PROCEEDINGS OF
INTERNATIONAL CONFERENCE ON INTELLIGENT SYSTEMS AND NEW APPLICATIONS
https://proceedings.icisna.org/
3rd International Conference on Intelligent Systems and New Applications (ICISNA'25), Antalya, December 12-14, 2025.

Comparative Evaluation of Multi-Criteria Decision-Making Methods in the Online-CADCOM Platform

Lavdim Menxhiqi[1]

[1]Computer Science and Engineering, UBT – Higher Education Institution, Pristina, Kosovo
lavdim.menxhiqi@ubt-uni.net, ORCID: 0000-0002-5314-8741

***Abstract*—The Online-CADCOM platform operates as a cloud-based decision support system which lets users pick Computer-Aided Design (CAD) tools for telecommunications and electronics applications. The production platform uses two Multi-Criteria Decision Analysis (MCDA) methods MAUT and PROMETHEE II to evaluate tools through binary feature criteria stored in a PostgreSQL knowledge base [3], [4]. The MCDA engine receives three additional decision analysis methods which include TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) and VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) and COPRAS (Complex Proportional Assessment). The research module contains all five evaluation methods which process equal decision matrices to generate agreement metrics through Spearman rank correlation and top-k overlap analysis. The evaluation of three actual selection cases including PCB design tool selection and PCB calculator selection and SMPS design tool selection produced similar decision patterns. The three methods MAUT and PROMETHEE II and VIKOR create a consensus group which produces identical rankings throughout most evaluation scenarios while COPRAS follows MAUT patterns and TOPSIS produces different results when criteria coverage is limited or when criteria have negative correlations with value-based methods. The five methods produce identical rankings because their tools display different characteristics. The research adds three main contributions to the field: (1) The Online-CADCOM engine now supports TOPSIS and VIKOR and COPRAS as additional decision analysis methods. (2) The research evaluates five MCDA methods through actual tool passport data from three engineering fields. The research establishes essential guidelines which engineers need to select proper MCDA methods for their tool selection work.**

***Keywords*— Online-CADCOM; multi-criteria decision-making; MAUT; PROMETHEE; TOPSIS; VIKOR; COPRAS; CAD tool selection; PCB design; decision support system**

I. Introduction

The selection of appropriate tools for electronics design becomes an intricate engineering choice because of numerous specialized Computer-Aided Design (CAD) and Electronic Design Automation (EDA) tools available. Designers who select software for printed circuit board (PCB) layout and switched-mode power supply (SMPS) design and RF analysis and analogue filter synthesis need to evaluate tool costs against their features and operational complexity and system compatibility and maintenance support from vendors [1], [2].

The selection of tools without proper evaluation results in workflow disruptions and system incompatibilities which produce negative effects on design output quality. The selection process becomes more difficult for students and entry-level engineers because they need to handle different tool systems.

The Online CADCOM platform solves this issue through its combination of tool "passports" in a structured database with MCDA methods that generate tool rankings according to user-defined evaluation criteria [3], [4]. The system began with filter design and other specific application areas [1], [2]. The system received its update through a new dynamic expert module which integrated React front-end technology with .NET 8 back-end and PostgreSQL database management for web-based tool and criterion administration [5]. The knowledge base received expansion through the addition of PCB design tools and calculators and passive element design capabilities [3], [8]. The system received two new features which included AI-based PCB workflow assistance and automated workflow completion through language model implementation [6], [7]. The platform has evolved into a universal decision-making platform for CAD and EDA tools through its various system enhancements.

Figure 1. System architecture of the Online-CADCOM platform, illustrating the interaction between the web user interface, the multi-method MCDA engine (MAUT, PROMETHEE II, TOPSIS, VIKOR, COPRAS) and the PostgreSQL-based knowledge base with tool passports.

The current production platform supports two MCDA methods: MAUT (Multi Attribute Utility Theory) and PROMETHEE II, which rank tools using binary criteria and three importance levels [4], [5]. The overall system architecture is shown in Figure 1.

MAUT implements a weighted sum utility model, while PROMETHEE II performs pairwise comparisons and computes net preference flows. Prior experiments showed that both methods discriminate effectively among PCB design tools, often producing similar top ranked results [3], [5]. However, the MCDA literature emphasizes that no single method is universally optimal [9], [12]. Distance based, compromise based and proportional assessment methods use different preference aggregation philosophies and can produce different rankings for the same decision matrix.

