Contribution of the MCDM techniques in the maintenance function: PROMETHEE VS TOPSIS & Criticality matrix

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Presentation plan

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  - Proposed approach
  - Methods used
- **Application in a gas industry: Equipment prioritization**
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  - Performance table
  - Criticality matrix ranking
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  - TOPSIS ranking
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Study context

Problematic

Gas complex equipment

What are the critical pieces of equipment ?

Study context

Proposed approach

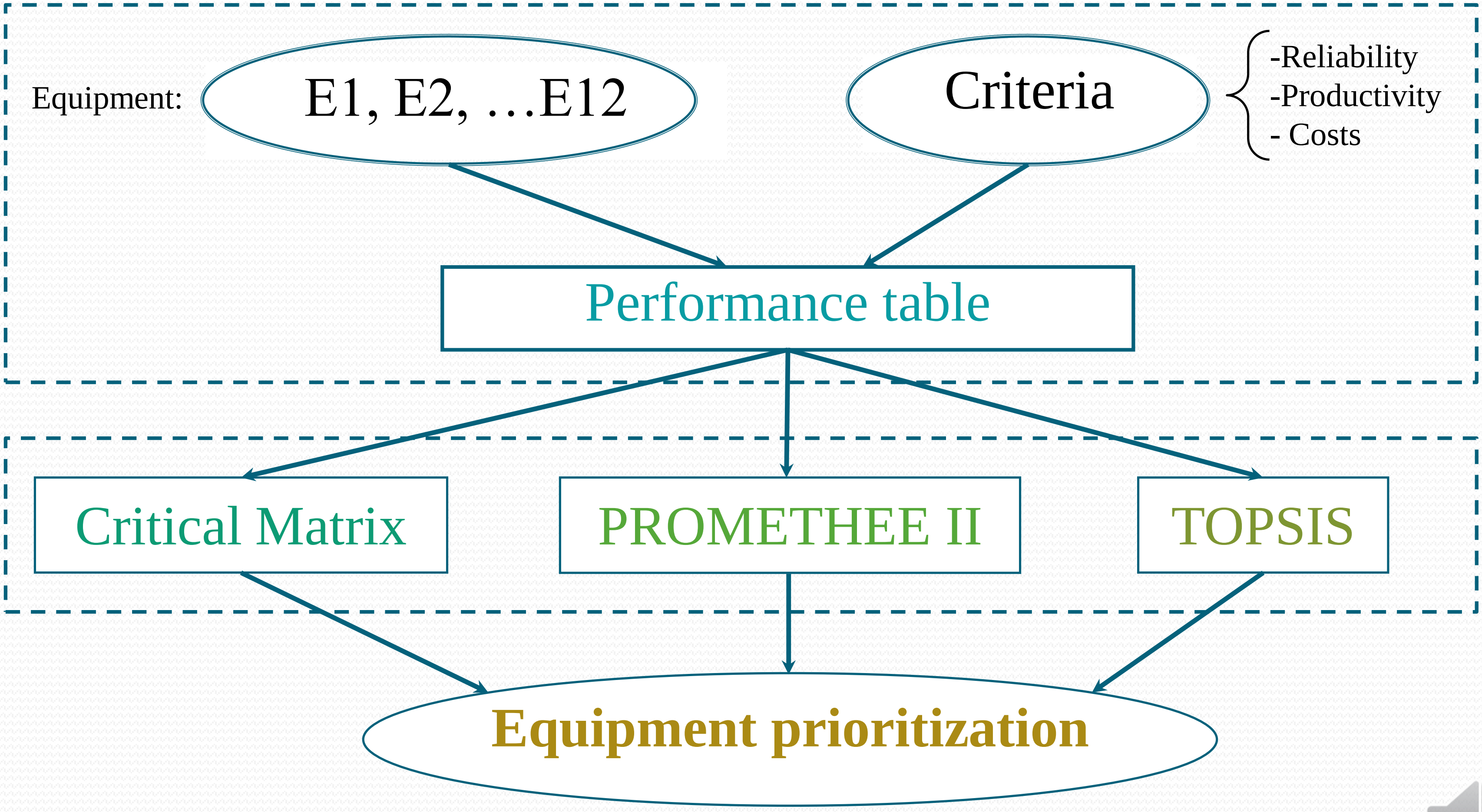
Comparative approach :

