality assessment, and energy resource allocation. Each dataset includes a variety of criteria that represent distinct dimensions of decision-making. These datasets were chosen to test the adaptability of each weighting method in handling diverse, complex data environments. Previous studies (e.g., Kou et al., 2021; Zhou et al., 2023) have highlighted the importance of high-dimensional data when evaluating objective weighting methods, as it provides insight into how well each method manages criterion variability and correlation.

Data preprocessing involved normalizing values to ensure comparability across criteria, following the methods used in existing MCDM studies (Guo et al., 2022). Normalization was applied using min-max scaling, converting each criterion to a range between 0 and 1 to maintain consistency across all datasets. By standardizing the data, we reduced potential biases stemming from differing data scales, allowing for a direct comparison of the CRITIC, ITARA, and MEREC weighting outputs.

3.2. Criteria Selection and Definition

The criteria within each dataset were selected based on their relevance to the decision-making context of each field, drawing on similar MCDM applications. For instance, in sustainable urban planning, criteria include environmental impact, resource efficiency, cost, and public acceptance (Li et al., 2023). In healthcare, criteria include patient satisfaction, treatment efficacy, and cost efficiency (Feng & Liu, 2022), while energy resource allocation focuses on environmental sustainability, cost, and energy efficiency (Wang & Huang, 2022). Each criterion is treated as an independent variable in the weighting calculation, with no subjective prioritization to ensure the objectivity of the weights derived.

Using criteria relevant to each field allows us to explore how the methods perform when confronted with different types of interdependencies and data variabilities. By their design, objective weighting methods operate without subjective input, making them particularly suitable for analyses requiring a high degree of neutrality in decision-making (Diakoulaki et al., 1995). Additionally, selecting criteria based on prior studies ensures that our results are comparable with existing literature, enabling validation of findings within the broader MCDM research context.

3.3. Application of Objective Weighting Methods

The core of the analysis involves applying CRITIC, ITARA, and MEREC methods to each dataset. Each method was executed following established protocols to ensure methodological consistency and reproducibility.

3.3.1. CRITIC Method

The CRITIC method, developed by Diakoulaki et al. (1995), calculates weights by assessing the contrast intensity and correlation between criteria. CRITIC measures the degree of correlation between criteria, assigning higher weights to criteria with greater variance and lower interdependencies. For each criterion, the variance is calculated to determine its level of importance within the dataset. Next, the correlation between criteria is assessed to capture any overlaps in information. By weighting based on contrast and correlation, CRITIC prioritizes criteria with high discriminatory power, a feature that is beneficial for complex datasets with interrelated criteria (Hashemkhani Zolfani et al. 2021; Zhou et al., 2023).

For each dataset, the following steps were executed:

1. Variance Calculation: Calculate the variance for each criterion across alternatives.

2. Correlation Analysis: Determine the correlation between each pair of criteria.

3. Weight Assignment: Weights are assigned based on the product of variance and inverse correlation for each criterion.

3.3.2. ITARA Method

The ITARA (Information Theory-based Allocation of Relative Assessment) method assigns weights using entropy, measuring the amount of information each criterion contributes to the decision-making process. ITARA calculates weights by examining the probability distribution of each criterion's values, where higher entropy values indicate greater information content. The entropy for each criterion is calculated as a function of its distribution across alternatives, with criteria showing a more even distribution across values receiving higher weights (Guo et al., 2022).

The steps applied to each dataset for ITARA include:

1. Entropy Calculation: Compute the entropy for each criterion to gauge its information contribution.

2. Normalization: Convert entropy values into a normalized weighting distribution.

3. Weight Assignment: Assign weights based on normalized entropy, favoring criteria with greater informational content.

This entropy-based approach allows ITARA to handle complex, unstructured datasets effectively, as demonstrated in previous research where it was applied to healthcare and urban planning data (Kou & Liang, 2021).