To examine these differences, this paper extends the Online CADCOM decision engine with three additional MCDA methods: TOPSIS, VIKOR and COPRAS. All five methods are now available within a unified research module that evaluates identical decision matrices and computes ranking results, Spearman correlation and top k agreement.

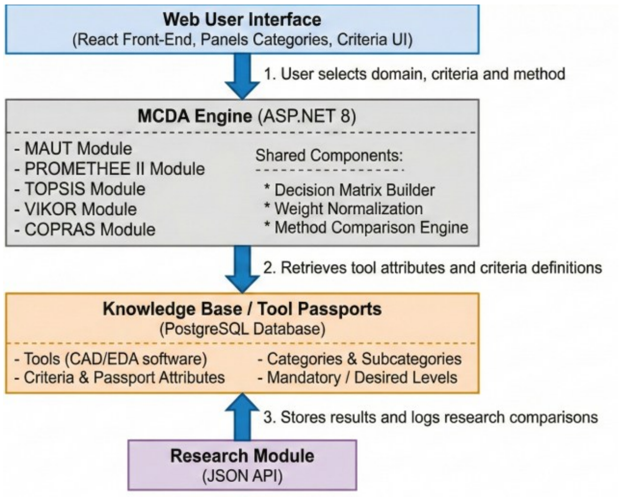

Fig. 1 System architecture of the Online-CADCOM platform, illustrating the interaction between the web user interface, the multi-method MCDA engine (MAUT, PROMETHEE II, TOPSIS, VIKOR, COPRAS) and the PostgreSQL-based knowledge base with tool passports

TABLE I. OVERVIEW OF MCDA METHODS IMPLEMENTED IN ONLINE CADCOM

Method	Method family	Main principle	Typical output
MAUT Multi Attribute Utility Theory	Value based	Weighted sum of criterion utilities	Single utility score and full ranking
PROMETHEE II Preference Ranking Organization Method for Enrichment Evaluations II	Outranking	Pairwise preference comparison and net flow computation	Net flow values and full ranking
TOPSIS Technique for Order Preference by Similarity to Ideal Solution	Distance based	Distance to positive and negative ideal solutions	Closeness coefficient and ranking
VIKOR VlseKriterijumska Optimizacija I Kompromisno Resenje	Compromise based	Balance between group utility and individual regret	Compromise index and ranking
COPRAS Complex Proportional Assessment	Proportional assessment	Normalised proportional contribution of criteria (benefit/cost)	Relative significance and utility degree

The methodology is evaluated using three realistic scenarios extracted from the existing knowledge base: PCB design tools, PCB design calculators and SMPS design tools. These scenarios represent different levels of tool similarity, criteria sparsity and feature distribution. The experiments quantify when MCDA methods agree, when they diverge and how sensitive they are to binary criteria distributions. The overall goal is not to identify a single best method, but to provide engineers and students using Online CADCOM with validated and practical guidance for selecting appropriate MCDA techniques for different tool selection contexts.

II. BACKGROUND AND RELATED WORK

Multi-Criteria Decision-Making (MCDM) addresses decision problems involving alternatives evaluated against multiple, often conflicting criteria [9], [12]. Let

$$A = \{a_1, a_2, \dots, a_m\}$$

be the set of tools,

$$C = \{c_1, c_2, \dots, c_n\}$$

the set of criteria,

$$X = [x_{ij}]$$

the binary decision matrix (feature satisfaction), and

$$W = \{w_1, w_2, \dots, w_n\}, \qquad \sum_{j=1}^{n} w_j = 1$$

the weight vector.

The objective in MCDM is to compute a preference structure resulting in a full ranking or selection of one or more preferred tools.

MCDM approaches are commonly grouped into methodological families [9], [12]:

- Value-based: compute an aggregated score (e.g., SAW, MAUT)
- Outranking: compare alternatives pairwise (e.g., PROMETHEE)
- Distance-based: measure proximity to ideal solutions (e.g., TOPSIS)
- Compromise-based: balance group utility and individual regret (e.g., VIKOR)
- Proportional-assessment: apply normalised benefit/cost ratios (e.g., COPRAS)

An overview of the MCDA method families used in this paper is given in Table I.

A. MCDA in CAD/EDA Tool Selection

Previous work applied MCDA to filter design software selection within the Online-CADCOM ecosystem [1], [2]. Later studies expanded the system to additional engineering domains and incorporated more comprehensive tool-passport structures and criteria taxonomies [3], [4], [8].