- PROMETHEE VS TOPSIS & Criticality matrix
- Sample of 12 pieces of equipment belonging to a production train in a gas complex
- Criteria: reliability, productivity and costs
- Real history data

Study context

Proposed approach

Methodology :



Criticality matrix

- Considered as a complete aggregation approach

- Criticality C, by per criterion, is defined as the product of the occurrence probability O and its severity S:

$$C = O \times S \qquad (1)$$

- Overall criticality Cr of each equipment is then calculated by multiplying the criticalities per criterion:

$$Cr = \Pi\ Ci\ (i = 1 \text{ to } n),\ (n = \text{number of criteria}) \qquad (2)$$

PROMETHEE

- Partial criteria aggregation method
- Calculation of the index $\pi\ (a, b)$ representing over-classification degree between the alternatives a and b according to whole set n of criteria:

$$^{\pi}(a,b) = \frac{\sum_{i=1}^{n} F_i\ (a,b)\ \text{x}\ w_i}{\sum w_i} \qquad (3)$$

- Calculation of outcoming flow $\Phi^{+}\ (a)$ and incoming flow $\Phi^{+}\ (a)$, reflecting, respectively, the strength and weakness of the alternative a over the remaining alternatives x:

$$\Phi^{+}\ (a) = \frac{\sum \pi\ (a,x)}{m-1} \qquad (4)$$

$$\Phi^{-}\ (a) = \frac{\sum \pi\ (x,a)}{m-1} \qquad (5)$$

(where m is the number of the considered alternatives)

- Calculation of the net flow $^{\phi}(a)$ allowing to rank alternatives accordingly, where highest value represents the best alternative, while the lowest value represents the worst alternative:

$$\phi(a) = \phi^{+}\ (a) - \phi^{-}\ (a) \qquad (6)$$

TOPSIS

- Complete criteria aggregation method
- Derivation of the normalized decision matrix $(R_{ij})_{m \times n}$ by rescaling inputs according:

$$R_{ij} = \frac{X_{ij}}{\sqrt{\sum_{k=1}^{m} X_{ij}^2}} \quad (7)$$

$(X_{ij})_{m \times n}$: decision matrix where m is the number of alternatives and n is the number of criteria

- Calculation of the weighted normalized decision matrix $(V_{ij})_{m \times n}$ using:

$$V_{ij} = R_{ij} \times w_j \quad (8)$$

(w_j is the relative weight of the criterion j)

- Identification of ideal solution V_j^+ and anti-ideal solution V_j^-, in each column:

$$V_j^+ = (max\ V_{ij} \mid j \in J^+), (mix\ V_{ij} \mid j \in J^-) \quad (9)$$

$$V_j^- = (min\ V_{ij} \mid j \in J^+), (max\ V_{ij} \mid j \in J^-) \quad (10)$$

(where $J^+ = \{j = 1,2, \dots n \mid j\}$ $J^- = \{j = 1,2, \dots n \mid j\}$)

- Calculation of distance separating each alternative from the ideal and the anti-ideal solutions, using 11 and 12:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^+)^2} \quad (11)$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^-)^2} \quad (12)$$

(where $i = 1, 2, 3, \dots m$)

- Allowing to rank the alternatives accordingly, calculation of the performance score Pi for each alternative using:

$$P_i = S_i^- / (S_i^- + S_i^+ \quad (13)$$

($where\ 0 \le Pi \le 1\ and\ 1 = 1, 2, 3, \dots, m$)