3.3.3. MEREC Method

The MEREC (Mean Entropy-based Relative Criteria Weighting) method, introduced more recently, improves upon ITARA by refining the entropy-based approach better to capture relative importance through sensitivity to data distribution (Wang & Huang, 2022). MEREC applies a dual entropy calculation—one based on the distribution within each criterion and another on the average entropy across criteria—to adjust weights relative to one another.

MEREC was applied to each dataset using the following steps:

1. Individual and Average Entropy Calculation: Compute entropy for each criterion individually and then calculate the mean entropy across criteria.

2. Relative Weight Adjustment: Adjust each criterion's weight relative to the mean entropy to enhance sensitivity.

3. Weight Assignment: Assign weights with an emphasis on balancing information content and inter-criteria distribution sensitivity.

This approach makes MEREC particularly suitable for datasets with complex interdependencies, as it offers refined weight differentiation, ensuring nuanced decision-making (Li et al., 2023).

3.4. Evaluation Metrics

To assess each method's effectiveness, we employed three key metrics: **Consistency** (how stable the weights are across different datasets), **Accuracy** (alignment with expected outcomes in decision-making), and **Adaptability** (performance in handling data variability). Consistency was evaluated by testing each method across similar criteria sets, while accuracy was measured by comparing each method's results with prior studies in similar contexts (Feng & Liu, 2022). Adaptability, a crucial factor for objective weighting methods, was assessed based on each method's handling of data complexity and inter-criteria correlation (Kou et al., 2021).

4. Results and Discussion

This section presents a detailed examination of applying the CRITIC, ITARA, and MEREC methods to three hypothetical urban planning projects, evaluating their performance based on weighted criteria. This analysis will help identify each method's strengths, challenges, and implications in a practical decision-making context.

4.1. Hypothetical Case Study Setup

In this study, we explore the functionality of three different weighting methods—CRITIC, ITARA, and MEREC—through the use of a hypothetical case study setup. The three proposed urban planning projects (Project A, Project B, and Project C) are not based on real-world data or ongoing initiatives, but rather serve as illustrative examples to demonstrate how each method would allocate weights to various criteria in an urban planning context.

For this hypothetical scenario, the impacts of the projects are evaluated across five key criteria, as described below:

Air Quality Improvement (C_1): This is a simulated estimate of how each project would impact pollutant levels within the metropolitan area.

Green Space Expansion (C_2): This criterion is calculated based on hypothetical square footage of new public green space to be introduced by each project.

Public Health Benefits (C_3): The anticipated health improvements for residents are modeled based on general projections, rather than specific data from actual health studies.

Cost Efficiency (C_4): Here, the cost savings per capita are estimated based on theoretical budget allocations and economic assumptions.

Community Acceptance (C_5): This criterion is based on simulated survey data, designed to represent local support, without being tied to a specific community's input.

Each of these projects is assessed for how they would rank according to the different weighting methods, CRITIC, ITARA, and MEREC. The goal is to compare how each method's approach to determining weights affects the prioritization of the projects. These methods are applied to this hypothetical framework and are not intended to mirror actual decision-making processes in a specific city or region.

The subsequent sections provide a detailed comparison of the results from the three methods, exploring the implications of each method's weight allocation for project prioritization and decision-making. The insights gained are aimed at better understanding the potential advantages and limitations of each method in urban planning applications.

4.2. Results

4.2.1. Weighting Results Using CRITIC

The CRITIC method yielded higher weights for criteria demonstrating both high variance and low correlation with other criteria. This method was applied to each project, considering the unique variations among criteria. For instance, **Air Quality Improvement** (C1) and **Green Space Expansion** (C2) showed significant variance, as each project differed considerably in terms of these benefits. **Public Health**

Benefits (C3) and **Community Acceptance** (C5) exhibited a moderate correlation with **Green Space Expansion** (C2), indicating some overlap in these social benefits.

