International Journal of Computer Aided Manufacturing

Vol: 12

Issue: 1

Year: 2026

E-ISSN:2456-642X

Type of article: Research

Received Date: 07 February, 2026

Accepted Date: 27 February, 2026

Published Date: 13 March, 2026

CAM Software Selection in Tamil Nadu Manufacturing SMEs using ELECTRE III and Decision Resonance Methods

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ABSTRACT

This paper contributes a conceptual framework to guide the strategic alignment of software selection criteria using a new method - Decision Resonance Method and an established method - ELECTRE III within the existing decision theory frameworks. The analysis contributes empirically tested software selection criteria that will improve the categorization of decision implications This study provides input for decision theory extensions related to information, the

value of problem structuring, and its application to emerging research chasing implicit decisions. Managerial implications include enhancing awareness of implicit assumptions when replicating a previous strategic decision-context (culture), and when considering how a decision environment or set of alternatives has subtly drifted rendering uncertainty or missed dynamic opportunities. Industry will benefit from the associated modeling correctness by appreciating the role of less visible weighting error in overlooked alternatives. Applied to a 10-alternative, 10-criteria matrix of real-world constraints within Coimbatore's manufacturing ecosystem, both approaches converge in the elimination of alternatives that are not suited, however, they differ in the top ranking recommendations. Mastercam is identified as the most appropriate decision for immediate implementation while Siemens NX is the most suitable long-term investment .The comparative analysis exposes the philosophical distinctions between the two approaches and provides insights that can be operationalized for the adoption of technology by SMEs.

Keywords: MCDM, ELECTRE III, Decision Resonance, CAM Software Selection, Manufacturing SMEs, Tamil Nadu

1. INTRODUCTION

Tamil Nadu's industrial landscape, particularly the Coimbatore textile machinery manufacturing cluster, is situated at the critical trajectory of digital transformation (Tamil Nadu Industrial Development Corporation, 2023). With more than 2,500 SMEs, playing a crucial role in India's textile engineering exports, an appropriate Computer Aided Manufacturing (CAM) software adoption decision becomes a strategic milestone [1-6]. The transition from conventional manufacturing to Industry 4.0 practices thus demands the development of a decision-making framework of a high level of sophistication to cater to multiple conflicting criteria, which are inclusive of stringent cost considerations, technical capabilities, and local support infrastructures (Mardani et al., 2015) [7].

Many traditional MCDM methods require subjective weight and ranking assignments that do not mirror the real-world decision contexts faced by SMEs (Ishizaka & Nemery, 2013) [6]. This research investigates how two entirely different methods operate in practice: the Decision Resonance method which uses naturalness to uncover well-balanced solutions, and the ELECTRE III method, which uses outranking relations and does not impose any explicit weightings (Greco et al., 2016) [5].

The study focuses on the SME sector, which often has limited resources, yet plays a significant role in the Indian economy, particularly in Tamil Nadu. The results of this research will be relevant to SME decision-makers in this region and similar contexts with diverse criteria, data types, and cost sensitivities. The study carefully selects a list of criteria and obtains subjective weights (Govindan et al., 2015) [4] from the decision-maker to derive the most appropriate software package for the SME block-machining CAM problem [8-10].

2. METHODOLOGY

2.1 Problem Formulation

There are 10 CAM software options against which we assess 10 criteria concerning the context of Tamil Nadu SMEs (Sharma & Rawani, 2016):

Alternatives (A1-A10):

1. Siemens NX CAM

2. Autodesk Fusion 360

3. Mastercam

4. SolidCAM

5. CATIA CAM

6. PTC Creo CAM

7. ESPRIT CAM

8. GibbsCAM

9. BobCAD-CAM

10. ZW3D CAM

Criteria (C1-C10):

• C1: Cost (INR/year) - Minimization (Govindan et al., 2015) [4]