The platform's architecture evolved significantly, culminating in a modern React + ASP.NET + PostgreSQL implementation that supports dynamic tool passport management and automated ranking [5]. More recent contributions explored AI assistance:

- AI-supported PCB design workflows [6]
- Large-language-model-based workflow completion [7]

These studies demonstrate the feasibility of integrating rule-based MCDA with machine learning to support engineering decision workflows.

B. Limitations of Prior Approaches

The existing Online-CADCOM platform supports MAUT and PROMETHEE II for ranking tools using binary criteria and three-level weights [4], [5]. Although these methods often agree in practice — especially in PCB design scenarios [3], [5] — MCDA literature emphasises that different families of methods may produce different results under the same decision matrix [9], [12].

Distance-based and proportional-assessment techniques behave differently from utility-based and outranking methods when:

- criteria are unevenly distributed
- alternatives share highly similar feature vectors
- feature sparsity amplifies geometric effects in the decision space

These conditions frequently occur in engineering tool-passport datasets.

C. Contribution to Literature

By integrating TOPSIS, VIKOR, and COPRAS alongside MAUT and PROMETHEE II into the same operational environment, this work expands the Online-CADCOM platform and enables:

- systematic cross-method evaluation
- empirical observation of ranking divergence
- quantitative assessment through correlation metrics
- practical guidelines for MCDM method selection

This multi-method analysis fills a gap in CAD/EDA engineering literature, where comparative studies under identical binary decision matrices are rare.

III. Online-CADCOM Multi-Method MCDA Engine

The Online CADCOM platform organises engineering design tools into a hierarchy of panels, categories and subcategories that correspond to practical domains such as PCB design, SMPS converters and PCB calculators [3], [5]. Each tool is represented by a structured passport that contains feature information, supported standards, design capabilities, integration options and platform details. These attributes form the basis for the Multi Criteria Decision Making evaluation.

Users initiate a selection process by choosing a domain and selecting criteria that are mandatory, desired with high importance or desired with lower importance. The system then constructs a binary decision matrix X where x_ij = 1 indicates that tool a_i satisfies criterion c_j and x_ij = 0 otherwise. Mandatory criteria act as hard filters. Any tool that fails at least one mandatory criterion is removed before ranking.

A. MCDA Input Model

All five MCDA methods operate on the same binary matrix X and the same weight vector W. Three weight levels are used in the Online CADCOM platform: 1.00 for mandatory, 0.50 for high priority desired and 0.33 for low priority desired criteria [4], [5]. The weights are normalised to ensure that:

$$\sum_{j=1}^{n} w_j = 1$$

All subsequent MCDA calculations use these normalised weights and the filtered matrix X.

B. Unified Multi Method Engine

Earlier versions of the platform supported only MAUT and PROMETHEE II [4], [5]. The new research module extends this functionality by integrating TOPSIS, VIKOR and COPRAS as additional methods within the same processing pipeline.

The back end implements a strategy pattern. An abstract class defines the Evaluate function and concrete classes implement the five algorithms. This design ensures consistent input handling and allows ranking results to be compared directly.

The server exposes two primary API endpoints:

- /api/DecisionMaking/evaluate for running a single MCDA method
- /api/DecisionMaking/compare-methods for executing all five methods and generating comparison metrics (me nr)

The comparison endpoint produces:

- A ranked list of tools for each of the five methods
- A Spearman rank correlation matrix
- Top k agreement statistics (k = 1 and k = 3)
- A combined results table

The Spearman rank correlation coefficient measures the agreement between two method rankings and is calculated as:

$$\rho = 1 - \frac{(6 \times \Sigma d_i^2)}{\left(n(n^2 - 1)\right)}$$

where d_i is the difference between ranks assigned to tool i by the two methods, and n is the number of ranked tools. Values of ρ range from -1 (completely reversed rankings) through 0 (no correlation) to +1 (identical rankings).

Top-k agreement quantifies whether methods select the same tools in their top k positions, calculated as the percentage of tools appearing in the top-k set across all five methods.

C. Workflow for MCDA Comparison

The workflow consists of the following steps:

- The user selects panel, category and criteria.
- The system builds the decision matrix X and normalises weights.
- Mandatory criteria filter out non-viable tools.
- The MCDA engine applies MAUT, PROMETHEE II, TOPSIS, VIKOR and COPRAS on the same data.
- The comparison module computes agreement metrics and visualizes results.

This integrated multi method evaluation approach ensures that all rankings are directly comparable, since they are based on the same tool set and the same selected criteria.

