

## Article

# A Comparative Analysis of Multi-Criteria Decision-Making Methods and Normalization Techniques in Holistic Sustainability Assessment for Engineering Applications

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**Abstract:** The sustainability evaluation of engineering processes and structures is a multifaceted challenge requiring the integration of diverse and often conflicting criteria. To address this challenge, Multi-Criteria Decision-Making (MCDM) methods have emerged as effective tools. However, the selection of the most suitable MCDM approach for problems involving multiple criteria is critical to ensuring robust, reliable, and actionable outcomes. Equally significant is the choice of a proper normalization technique, which plays a pivotal role in determining the robustness and reliability of the results. This study investigates the impact of common MCDM tools on the decision-making process concerning diverse aspects of sustainability. It also examines how different normalization methods influence the final outcomes. Sustainability in this context is understood as a trade-off among five key dimensions: performance, environmental impact, economic impact, social impact, and circularity. The outcome of the MCDM process is represented by an aggregated metric, referred to as the Sustainability Index (SI). This index offers a comprehensive and robust framework for evaluating sustainability and facilitating decision-making when conflicting criteria are present. To assess the effects of implementing different MCDM and normalization choices on the sustainability assessment, a dataset from the aviation sector is employed. Specifically, a typical aircraft component is analyzed as a case study for holistic sustainability assessment, utilizing data that represent the various dimensions of sustainability mentioned above, for this component. Additionally, the study investigates the influence of initial data variations and weight variations within the MCDM process on the results. The results indicate that, overall, the different MCDM and normalization methods lead to similar outcomes when applied to the design alternatives. However, a deeper dive into the results reveals that the weighted sum method, when paired with min-max normalization, appears to be more appropriate, based on the use case involved for the present investigation, due to its robustness regarding small variations in the initial data and its sensitivity to large ones. This research underscores the critical importance of selecting appropriate MCDM tools and normalization methods to enhance transparency, robustness, reliability, and consistency of sustainability assessments within a holistic framework.

**Keywords:** sustainability evaluation; Sustainability Index (SI); Multi-Criteria Decision Making (MCDM); normalization methods; sensitivity analysis; aviation sector; holistic sustainability assessment; decision-making process; robustness and reliability; consistency of sustainability assessments

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# Multi Criteria Decision Making Methods A Comparative Study

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