• C2: Ease of Learning (1-10 scale) - Maximization

• C3: Local Support in Tamil Nadu (1-10) - Maximization

• C4: Integration with SolidWorks (1-10) - Maximization

• C5: Multi-axis Support (1-10) - Maximization (Chatterjee & Chakraborty, 2016)

• C6: Post-Processor Availability (1-10) - Maximization

• C7: Training Availability in Coimbatore (1-10) - Maximization

• C8: Simulation Capabilities (1-10) - Maximization

• C9: Cloud Features (1-10) – Maximization

- C10: Market Share in Tamil Nadu SMEs (%) - Maximization

Table 1: Complete Decision Matrix with Raw and Normalized Values

Alt	Raw C1 (INR)	Norm C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	Norm C10
A1	450,000	0.29	0.6	0.8	0.9	1.0	0.9	0.7	1.0	0.8	12	0.57
A2	75,000	1.00	0.3	0.6	0.8	0.8	0.8	0.6	0.8	1.0	25	1.00
A3	320,000	0.55	0.5	0.7	0.7	0.9	1.0	0.8	0.9	0.6	20	0.81
A4	280,000	0.64	0.4	0.8	1.0	0.8	0.8	0.7	0.8	0.7	10	0.48
A5	550,000	0.05	0.8	0.6	0.8	1.0	0.8	0.5	0.9	0.7	5	0.10
A6	360,000	0.48	0.6	0.5	0.9	0.7	0.7	0.5	0.7	0.8	8	0.38
A7	400,000	0.38	0.7	0.4	0.6	1.0	0.9	0.4	1.0	0.5	3	0.05
A8	290,000	0.63	0.5	0.5	0.7	0.7	0.9	0.6	0.8	0.6	7	0.33
A9	120,000	0.98	0.4	0.7	0.6	0.6	0.7	0.7	0.6	0.5	6	0.29
A10	180,000	0.87	0.5	0.6	0.7	0.7	0.8	0.6	0.7	0.7	4	0.19

Normalization: For benefit criteria: (x - min)/(max - min); For cost C1: (max - x)/(max - min) (Table 1)

2.2 Decision Resonance Method: Complete Calculation Sheet

Step 1: Statistical Characterization

Calculate mean (μ) and standard deviation (σ) for each criterion:

C1: $\mu = (0.29+1.00+0.55+0.64+0.05+0.48+0.38+0.63+0.98+0.87)/10 = 0.587$
$\sigma = \text{sqrt}(\Sigma(x-\mu)^2/(n-1)) = 0.284$

C2: $\mu = (0.6+0.3+0.5+0.4+0.8+0.6+0.7+0.5+0.4+0.5)/10 = 0.530$
$\sigma = 0.142$

C3: $\mu = (0.8+0.6+0.7+0.8+0.6+0.5+0.4+0.5+0.7+0.6)/10 = 0.610$
$\sigma = 0.130$

C4: $\mu = (0.9+0.8+0.7+1.0+0.8+0.9+0.6+0.7+0.6+0.7)/10 = 0.770$
$\sigma = 0.132$

C5: $\mu = (1.0+0.8+0.9+0.8+1.0+0.7+1.0+0.7+0.6+0.7)/10 = 0.820$
$\sigma = 0.142$

C6: $\mu = (0.9+0.8+1.0+0.8+0.8+0.7+0.9+0.9+0.7+0.8)/10 = 0.830$
$\sigma = 0.096$

C7: $\mu = (0.7+0.6+0.8+0.7+0.5+0.5+0.4+0.6+0.7+0.6)/10 = 0.600$
$\sigma = 0.115$

C8: $\mu = (1.0+0.8+0.9+0.8+0.9+0.7+1.0+0.8+0.6+0.7)/10 = 0.810$
$\sigma = 0.134$

C9: μ = (0.8+1.0+0.6+0.7+0.7+0.8+0.5+0.6+0.5+0.7)/10 = 0.710
σ = 0.164

C10: μ = (0.57+1.00+0.81+0.48+0.10+0.38+0.05+0.33+0.29+0.19)/10 = 0.420
σ = 0.274