IV. MCDM Methods and Binary Adaptation

All five MCDA methods in Online CADCOM operate on the same binary decision matrix and weight vector. After mandatory filtering, each tool a_i is evaluated using the selected method. The input model is defined by:

$$X = [x_{ij}]$$

Weights:

$$W = \{w_1, \dots, w_n\}, \qquad \sum_{j=1}^{n} w_j = 1$$

Since all criteria in Online CADCOM are binary and represent benefit attributes, each method is adapted to work with discrete feature coverage rather than continuous measures.

A. MAUT and PROMETHEE II (Existing Methods)

1) MAUT computes a weighted sum of satisfied criteria. With binary values and identity utilities, the utility function becomes:

Formula MAUT 1: Weighted Sum Utility

$$U(a_i) = \sum_{j=1}^{n} w_j x_{ij}$$

Tools are ranked in descending order of U(a_i). This formulation is easy to explain to engineers and is widely used for decision support [3], [4].

2) PROMETHEE II applies pairwise comparison using a usual preference function:

$$P_{j(a_i,a_k)} = \begin{cases} 1 & x_{ij} = 1 \; and \; x_{kj} = 0 \\ 0 & otherwise \end{cases}$$

Aggregated preference:

$$\pi(a_i, a_k) = \sum_{(j=1)}^{n} w_j P_j(a_i, a_k)$$

Positive and negative preference flows:

$$\varphi^{+(a_i)} = \left(\frac{1}{m-1}\right) * \sum_{k \neq i} \pi(a_i, a_k)$$

$$\varphi^{-(a_i)} = \left(\frac{1}{m-1}\right) * \sum_{k \neq i} \pi(a_k, a_i)$$

In the Online-CADCOM implementation, the normalization factor 1/(m-1) is omitted from the flow calculations, as it does not affect the ranking order.

The implementation computes raw flow sums, which are then used to determine net flow and final rankings.

$$\varphi(a_i) = \varphi^{+(a_i)} - \varphi^{-(a_i)}$$

PROMETHEE II produces a complete ranking by sorting tools by $\varphi(a_i)$.

B. TOPSIS

TOPSIS evaluates how close each alternative is to an ideal tool. The first step is vector normalisation:

Formula TOPSIS 1: Normalisation

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{k=1}^{m} x_{kj}^2}}$$

Weighted normalised values:

$$v_{ij} = w_j r_{ij}$$

Distances to ideal and anti-ideal points:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+ \right)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^- \right)^2}$$

Closeness coefficient:

$$C_i = \frac{S_i^-}{(S_i^+ + S_i^-)}$$

Tools are ranked in descending order of C_i.

C. VIKOR

VIKOR computes group utility (S) and individual regret (R). For binary criteria:

Best and worst values:

$$f_j^* = 1$$
$$f_j^- = 0$$

Utility measure:

$$S_i = \sum_{j=1}^{n} w_j \left(\frac{(f_j * - x_{ij})}{(f_j * - f_j -)} \right)$$

Regret measure:

$$R_i = \max_j \left[w_j \left(\frac{(f_j * - x_{ij})}{(f_j * - f_j -)} \right) \right]$$

Reference values:

$$S^* = \min S_i, \qquad S^- = \max S_i$$
$$R^* = \min R_i, \qquad R^- = \max R_i$$

VIKOR index (v = 0.5 in this study):

$$Q_i = v \left(\frac{(S_i - S*)}{(S - - S*)} \right) + (1 - v) \left(\frac{(R_i - R*)}{(R - - R*)} \right)$$

The compromise parameter v = 0.5 assigns equal weight to group utility maximization (S) and individual regret minimization (R). This balanced configuration is the standard default in VIKOR applications and represents a consensus-seeking strategy that neither favors maximum group benefit nor focuses exclusively on minimizing worst-case outcomes [10]. Tools are ranked in ascending order of Q_i.