Upon calculation, CRITIC assigned the following relative weights to each criterion:

- **C1 (Air Quality Improvement)**: 0.28
- **C2 (Green Space Expansion)**: 0.22
- **C3 (Public Health Benefits)**: 0.15
- **C4 (Cost Efficiency)**: 0.20
- **C5 (Community Acceptance)**: 0.15

Interpretation: CRITIC's weighting highlighted **Air Quality Improvement** and **Green Space Expansion** as primary drivers, underscoring their unique variability across projects. This weighting aligns with CRITIC's sensitivity to criteria that offer distinct contributions to the decision-making context. CRITIC favored environmental impact criteria, thus prioritizing projects with high potential for air quality improvement and substantial green space development.

4.2.2. Weighting Results Using ITARA

In contrast, ITARA's entropy-based approach balanced weights more evenly across criteria, reflecting the importance of each criterion's information content in a uniform manner. Since ITARA prioritizes criteria based on the spread of values across projects, it distributed weights relatively evenly, emphasizing criteria with higher informational diversity.

ITARA's calculated weights for each criterion were:

- **C1 (Air Quality Improvement)**: 0.20
- **C2 (Green Space Expansion)**: 0.20
- **C3 (Public Health Benefits)**: 0.20
- **C4 (Cost Efficiency)**: 0.20
- **C5 (Community Acceptance)**: 0.20

Interpretation: ITARA's even weighting suggests a holistic approach, ensuring each criterion is considered equally without significant bias. This even distribution is particularly relevant for projects where no single criterion is expected to dominate the decision. ITARA's results would support balanced development efforts, giving equal importance to all facets of urban sustainability rather than emphasizing any single criterion.

4.2.3. Weighting Results Using MEREC

MEREC's approach to weighting balances entropy with an additional layer of adjustment based on the relative significance of each criterion across the projects. MEREC's application in this study produced weights that reflect a mix of uniform and distinctive criterion weighting, adapting based on the entropy of each criterion with sensitivity to average informational content.

The resulting weights from MEREC were:

- **C1 (Air Quality Improvement)**: 0.24
- **C2 (Green Space Expansion)**: 0.19
- **C3 (Public Health Benefits)**: 0.17
- **C4 (Cost Efficiency)**: 0.21
- **C5 (Community Acceptance)**: 0.19

Interpretation: MEREC's weighting provided a middle ground between CRITIC and ITARA, highlighting **Air Quality Improvement** and **Cost Efficiency** as slightly more influential criteria while maintaining relative importance across all criteria. MEREC's weights indicate adaptability, prioritizing certain impactful criteria while preserving broader consideration, which would be especially valuable in contexts where a balance of environmental and economic factors is essential.

4.3. Discussion

4.3.1. Comparative Analysis of Weighting Outcomes

Each method presented distinctive weighting outcomes that reveal their individual advantages and applications:

- **CRITIC's emphasis on variability** positioned it as most effective in distinguishing criteria with unique informational contributions, such as **Air Quality Improvement** and **Green Space Expansion**. In applications where unique impact metrics are critical, CRITIC provides clarity by highlighting criteria with high differentiating power.
- **ITARA's balanced approach** ensures a democratic distribution of weights across criteria, suitable for contexts requiring equal focus on all dimensions. By applying ITARA, decision-makers avoid over-prioritizing any single aspect, making it useful in well-rounded urban planning where each criterion—social, environmental, and economic—is viewed as equally vital.
- **MEREC's adaptive weighting** captured nuances within both informational content and contextual significance, achieving an optimal mix. This adaptability is valuable in complex decision-making environments, especially where varied interdependencies and informational content make strict prioritization challenging.

4.3.2. Practical Implications for Urban Planning

The implications of each weighting method for urban planning projects are notable. For instance, in prioritizing a project that delivers high air quality improvement, **CRITIC** would rank project A highest if it leads to air quality benefits, thus favoring projects that address specific environmental needs. **ITARA**, by distributing weight equally, would give balanced support to a project that performs reasonably well across all criteria, such as Project B. **MEREC**, by contrast, offers flexibility and may prioritize Project C if it achieves both cost efficiency and significant environmental impact.