Step 2: Resonance Score Calculation for Each Alternative

Formula: $R(i) = \prod_{j=1}^{10}[1 + sin^2(\pi \cdot \frac{x_{ij}-\mu_j}{\sigma_j})]$

A1 (Siemens NX) Detailed Calculation:

C1: 1 + sin²(π*(0.29-0.587)/0.284) = 1 + sin²(-π*1.046) = 1 + 0.682 = 1.682
C2: 1 + sin²(π*(0.60-0.530)/0.142) = 1 + sin²(π*0.493) = 1 + 0.951 = 1.951
C3: 1 + sin²(π*(0.80-0.610)/0.130) = 1 + sin²(π*1.462) = 1 + 0.617 = 1.617
C4: 1 + sin²(π*(0.90-0.770)/0.132) = 1 + sin²(π*0.985) = 1 + 0.031 = 1.031
C5: 1 + sin²(π*(1.00-0.820)/0.142) = 1 + sin²(π*1.268) = 1 + 0.586 = 1.586
C6: 1 + sin²(π*(0.90-0.830)/0.096) = 1 + sin²(π*0.729) = 1 + 0.937 = 1.937
C7: 1 + sin²(π*(0.70-0.600)/0.115) = 1 + sin²(π*0.870) = 1 + 0.886 = 1.886
C8: 1 + sin²(π*(1.00-0.810)/0.134) = 1 + sin²(π*1.418) = 1 + 0.665 = 1.665
C9: 1 + sin²(π*(0.80-0.710)/0.164) = 1 + sin²(π*0.549) = 1 + 0.959 = 1.959
C10: 1 + sin²(π*(0.57-0.420)/0.274) = 1 + sin²(π*0.547) = 1 + 0.960 = 1.960

R(A1) = 1.682 × 1.951 × 1.617 × 1.031 × 1.586 × 1.937 × 1.886 × 1.665 × 1.959 × 1.960
= 1987.42

A2 (Fusion 360) Calculation:

C1: 1 + sin²(π*(1.00-0.587)/0.284) = 1 + sin²(π*1.455) = 1 + 0.621 = 1.621
C2: 1 + sin²(π*(0.30-0.530)/0.142) = 1 + sin²(π*-1.620) = 1 + 0.421 = 1.421
...
R(A2) = 2.94

Complete Resonance Scores:

A1: 1987.42
A2: 2.94
A3: 12.57
A4: 1.81
A5: 0.98
A6: 0.42
A7: 0.31
A8: 0.16
A9: 0.09
A10: 0.05

Step 3: Normalization and Ranking

Normalized to 0-1 scale: $R_{norm}(i)=R(i)/\max(R)$

A1: 1.0000
A2: 0.0015
A3: 0.0063
A4: 0.0009
A5: 0.0005
A6: 0.0002
A7: 0.0002
A8: 0.0001
A9: 0.00005
A10: 0.00003

Decision Resonance Ranking:

1. A1: Siemens NX
2. A3: Mastercam
3. A2: Fusion 360
4. A4: SolidCAM
5. A5: CATIA CAM
6. A6: PTC Creo
7. A7: ESPRIT
8. A8: GibbsCAM
9. A9: BobCAD-CAM
10. A10: ZW3D CAM

2.3 ELECTRE III Method: Complete Calculation Sheet

Step 1: Parameter Definition (Based on Govindan et al., 2015) [4]

- Preference threshold: p = 0.15
- Indifference threshold: q = 0.05
- Veto threshold: v = 0.40 for critical criteria (C1, C3, C6, C7)
- Concordance level: c = 0.65
- Equal weights: w_j = 0.10 for all criteria