D. COPRAS

COPRAS evaluates alternatives based on proportional significance. Columns of X are normalised:

Formula COPRAS 1: Column Normalisation

$$r_{ij} = \frac{x_{ij}}{\sum_{k=1}^{m} x_{kj}}$$

Weighted values:

$$v_{ij} = w_j r_{ij}$$

Since all criteria are benefits in Online CADCOM:

$$S_i^+ = \sum_{j=1}^{n} v_{ij}$$

Relative significance:

$$Q_i = S_i^+$$

Utility degree:

$$N_i = \left(\frac{Q_i}{max_k\, Q_k}\right) * 100$$

V. Experimental Evaluation

This section evaluates the five MCDA methods (MAUT, PROMETHEE II, TOPSIS, VIKOR and COPRAS) using real tool passports stored in the Online-CADCOM knowledge base. Three test scenarios were designed to reflect realistic tool-selection tasks across three engineering domains. Each scenario simulates a user profile with specific design requirements and applies all MCDA methods to the same decision matrix.
The methods are compared using:

- Rank convergence (top-1 and top-3 agreement)
- Spearman rank correlation coefficient
- Ranking tables
- Consensus patterns across method families

A. *Use Case Scenarios*

Three scenarios were constructed using actual tool data from Online-CADCOM. Each scenario differs in the number of tools, number of criteria, and the weight distribution (mandatory, high-priority desired, low-priority desired).
The three evaluation scenarios are summarized in Table II

TABLE II. Overview of use case scenarios.

S	Domain	Sub-Category	Tools (n)	Criteria (m)	Weight Distribution
S_1	PCB Design Tools	PCB Design Tool	8	11	3 Mandatory, 4 High, 4 Low
S_2	PCB Calculators	PCB Design Calculator	15	6	1 Mandatory, 3 High, 2 Low
S_3	SMPS Design Tools	SMPS Converters/ Reg.	8	8	1 Mandatory, 3 High, 4 Low

B. *Scenario S_1: PCB Design Tool Selection*

This scenario simulates a designer selecting a PCB layout tool for medium-complexity boards. Criteria include board size limits, layer count, footprint libraries, design verification features, autorouting, simulation support, 3D view, platform compatibility and cloud integration.
Table III summarizes the criteria and weights for Scenario S_1.

TABLE III. Scenario S_1 – PCB design tool requirements.

Criterion	Priority	Weight	Selected Requirement
Board Size	Mandatory	1.00	Up to 80 cm²
Number of Layers	Mandatory	1.00	Up to 16
Footprints in Libraries	Mandatory	1.00	Up to 8,000
Design Verification	Desired-H	0.50	DRC/ERC required
Auto-Routing	Desired-H	0.50	Required
Import/Export	Desired-H	0.50	BOM, Gerber, DXF
Simulation	Desired-H	0.50	SPICE simulation
3D View	Desired-L	0.33	Required
Cloud Integration	Desired-L	0.33	Required
Technical Support	Desired-L	0.33	Docs, Tutorials
Cross-Platform Support	Desired-L	0.33	Windows

Tools considered (n = 8):
DesignSpark PCB, EasyEDA, CircuitMaker, EAGLE, KiCad, LibrePCB, ExpressSCH & ExpressPCB, TinyCAD.

After mandatory filtering, 5 tools remained. Three tools were excluded for failing mandatory criteria: LibrePCB (insufficient footprint library), ExpressSCH & ExpressPCB (does not support 16-layer designs), and TinyCAD (schematic-only tool without PCB layout capability).

Ranking results (M - MAUT, P - PROMETHEE, T - TOPSIS, V - VIKOR, C - COPRAS) are shown in Table IV.

TABLE IV. Scenario S_1 – Ranking comparison for PCB design tools.

Tool	M	P	T	V	C
EAGLE	1	1	1	1	1
CircuitMaker	2	2	2	2	2
EasyEDA	3	3	3	3	3
KiCad	4	4	4	4	4
DesignSpark PCB	5	5	5	5	5

All five methods returned the identical ranking:

1) EAGLE
2) CircuitMaker
3) EasyEDA
4) KiCad
5) DesignSpark PCB

Correlation Analysis (**M** - MAUT, **P** - PROMETHEE, **T** - TOPSIS, **V** - VIKOR, **C** - COPRAS)
The Spearman rank correlation coefficients between the five methods for Scenario S_1 are given in Table V.

TABLE V. Scenario S_1 – Spearman rank correlation between methods.

	M	P	T	V	C
M	1.000	1.000	1.000	1.000	1.000
P	1.000	1.000	1.000	1.000	1.000
T	1.000	1.000	1.000	1.000	1.000
V	1.000	1.000	1.000	1.000	1.000
C	1.000	1.000	1.000	1.000	1.000

Key Result (Scenario S_1)
Full agreement (100%) across all five methods, with perfect Spearman correlation ($\rho = 1.000$). This occurs when one tool (EAGLE) clearly dominates across multiple high-priority criteria, demonstrating strong method stability when alternatives are well-differentiated

C. *Scenario S_2: PCB Calculator Selection*

The engineer's selected criteria and their assigned priorities are summarized in Table VI. This scenario simulates a signal-integrity engineer selecting a PCB calculator for trace-width analysis. The engineer requires only trace-width/current calculation as a mandatory capability. Other potential mandatory criteria available in the knowledge base—

impedance calculation, thermal analysis, and PCB cost estimation—were not selected as requirements for this particular evaluation, allowing a broader pool of tools to be considered.