Equipment prioritization

Criteria evaluation

Scale per criterion			1	2	3	4
Reliability	MTBF (Hours)	O	≤ 250	≤ 1000 > 250	≤ 2000 > 1000	> 2000
	Availability (%)	S	≤ 80%	> 80% ≤ 85%	> 85% ≤ 95%	> 95%
Production	Stops/year	O	≥ 3	< 3 ≥ 1	< 1 > 0	= 0
	Shortage (%)	S	> 5	≤ 5 > 2	≤ 2 > 0	= 0
Cost	ABC Analysis	O	A: 20-50	B: 30-15	C: 50-5	
	Cost / Global cost	S	≥ 0.075	< 0.075 ≥ 0.01	< 0.01 > 0.002	≤ 0.002

- Each criterion was evaluated through a 4 levels judgement scale from the most to the least critical, according to a probability of occurrence (O) and a severity (S).

Equipment prioritization

Performance table

from real history data

Code	Designation	Criticality (C)		
		Reliability	Production	Cost
[E1]	2nd stage compressor for MCR	16	9	1
[E2]	Combustible gas compressor turbine	16	16	1
[E3]	Reactivation Blower	16	16	1
[E4]	1st stage compressor for MCR	16	6	1
[E5]	Propane compressor	16	6	1
[E6]	Main exchanger	12	1	1
[E7]	Absorber column of MEA	16	9	2
[E8]	Combustible gas compressor	16	16	2
[E9]	Main lubricant oil pump	16	16	6
[E10]	Butane recycling pump	8	16	2
[E11]	Secondary Butane recycling pump	12	16	2
[E12]	Dust filter	16	3	4

Implementation of the determined Performance table in the 3 methods: Criticality matrix, PROMETHEE and TOPSIS.

Equipment prioritization

Criticality matrix ranking

Equipment	Cr	Class
[E6]	12	1
[E4]	96	2
[E5]	96	
[E1]	144	3
[E12]	192	4
[E2]	256	5
[E3]	256	
[E10]	256	
[E7]	288	6
[E11]	384	7
[E8]	512	8
[E9]	1536	9

- The results obtained show the arrangement of the 12 pieces of equipment, according to their degree of criticality, following 9 classes.