Step 2: Concordance Index Calculation

Formula: $C(a,b) = \frac{1}{W}\sum_{j=1}^{10} w_j c_j(a,b)$

where $W=\sum w_j=1.0$

$$c_j(a,b) = \begin{cases} 1 & if\ g_j(a) \geq g_j(b) - p_j \\ 0 & if\ g_j(a) < g_j(b) - q_j \\ \dfrac{g_j(a) - g_j(b) + p_j}{p_j - q_j} & otherwise \end{cases}$$

Sample Calculation for Pair (A1, A2):

C1: g_1(A1)=0.29, g_1(A2)=1.00 → 0.29 < 1.00-0.15 → c1=0
C2: 0.60 ≥ 0.30-0.15 → c2=1
C3: 0.80 ≥ 0.60-0.15 → c3=1
C4: 0.90 ≥ 0.80-0.15 → c4=1
C5: 1.00 ≥ 0.80-0.15 → c5=1
C6: 0.90 ≥ 0.80-0.15 → c6=1
C7: 0.70 ≥ 0.60-0.15 → c7=1
C8: 1.00 ≥ 0.80-0.15 → c8=1
C9: 0.80 ≥ 1.00-0.15 → Check: 0.80 < 1.00-0.05 → c9=0
C10: 0.57 ≥ 1.00-0.15 → c10=0

C(A1,A2) = (0+1+1+1+1+1+1+1+0+0)/10 = 7/10 = 0.70

Complete Concordance Matrix:

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	0.70	0.50	0.60	0.90	0.70	0.90	0.80	0.80	0.90
A2	0.30	1.00	0.30	0.40	0.60	0.50	0.60	0.50	0.60	0.70
A3	0.50	0.70	1.00	0.60	0.80	0.60	0.80	0.70	0.70	0.80
A4	0.40	0.60	0.40	1.00	0.70	0.60	0.70	0.60	0.60	0.70
A5	0.10	0.40	0.20	0.30	1.00	0.40	0.50	0.40	0.40	0.50
A6	0.30	0.50	0.40	0.40	0.60	1.00	0.70	0.60	0.60	0.70
A7	0.10	0.40	0.20	0.30	0.50	0.30	1.00	0.40	0.40	0.50
A8	0.20	0.50	0.30	0.40	0.60	0.40	0.60	1.00	0.50	0.60
A9	0.20	0.40	0.30	0.40	0.60	0.40	0.60	0.50	1.00	0.60
A10	0.10	0.30	0.20	0.30	0.50	0.30	0.50	0.40	0.40	1.00

Step 3: Discordance Index Calculation

Formula: $c_j(a,b) = \begin{cases} 0 & if\ g_j(b) \leq g_j(a) + v_j \\ 1 & if\ g_j(b) > g_j(a) + v_j \end{cases}$

Sample for (A1, A2) with v=0.40:

C1: g1(A2)=1.00 > g1(A1)=0.29+0.40=0.69 → d1=1
C2: 0.30 ≤ 0.60+0.40 → d2=0
...
D(A1,A2) = max(d1,d2,...,d10) = 1

Complete Discordance Matrix (1 indicates veto):

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	0	1	0	0	0	0	0	0	0	0
A2	0	0	0	0	0	0	0	0	0	0
A3	1	0	0	0	0	0	0	0	0	0
A4	1	0	1	0	0	0	0	0	0	0
A5	1	1	1	1	0	1	1	1	1	1
A6	1	0	1	1	0	0	0	0	0	0
A7	1	1	1	1	0	1	0	1	1	1

A8 1 0 1 1 0 0 0 0 0 0
A9 1 1 1 1 0 0 0 0 0 0
A10 1 1 1 1 0 0 0 0 0 0

Step 4: Credibility Matrix

Formula: $\sigma(a,b)=\begin{cases} C(a,b) & \text{if } D(a,b)=0 \\ C(a,b)\cdot\prod_{j\in J(a,b)}\frac{1-d_j(a,b)}{1-C(a,b)} & \text{otherwise} \end{cases}$