TABLE VI. SCENARIO S_2 – PCB CALCULATOR REQUIREMENTS.

Criterion	Priority	Weight	Selected Requirement
Trace Width/Current Capability	Mandatory	1.00	Required
Industry Standard Basis	Desired-H	0.50	IPC-2141A, IPC-2152, IPC-2221, IPC-2251 compliant
Platform Accessibility	Desired-H	0.50	Web - No install
Multi-functionality	Desired-H	0.50	Covers ≥ 2 domains
Graphical Output	Desired-L	0.33	Dynamic plot/graph
Data Export	Desired-L	0.33	File/API export

Tools considered include:
Saturn PCB Toolkit, Digi-Key Calculators, EEWeb Calculator, Omni Calculator, AdvancedPCB Calculator, Sierra Circuits Calculator, Circuit Digest Calculator, and others.

Ranking results (M - MAUT, P - PROMETHEE, T - TOPSIS, V - VIKOR, C - COPRAS) for the top eight calculators are shown in Table VII.

TABLE VII. SCENARIO S_2 – RANKING COMPARISON FOR THE TOP EIGHT PCB CALCULATORS.

Tool	M	P	T	V	C
Megabyte Circuit PCB Calculator	1	1	2	1	2
AdvancedPCB Trace Width Calculator	2	2	5	2	5
Circuit Digest Calculator	3	3	6	3	6
Digi-Key Calculator	4	4	7	4	7
EEWeb Microstrip Calculator	5	5	8	5	8
Omni Calculator	6	6	1	6	1
Saturn PCB Toolkit	7	7	3	7	3
Sierra Circuits Calculator	8	8	4	8	4

A strong divergence is observed between the method families:

- MAUT / PROMETHEE / VIKOR cluster: Rank Megabyte PCB Calculator first
- TOPSIS: Ranks Omni Calculator first
- COPRAS: Also ranks Omni Calculator first

This indicates that the distance-based and proportional-assessment methods favour a different type of tool profile than the utility-based methods.

Spearman correlation (**M** - MAUT, **P** - PROMETHEE, **T** - TOPSIS, **V** - VIKOR, **C** - COPRAS)

The Spearman rank correlation coefficients between the five MCDA methods for Scenario S_2 are shown in Table VIII.

TABLE VIII. SCENARIO S_2 – SPEARMAN RANK CORRELATION BETWEEN METHODS.

	M	P	T	V	C
M	1.0000	1.0000	-0.1190	1.0000	-0.1190
P	1.0000	1.0000	-0.1190	1.0000	-0.1190
T	-0.1190	-0.1190	1.0000	-0.1190	1.0000
V	1.0000	1.0000	-0.1190	1.0000	-0.1190
C	-0.1190	-0.1190	1.0000	-0.1190	1.0000

Findings:

- Value-based methods (MAUT, PROMETHEE, VIKOR) form one consistent cluster
- TOPSIS and COPRAS form a separate cluster
- Between-cluster correlation is negative ($\rho = -0.1190$)
- Top-1 agreement across all methods: 33.33%

This scenario reveals maximum divergence among the five MCDA methods.

Key Result (Scenario S_2)

Scenario S_2 demonstrates that TOPSIS becomes highly sensitive when criteria vectors are sparse and tools have complementary rather than overlapping features. In such cases, TOPSIS and COPRAS may favor tools with balanced feature profiles, whereas MAUT, PROMETHEE, and VIKOR favor tools with stronger coverage of high-priority features.

D. *Scenario S_3: SMPS Design Tool Selection*

This scenario models a power electronics engineer selecting an SMPS (Switched-Mode Power Supply) design tool for a DC-DC flyback converter project. The designer requires DC-DC converter support as the only mandatory criterion. Other mandatory criteria available in the SMPS subcategory—AC-DC support, input/output voltage ranges, current limits, and schematic generation—were not selected, as the project focuses specifically on simulation and thermal analysis capabilities. Eight tools were evaluated in this scenario.

The engineer's selected requirements and their corresponding weights are summarized in Table IX.