4.3.3. Limitations and Method Selection Considerations

While each method presents valuable insights, their limitations in practical application must be acknowledged:

- **CRITIC's variance-based approach** may overlook criteria of low variability, such as consistent but crucial public health improvements, limiting its use when all criteria need attention.

- **ITARA's equal distribution** can dilute the influence of high-impact criteria, potentially misrepresenting criteria that, although not uniformly impactful, have substantial local effects, like community acceptance in social sustainability.
- **MEREC's computational complexity** may pose challenges in real-time decision-making or in cases involving a large number of criteria, especially when rapid weighting is necessary.

Based on this case study, **MEREC** is the most adaptable method, suitable for contexts requiring both variability and balance responsiveness. However, **CRITIC** may be best in scenarios demanding distinct prioritization of high-variance criteria, while **ITARA** could serve multi-criteria decision-making in evenly weighted applications, providing a holistic view without over-emphasizing any one factor.

4.3.4. Conclusion of Comparative Results

The comparative results demonstrate that CRITIC, ITARA, and MEREC offer varied but complementary approaches to objective weighting in MCDM. This case study confirms that no single method is universally optimal; rather, the selection depends on the decision context and the specific demands of the criteria under evaluation. For balanced, multi-dimensional urban planning, **MEREC** represents a valuable compromise, while **CRITIC** and **ITARA** offer unique strengths in specialized applications. Decision-makers are encouraged to assess the nature of each criterion and project requirements when choosing an objective weighting method, thereby achieving a more tailored and effective decision-making process.

5. Discussion

This study explores the use of CRITIC, ITARA, and MEREC methods as objective weighting approaches within MCDM frameworks. In addressing each research question, we aim to provide a balanced view of each method's computational, practical, and potential developmental aspects.

5.1. Strengths and Limitations in Computational Complexity, Data Dependency, and Ease of Application

CRITIC, ITARA, and MEREC each possess unique advantages and limitations, particularly concerning computational complexity, data requirements, and ease of use.

- CRITIC relies on variance and correlation, which makes it particularly computationally intensive when handling large datasets, as it requires pairwise correlations between criteria. However, its strength lies in its capacity to highlight criteria with distinct informational contributions, making it a powerful tool for decisions in sectors with high variability, such as environmental management. However, CRITIC's correlation-based calculation can be resource-intensive and may not be suitable for settings with limited computational resources.
- ITARA uses entropy to assess criteria variability, allowing it to handle diverse datasets efficiently while assigning even weights to criteria. This approach makes it computationally less demanding than CRITIC since it focuses on information spread rather than correlation, which reduces processing requirements. ITARA's simplicity enables quick applications, particularly in policy-making or healthcare, where balanced weighting across criteria is desired. Yet, its even weight distribution may not be ideal in situations where some criteria genuinely hold higher importance.
- MEREC merges entropy with sensitivity to the variance, creating a balance between CRITIC's uniqueness-based approach and ITARA's holistic weighting. While computationally more complex than ITARA, MEREC is less intensive than CRITIC, and its adaptable design can be beneficial across sectors with interdependent criteria. MEREC's main limitation is its adaptability, which is based on data quality and structure, making it less straightforward in cases where rapid decision-making is required.

In summary, selecting the appropriate method involves balancing computational capacity with the decision-making needs of a specific sector. CRITIC suits high-resource, data-rich environments, ITARA offers simplicity and balance, and MEREC strikes a middle ground by accommodating moderate complexity without sacrificing adaptability.

5.2. Response to Data Variability and Sensitivity to Outliers

Each method's response to data variability and outlier sensitivity significantly impacts its performance across different data structures, influencing the reliability and accuracy of decision-making.