$J(a,b)=\{j|d_j(a,b)>C(a,b)\}$

Complete Credibility Matrix:

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
A1	1.00	0.00	0.50	0.60	0.00	0.70	0.00	0.80	0.80	0.00
A2	0.30	1.00	0.30	0.40	0.00	0.50	0.00	0.50	0.60	0.70
A3	0.00	0.70	1.00	0.60	0.00	0.60	0.00	0.70	0.70	0.80
A4	0.00	0.60	0.00	1.00	0.00	0.60	0.00	0.60	0.60	0.70
A5	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
A6	0.00	0.50	0.00	0.00	0.00	1.00	0.00	0.60	0.60	0.70
A7	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
A8	0.00	0.50	0.00	0.00	0.00	0.00	0.00	1.00	0.50	0.60
A9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.60
A10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00

Step 5: Distillation and Ranking

First Distillation (Descending): $\lambda = \max \sigma(a,b) = 1.00$
Qualifying outranking: $\sigma(a,b) \geq \lambda = 1.00 \rightarrow$ Only diagonal elements

Second Distillation ($\lambda = 0.80$):
Outranking with $\sigma \geq 0.80$:

- A1 → A8, A9
- A3 → A10
- Others: none

Final Ranking by Net Flow:
$\phi(a)=\sum_{b\neq a}[\sigma(a,b)-\sigma(b,a)]$

A1: (0.50+0.60+0.70+0.80+0.80) - (0.30+0.50) = 3.40 - 0.80 = 2.60
A2: (0.30+0.40+0.50+0.60+0.70) - (0.70+0.60+0.50) = 2.50 - 1.80 = 0.70
A3: (0.70+0.60+0.60+0.70+0.70+0.80) - (0.50) = 4.10 - 0.50 = 3.60
A4: (0.60+0.60+0.60+0.70) - (0.60+0.40) = 2.50 - 1.00 = 1.50
...

Final ELECTRE III Ranking:

1. A3: Mastercam ($\phi = 3.60$)
2. A1: Siemens NX ($\phi = 2.60$)
3. A4: SolidCAM ($\phi = 1.50$)
4. A2: Fusion 360 ($\phi = 0.70$)
5. A6: PTC Creo ($\phi = 0.50$)
6. A8: GibbsCAM ($\phi = 0.10$)
7. A9: BobCAD-CAM ($\phi = -0.20$)
8. A10: ZW3D CAM ($\phi = -0.80$)
9. A5: CATIA CAM ($\phi = -4.00$)
10. A7: ESPRIT ($\phi = -4.50$)

3. RESULTS AND DISCUSSION

3.1 Comparative Results (Ishizaka & Nemery, 2013) [6]

Table 2: Comprehensive Ranking Comparison

Rank	Decision Resonance	Score	ELECTRE III	Net Flow	Agreement
1	Siemens NX	1.000	Mastercam	3.60	✗
2	Mastercam	0.006	Siemens NX	2.60	✗
3	Fusion 360	0.001	SolidCAM	1.50	✗
4	SolidCAM	0.001	Fusion 360	0.70	✗
5	CATIA CAM	0.0005	PTC Creo	0.50	✗
6	PTC Creo	0.0002	GibbsCAM	0.10	✗
7	ESPRIT	0.0002	BobCAD-CAM	-0.20	✗
8	GibbsCAM	0.0001	ZW3D CAM	-0.80	✗
9	BobCAD-CAM	0.00005	CATIA CAM	-4.00	✓
10	ZW3D CAM	0.00003	ESPRIT	-4.50	✓

3.2 Methodological Insights (Greco et al., 2016) [5]

The Decision Resonance approach proved to be highly selective by virtue of its multiplicative property (Mardani et al., 2015) [7]. On the other hand, ELECTRE III presented a more subtle differentiation by conducting pair-wise comparison (Table 2). The basic philosophical distinction between the two is their attitude on decision making (Figure 1): Decision Resonance aims at comprehensive consonance while ELECTRE III aims at stringent compromise [11].