Equipment prioritization

PROMETHEE ranking

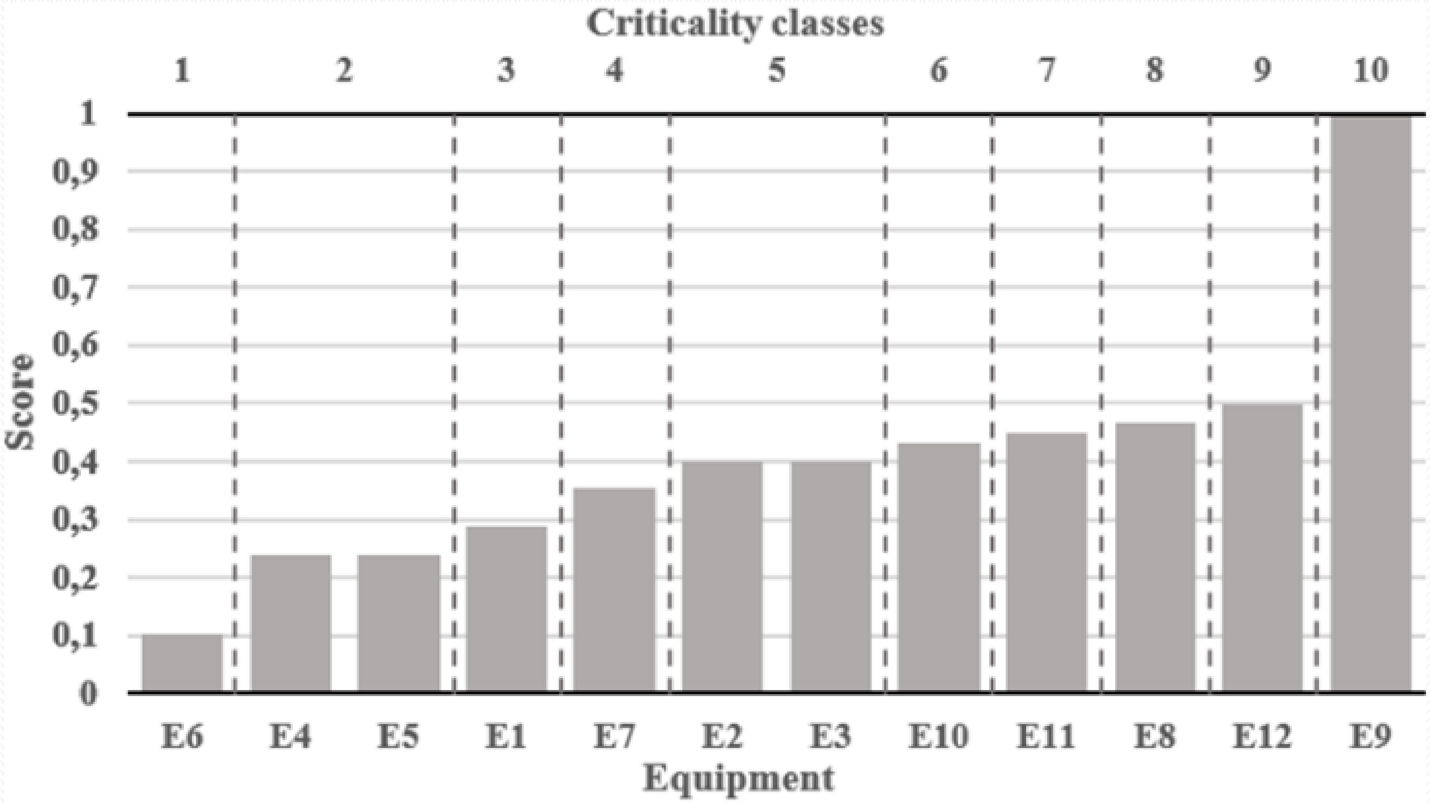
PROMETHEE Flow Table

	Action	Phi	Phi+	Phi-
1	E6	0.7576	0.7879	0.0303
2	E4	0.2727	0.4242	0.1515
3	E5	0.2727	0.4242	0.1515
4	E1	0.1515	0.3636	0.2121
5	E10	0.0303	0.3939	0.3636
6	E11	-0.0606	0.3333	0.3939
7	E2	-0.0909	0.1818	0.2727
8	E3	-0.0909	0.1818	0.2727
9	E12	-0.0909	0.3333	0.4242
10	E7	-0.1515	0.2424	0.3939
11	E8	-0.3939	0.0606	0.4545
12	E9	-0.6061	0.0000	0.6061

- The arrangement of the 12 pieces equipment is done according to a hierarchy of the net flow (Φ), producing 9 classes.

Equipment prioritization

TOPSIS ranking



- The arrangement of the 12 pieces equipment is done according to a hierarchy of the performance scores, producing 10 classes.

Interpretation and discussion of the results :

Criticality classes	Obtained criticality ranking		
	Criticality matrix	PROMETHEE	TOPSIS
1	[E6]	[E6]	[E6]
2	[E4-E5]	[E4-E5]	[E4-E5]
3	[E1]	[E1]	[E1]
4	[E12]	[E10]	[E7]
5	[E2-E3] – [E10]	[E11]	[E2-E3]
6	[E7]	[E2-E3] – [E12]	[E10]
7	[E11]	[E7]	[E11]
8	[E8]	[E8]	[E8]
9	[E9]	[E9]	[E12]
10			[E9]

Comparison of the results

- [E6], [E4-E5], [E1] and [E8] are classified in the same positions (1st, 2nd, 3rd, and 8th respectively) according to the 3 methods.
- [E9] is classified in the 9th position by PROMETHEE and criticality matrix, while it shows up in the 10th class in TOPSIS classification. Nevertheless, it is the least critical piece, in either cases.
- [E2-E3], [E7], [E10], [E11] and [E12] are classified differently in the 3 methods. [E2-E3] are in 6th position in PROMETHEE and 5th in both criticality matrix and TOPSIS. [E11] is in 5th position in PROMETHEE and 7th both in criticality matrix and TOPSIS. Respectively, [E7], [E10], [E12] are 7th, 4th, 6th in PROMETHEE but 6th, 5th, 4th in criticality matrix and 4th, 6th, 9th in TOPSIS.