TABLE IX. SCENARIO S_3 – SMPS TOOL REQUIREMENTS.

Criterion	Priority	Weight	Selected Requirement
DC-DC Converter Support	Mandatory	1.00	Required
Simulation	Desired-H	0.50	Required
Tambient	Desired-H	0.50	Required
Topology	Desired-H	0.50	Flyback
Product Catalog	Desired-L	0.33	Required
Price Information	Desired-L	0.33	Required
Feedback	Desired-L	0.33	Required
Temperature Analysis	Desired-L	0.33	PCB thermal analysis

Tools considered (n = 8):
ON Semiconductor Design Tools, PowerEsim, ST eDesign Suite, TI WEBENCH, Infineon PowerEsim, Monolithic Power Tools, ADIsimPower, TDK Tools.

Ranking results (**M** - MAUT, **P** - PROMETHEE, **T** - TOPSIS, **V** - VIKOR, **C** - COPRAS)

The rankings produced by the five MCDA methods for the S_3 SMPS scenario are shown in Table X.

TABLE X. SCENARIO S_3 – RANKING COMPARISON FOR SMPS DESIGN TOOLS.

Tool	M	P	T	V	C
ON Semiconductor Design Tools	1	1	3	1	3
PowerEsim	2	2	1	2	1
ST eDesign Suite	3	3	3	3	3
WEBENCH (TI)	4	4	2	4	2
Infineon PowerEsim	5	5	5	5	5
Monolithic Power Tools	6	6	6	6	6
ADIsimPower	7	7	8	7	8
TDK LC Filter Design Tool	8	8	8	8	8

Observations

The results reveal two distinct method families:

Utility-based cluster: MAUT, PROMETHEE, VIKOR

- These methods all rank ON Semiconductor Design Tools as the top-performing alternative.
- PowerEsim consistently ranks second in this family.

Distance-based cluster: TOPSIS and COPRAS

- Both distance-oriented methods place PowerEsim first.
- ON Semiconductor Design Tools drops to third in both TOPSIS and COPRAS.

Agreement Summary

- Top-3 agreement between all methods: 66.67%
- Demonstrates moderate alignment, with both families recognizing the same top three tools but in different order.

Spearman Correlation Analysis (**M** - MAUT, **P** - PROMETHEE, **T** - TOPSIS, **V** - VIKOR, **C** - COPRAS)

The Spearman rank correlation matrix for this scenario is presented in Table XI.

TABLE XI. SCENARIO S_3 – SPEARMAN RANK CORRELATION BETWEEN METHODS.

	M	P	T	V	C
M	1.0000	1.0000	0.8810	1.0000	0.8810
P	1.0000	1.0000	0.8810	1.0000	0.8810
T	0.8810	0.8810	1.0000	0.8810	1.0000
V	1.0000	1.0000	0.8810	1.0000	0.8810
C	0.8810	0.8810	1.0000	0.8810	1.0000

Findings

- MAUT, PROMETHEE, and VIKOR maintain perfect mutual correlation
  → $\rho = 1.000$
  confirming strong internal consistency.
- TOPSIS and COPRAS are also perfectly correlated → $\rho = 1.000$
- Correlation between the two method families is
  → $\rho \approx 0.8810$,
  indicating positive but non-identical rankings.

Key Result (Scenario S_3)

Scenario S_3 demonstrates moderate agreement across the five MCDA methods. The correlation is positive across all method pairs but not perfect due to differing preferences between utility-based and distance-based methods. This illustrates realistic behaviour in tool-selection tasks where no single tool dominates all high-priority criteria. In such cases, method families may prioritize different aspects (e.g., completeness vs. balance), leading to coherent but not identical rankings.

E. Cross-Scenario Comparison

This section summarizes the behavioural patterns of the five MCDA methods across the three experimental scenarios: PCB design tools (S_1), PCB calculators (S_2), and SMPS design tools (S_3). The comparison highlights differences in ranking stability, method agreement, and sensitivity to sparse or overlapping criteria. A consolidated overview of top-1 and top-3 agreement, as well as average Spearman correlation, is presented in Table XII.

TABLE XII. CROSS-SCENARIO SUMMARY OF AGREEMENT AND METHOD DIVERGENCE.