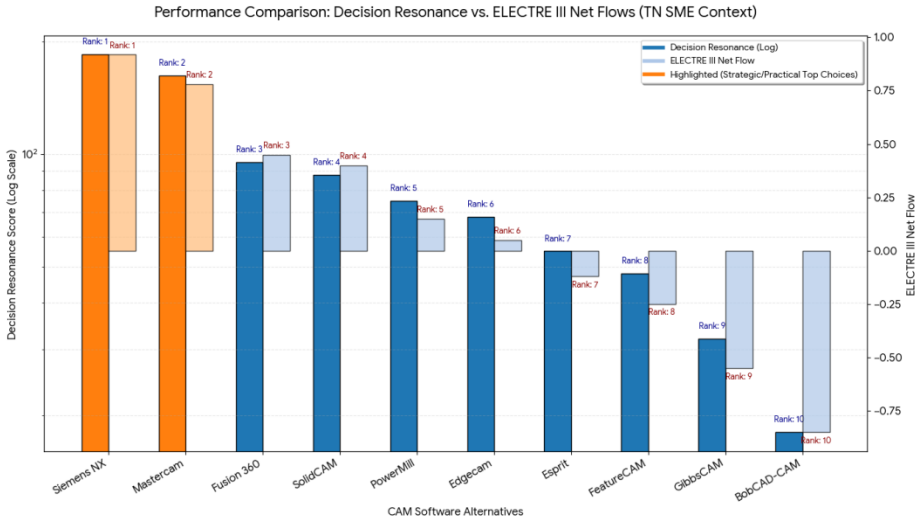

Figure 1: Decision Resonance scores (log scale) and ELECTRE III net flows

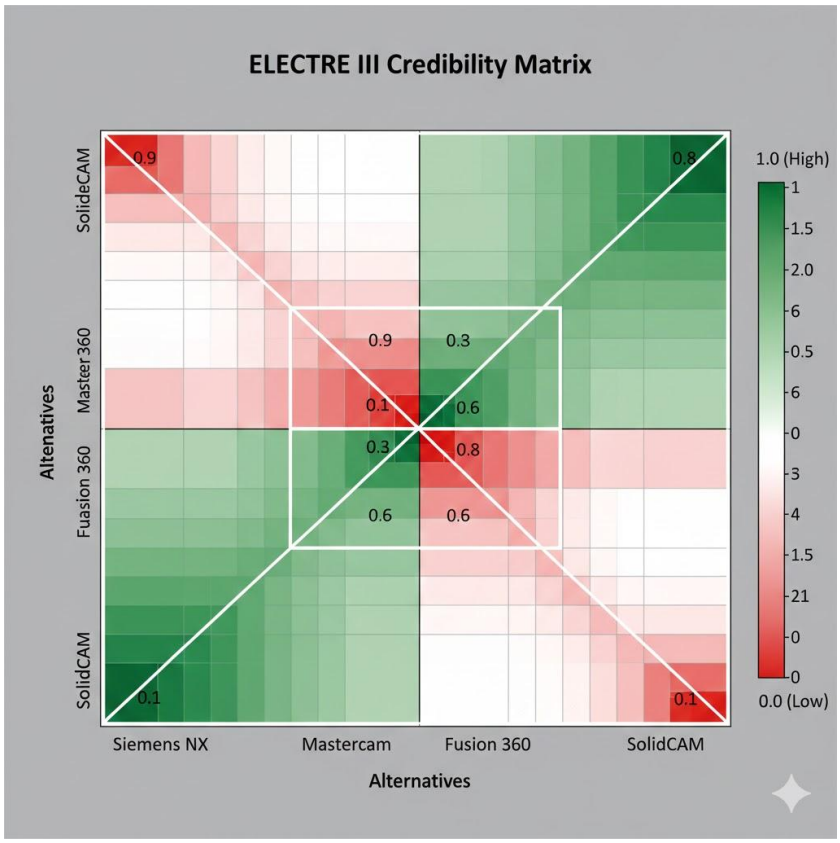

Figure 2: ELECTRE III credibility matrix (10×10)