Interpretation and discussion of the results

Criticality classes	Obtained criticality ranking		
	Criticality matrix	PROMETHEE	TOPSIS
1	[E6]	[E6]	[E6]
2	[E4-E5]	[E4-E5]	[E4-E5]
3	[E1]	[E1]	[E1]
4	[E12]	[E10]	[E7]
5	[E2-E3] – [E10]	[E11]	[E2-E3]
6	[E7]	[E2-E3] – [E12]	[E10]
7	[E11]	[E7]	[E11]
8	[E8]	[E8]	[E8]
9	[E9]	[E9]	[E12]
10			[E9]

Discussion of the results

1. 60% differences that start from the 4th class.
2. 9 classes by the criticality matrix and PROMETHEE and 10 by TOPSIS.
3. So, According to the input scores, [E10] is clearly more critical than [E2-E3], whereas these two pieces are less critical than [E11], as they perform slightly better, according to their input scores. This falls in favor of the PROMETHEE classification unlike TOPSIS and the criticality matrix.

Interpretation and discussion of the results

Criticality classes	Obtained criticality ranking		
	Criticality matrix	PROMETHEE	TOPSIS
1	[E6]	[E6]	[E6]
2	[E4-E5]	[E4-E5]	[E4-E5]
3	[E1]	[E1]	[E1]
4	[E12]	[E10]	[E7]
5	[E2-E3] – [E10]	[E11]	[E2-E3]
6	[E7]	[E2-E3] – [E12]	[E10]
7	[E11]	[E7]	[E11]
8	[E8]	[E8]	[E8]
9	[E9]	[E9]	[E12]
10			[E9]

Discussion of the results

4. Also, the positioning of [E12] in the penultimate class, in the TOPSIS classification rather than [E8], as in the PROMETHEE ranking, seems to be a misplacement. Although [E12] is as twice as efficient under the cost criterion, it remains more critical, as it is more than 5 times less efficient on the production criterion, while the equality dominates on the cost criterion. Consequently, it should be given a higher priority, and this is what we note in the PROMETHEE ranking where it appears in the 6th class next to [E2-E3].
5. From another side, [E8] has the closest local preferences to the ideal alternative ([E9]). So, it should be considered as the second least critical alternative after it, while it is more convenient to classify [E2-E3] close to [E8] as these are semi-copies; once again, this is the case in the PROMETHEE classification unlike TOPSIS and criticality matrix.
6. Finally, the fact of obtaining an additional class by TOPSIS, to move the [E9] equipment (the least critical by according to the 3 methods) from the 9th class (PROMETHEE and criticality matrix) to the 10th (TOPSIS), is useless in from the point of view of maintenance.

Conclusion

- The prioritization of the 12 pieces of equipment considered, was carried out according to reliability, productivity and costs criteria using real industrial history data.
- We have proposed a comparative approach between PROMETHEE – TOPSIS - Criticality matrix method.
- The comparison showed that the three methods give an identical rate of 40%.
- For the rest of the differences, the results obtained using PROMETHEE seem overall more correct, as they respect better the chosen criteria weighting and shows less mis-assessments.
- This comparative study contribute at:

1. Providing more knowledge about the behaviour of criticality matrix, PROMETHEE and TOPSIS methods
2. Assisting the decision maker to choose the best-fitting technique to prioritization industrial equipment.

- As future perspectives of this work, we suggest conducting further comparisons with other MCDM techniques to provide more knowledge in this scope.

Thank you for your attention

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