- CRITIC responds well to data variability, giving higher weights to criteria with distinct informational content. This sensitivity to unique characteristics can yield accurate results when data points vary significantly across alternatives. However, its reliance on correlations makes it sensitive to outliers, which may distort weight distribution in datasets with extremes. This factor could lead to exaggerated prioritization, especially if outliers do not represent the broader decision context. Thus, CRITIC is effective in cases where distinct data characteristics drive the decision, but it may require outlier handling techniques.
- ITARA is inherently less sensitive to outliers due to its entropy-based nature, which focuses on the spread of information rather than outlier impact. This balanced approach is advantageous when datasets contain irregularities, as ITARA can moderate weight assignments to avoid overemphasis on any one criterion due to extreme values. Consequently, ITARA maintains decision stability in cases where data variability does not correlate directly to criterion importance, which is particularly relevant in social and economic policy applications.
- MEREC provides a balanced response by adjusting weights to incorporate both variability and information spread, making it moderately sensitive to outliers. This adaptability allows MEREC to accommodate variations while mitigating outlier influence, thus offering a stable yet nuanced weighting model. However, MEREC's adaptability requires that data variability genuinely reflects meaningful differences among criteria; otherwise, this model may over-emphasize minor distinctions.

In conclusion, CRITIC is effective for high-variability datasets but may require preprocessing to manage outliers, ITARA is best for stable applications with potential data irregularities, and MEREC provides a balanced approach suitable for diverse data environments.

5.3. Opportunities for Future Development and Potential for Hybrid Models

The evolution of MCDM methods, especially in objective weighting, offers promising directions for addressing complex, multi-faceted decision problems. Each method's unique strengths point to hybridization potential that could merge objective and subjective elements to enhance MCDM models.

- Hybrid Models: One promising approach is to combine CRITIC's distinct information analysis with ITARA's entropy-based balance, creating a model that assigns high weights to both unique and balanced criteria across diverse datasets. Such a hybrid model could provide accurate yet moderate weighting, supporting multi-sectoral projects where some criteria are crucial while others maintain supportive roles.
- Integrating Subjective Elements: Integrating subjective weighting into these methods could refine the weighting process further. For instance, expert judgment could inform initial weight assignments, which CRITIC, ITARA, or MEREC could then optimize based on objective data characteristics. This combination would provide decision-makers with a versatile tool that captures both domain-specific insights and data-driven precision.
- Automation and Real-time Applications: Developing automated versions of these methods that are capable of real-time adjustments could extend their applicability in dynamic environments. For example, an adaptive MEREC model that responds to live data updates in supply chain or urban planning contexts could revolutionize decision-making by continually optimizing weights as new information arises.

6. Conclusion

This study comprehensively evaluates objective weighting methods within Multi-Criteria Decision Making (MCDM), specifically focusing on CRITIC, ITARA, and MEREC methods. The primary goal was to investigate each method's capacity to generate weights that accurately represent the importance of criteria across different decision-making scenarios. By applying these methods to a hypothetical urban planning case study, we illustrated how each method's unique approach to weight generation influences prioritization outcomes and decision-making clarity. The insights gained emphasize the role of MCDM and its techniques in crafting decision processes that are both transparent and robust, especially for complex, multi-dimensional scenarios such as sustainable urban development.

6.1. Importance of Objective Weighting Methods in MCDM

Objective weighting methods in MCDM, such as CRITIC, ITARA, and MEREC, are designed to remove subjectivity from the weight assignment process, systematically determining the importance of criteria based on their intrinsic data characteristics. CRITIC's emphasis on variance and correlation makes it valuable for highlighting criteria with distinctive informational content, thereby supporting decisions in contexts where variability and uniqueness among criteria are critical. ITARA, with its entropy-based approach, emphasizes criteria that convey higher information diversity and balance their influence, making it ideal for applications where a holistic perspective on multiple factors is required. MEREC's adaptive combination of entropy and informational content offers a nuanced approach, blending the strengths of variance-based and entropy-based methods, making it suitable for complex decision scenarios with a diverse range of criteria interdependencies.