S	Tools Evaluated	Criteria Used	Top-1 Agreement	Top-3 Agreement	Avg. Spearman ρ	Method Divergence
S_1	5 viable	11	100 %	100 %	1.0000	None
S_2	8 viable	6	33.33 %	33.33 %	0.5524	High
S_3	8 viable	8	66.67 %	66.67 %	0.9524	Moderate

Findings

Scenario S_1 – PCB Design Tools

- All five methods produced identical rankings.
- Perfect agreement across method families:
  → top-1 = 100 %, top-3 = 100 %, $\rho = 1.0000$
- Occurs when one tool (EAGLE) strongly dominates across several high-priority criteria.

Scenario S_2 – PCB Calculators

- Exhibits the highest divergence among methods.
- Value-based methods (MAUT, PROMETHEE, VIKOR) form one ranking cluster;
- TOPSIS and COPRAS form another cluster with nearly reversed ordering.
- Negative correlation between clusters ($\rho \approx -0.1190$).
- Top-1 agreement only 33.33 %.

Scenario S_3 – SMPS Design Tools

- Shows moderate stability across methods.
- Both method clusters recognise the same top tools, but in different order.
- Correlation between clusters is strongly positive ($\rho \approx 0.8810$).
- Top-1 and top-3 agreement: 66.67 %.

Consensus Patterns Across All Scenarios

1) MAUT, PROMETHEE, and VIKOR consistently form a consensus cluster.

- Identical rankings in S_1 and S_2.
- Always perfectly correlated internally ($\rho = 1.0000$).
- Demonstrate stable behaviour even with sparse criteria.

2) COPRAS generally tracks MAUT, due to similar linear-additive structure.

- Exception: Scenario S_2, where its column-sum normalization amplifies rare features.
- This can shift the top-ranked tool when criteria distribution is uneven.

3) TOPSIS is the most sensitive method, particularly to sparse binary vectors.

- Shows large rank changes when tools satisfy complementary sets of criteria.
- Performs best in scenarios with richer feature differentiation (e.g., S_1, S_3).

Implications for Online-CADCOM

The results offer practical guidance for users of the Online-CADCOM platform:

- MAUT or COPRAS
  Recommended when interpretability, simplicity, and transparency are critical.
  COPRAS may be preferred when highlighting tools with rare feature support.
- PROMETHEE II
  Recommended when pairwise dominance or outranking logic improves justification, especially for engineering training and design-review documentation.
- VIKOR
  Appropriate when the designer desires a compromise solution that minimizes regret, especially in cases where no tool dominates all key criteria.
- TOPSIS
  Should be used only when criteria coverage is dense and tools differ on many features.
  Better suited for sensitivity analysis or when evaluating well-structured numeric data.

VI. Conclusion and Future Work

The Online-CADCOM platform received an MCDA selector now operates as a five-method decision engine which includes MAUT and PROMETHEE II and adds TOPSIS and VIKOR and COPRAS to its functionality. The decision matrices from tool passports undergo weight assignment based on the three-level criteria model which all five methods use for their operations. The research module produces tool rankings and top-k agreement results and Spearman correlation matrices which enable users to perform systematic method performance analysis.

The experimental assessment of three actual tool selection cases showed that the different method families produced similar results. The three methods MAUT and PROMETHEE II and VIKOR produced identical or very similar rankings throughout all evaluation scenarios. The ranking results of COPRAS matched MAUT results except when the criteria weights showed significant variations. TOPSIS produced the most variable results because it used distance-based geometric methods which affected ranking outcomes when the binary criteria were sparse or complementary.

The extended MCDA module enables Online-CADCOM to function as an operational environment for studying different decision-making approaches. The platform enables users to study method variations through actual tool data analysis instead of depending on theoretical models. The results show that method selection becomes most critical when tools have identical features and evaluation criteria weights do not align with each other. Multiple evaluation methods lead to better decision accuracy because they generate extra data about ranking stability.

The research team has created various research directions which they will investigate through their future studies. The research will continue by adding ELECTRE and AHP-weighted scoring models and other outranking and hybrid decision methods to the comparison. The platform will learn user weighting preferences through adaptive weight-learning mechanisms which were first proposed in AI-assisted design workflow research [6] and [7]. The platform will use AI agents for structured decision support through recent developments in [13] and [14] to suggest both best design tools and most suitable MCDA methods based on decision scenario details.

Acknowledgment

This study is supported by the Bulgarian National Science Fund, Grant No: KP-06-N52/7. The work is partly supported by the CEEPUS network CIII-BG-1103-07-2223. The authors thank the Research and Development Sector of Technical University of Sofia for providing infrastructure and support for the Online-CADCOM platform development.

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