

Methodological Guide: Statistical Analysis for MCDA

Software Objective

The primary objective of this software is to provide a robust statistical framework for the pre-processing and validation of Multi-Criteria Decision Analysis (MCDA) matrices. In MCDA, decision matrices (Alternatives x Criteria) are often treated as deterministic truth. However, statistical analysis is crucial to identify redundancies (correlation), understand data distribution (descriptive stats), and test the robustness of the data (Monte Carlo) before applying methods like AHP or TOPSIS.

1. Descriptive Statistics

What it does: Calculates central tendency (Mean, Median) and dispersion (Standard Deviation, Variance, Coefficient of Variation).

Contribution to MCDA:

It helps the analyst understand the behavior of each criterion. A high *Standard Deviation* or *Coefficient of Variation* (CV) indicates a criterion with high discriminatory power (alternatives perform very differently). Conversely, a criterion with near-zero variance does not help distinguish alternatives and might be removed from the model.

2. Normality Tests (Shapiro-Wilk)

What it does: Tests the null hypothesis that the data for a specific criterion was drawn from a normal (Gaussian) distribution.

Contribution to MCDA:

Determining normality is a prerequisite for choosing subsequent tests. If data is normal, parametric tests (ANOVA) are suitable. If not, non-parametric tests (Kruskal-Wallis) are required to compare groups of alternatives.

3. Correlation Analysis (Pearson & Spearman)

What it does: Measures the strength and direction of the relationship between two criteria. Pearson measures linear relationships, while Spearman measures monotonic relationships.

Contribution to MCDA:

Redundancy Detection: In MCDA, criteria should ideally be independent. High correlation (e.g., > 0.9) between two criteria suggests they are measuring the same underlying factor (Double Counting). The analyst should consider removing one or merging them to avoid biasing the final ranking.

4. ANOVA and Tukey HSD

What it does: Analysis of Variance (ANOVA) tests if there are statistically significant differences between the means of three or more independent groups (e.g., Alternatives grouped by 'Region' or 'Manufacturer'). Tukey HSD performs pairwise comparisons to find exactly which groups differ.

Contribution to MCDA:

It validates if categorical groupings of alternatives actually result in different performance levels. If a 'Premium' group does not statistically differ from a 'Standard' group in a performance criterion, the classification may be invalid.

5. Linear Regression

What it does: Models the relationship between a dependent variable (Y) and one or more independent variables (X). It calculates R-squared, P-values, and VIF (Variance Inflation Factor).

Contribution to MCDA:

It allows the analyst to investigate if a specific Cost or Benefit criterion can be predicted by technical parameters. High VIF values confirm multicollinearity, reinforcing the need to restructure the criteria tree.

6. Monte Carlo Simulation

What it does: Performs thousands of iterations by adding random noise (Gaussian perturbation) to the input data and recalculating scores based on a normalized sum approach.

Contribution to MCDA:

Sensitivity and Robustness: It answers the question: 'If my data has a 5% error margin, does the best alternative change?' If the ranking fluctuates wildly with small noise, the decision is fragile. This is critical for Risk Analysis.

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