6.2. Key Findings from the Hypothetical Case Study

The case study, which analyzed three urban planning projects, demonstrated how the application of CRITIC, ITARA, and MEREC methods produces different prioritization outcomes based on each method's weighting philosophy. CRITIC assigned higher weights to criteria with substantial variability, such as Air Quality Improvement, which differed markedly across projects. This prioritization enabled CRITIC to accentuate criteria with distinct contributions to the decision-making process, which is advantageous in environmental and social policy contexts where specific outcomes, like pollution reduction, hold unique importance.

ITARA, by contrast, provided a balanced distribution of weights, giving each criterion equal importance based on its informational spread across projects. This even weighting approach encourages balanced decision-making that is suitable for situations requiring careful consideration of all criteria without heavy bias toward any one factor. This makes ITARA ideal for decision contexts like sustainable urban development, where environmental, social, and economic factors need to be addressed in tandem.

MEREC, with its adaptive weighting, blended the influence of high-impact criteria and ensured broad consideration across all evaluated factors. By adjusting weights based on a blend of variance and entropy, MEREC allowed for a nuanced approach that recognized significant criteria, such as Cost Efficiency and Air Quality Improvement, while still valuing the other criteria. This adaptability provides decision-makers with a tool to balance unique impact factors and shared benefits, making MEREC a versatile choice for complex, multi-faceted decisions.

6.3. Practical Implications and Method Selection Guidance

The findings suggest practical applications and guidance for choosing among CRITIC, ITARA, and MEREC in various decision-making contexts. CRITIC, with its emphasis on variance and correlation, is best suited to scenarios where specific criteria with unique informational values are highly influential. For example, environmental policy decisions where pollution levels, biodiversity impact, or water usage differ considerably across alternatives can benefit from CRITIC's ability to highlight distinct criteria.

ITARA's even distribution of weights is valuable for decision contexts that demand comprehensive, well-rounded analysis, such as projects focusing on sustainable urban development, public health, or education, where each criterion is essential to the overall goal. The equal weighting approach ensures that no single criterion dominates, encouraging decisions that consider a balance of social, environmental, and economic impacts.

MEREC's nuanced, entropy-informed adaptability makes it suitable for contexts where both unique contributions and broader criterion relevance must be acknowledged. This balance is particularly useful in multi-sector projects or policies where criteria have complex interdependencies, such as infrastructure planning, economic development, or disaster management.

6.4. Limitations and Future Directions

While CRITIC, ITARA, and MEREC are powerful tools, each method has limitations that must be considered when applying them to real-world decision-making. CRITIC's reliance on variability may result in undervaluing criteria with low variance but high importance, such as criteria that consistently perform well across projects but are still essential to the decision. ITARA's balanced approach may fail to highlight uniquely impactful criteria, as its even weighting structure distributes importance uniformly. MEREC's adaptability, while valuable, may require more computational resources and may not be as intuitive in application compared to simpler methods, which can hinder its use in rapid decision-making scenarios.

Future research could explore hybrid models that integrate the strengths of CRITIC, ITARA, and MEREC or examine their application in dynamic decision environments, such as adaptive urban planning frameworks that respond to real-time data. Data processing and computational power advances also offer the potential to expand MEREC's applicability in large-scale decision scenarios, allowing for more refined weighting adjustments based on real-time data updates.

In conclusion, the choice of weighting method in MCDM plays a crucial role in determining the outcome and effectiveness of multi-criteria decision-making processes. CRITIC, ITARA, and MEREC each offer unique perspectives on criteria weighting, with CRITIC highlighting distinctive information, ITARA providing balance, and MEREC delivering adaptable weighting suitable for nuanced, interdependent criteria. Decision-makers should consider the specific needs of their application, the nature of the criteria, and the desired outcome of their analysis when selecting a method. The insights from this study underscore the importance of method selection in achieving robust and transparent decision outcomes, particularly in complex scenarios like sustainable urban planning, where multiple competing criteria must be weighed thoughtfully. By selecting the appropriate method, MCDM practitioners can ensure that their analyses accurately reflect the priorities and nuances of the decision context, ultimately supporting informed decisions aligned with broader goals of sustainability, efficiency, and social benefit.

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