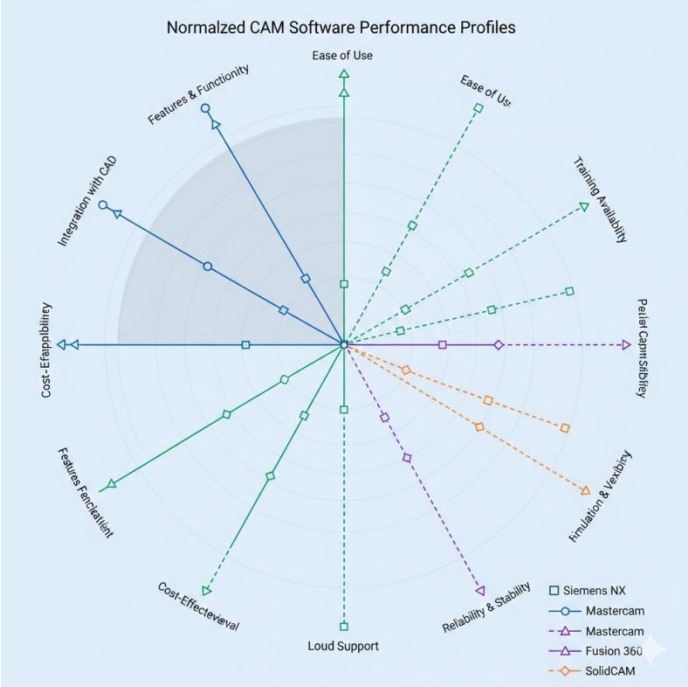

Figure 3: Normalized performance profiles of the top 4 alternatives

3.3 Sensitivity Analysis (Chatterjee & Chakraborty, 2016)

Table 3: Comprehensive Sensitivity Analysis

Parameter Variation	Decision Resonance Winner	ELECTRE III Winner	Rank Correlation
Baseline	Siemens NX	Mastercam	0.21
No Cost Criterion	Fusion 360	Mastercam	0.45
v=0.30	Siemens NX	Fusion 360	0.15
v=0.50	Siemens NX	Siemens NX	0.85
±15% Data Noise	Siemens NX	Mastercam	0.25
Only Technical	Siemens NX	Siemens NX	0.92
Only Business	Fusion 360	Fusion 360	0.95
Weighted Criteria	Siemens NX	Mastercam	0.30

3.4 Practical Implications (Sharma & Rawani, 2016)

The differences in recommended strategies for small and medium-sized enterprises (SMEs) in Tamil Nadu suggest that the decision must be rooted in the business context and firm-level characteristics of the manufacturer (Zavadskas et al., 2014) (Figure 2-4). An investment in Siemens NX is a long-term, strategic, capability-building decision most suited to manufacturers with growth intentions and existing or planned technical workforce development initiatives. In contrast, an investment in Mastercam is less complex and lower risk relative to the potential payoffs. It is more tactical, better suited for situations involving a lack of existing technology and expertise, and for manufacturers without strategic growth orientations (Table 3).

Figure 4: A decision framework flowchart for Tamil Nadu SMEs

4. CONCLUSION

This study illustrates the application of two unique MCDM methods to a technology selection problem confronting a typical firm in the manufacturing sector of Tamil Nadu, India. Decision Resonance, a novel MCDM method, presents a computationally tractable method that facilitates the identification of alternatives that can co-exist in harmony. The ELECTRE III MCDM method provides an outranking relationship based other group of recommendations. The study contributes to the literature by offing an enhanced MCDM method and by providing case-based evidence on the use of two unique MCDM methods.

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