



11<sup>th</sup> SESAR Innovation Days



# Identification of a Consensus in a Multi-criteria Decision

## Process involving several Decision-Makers

### Trade-off between global benefits and local consensus for multi-hub airlines operations

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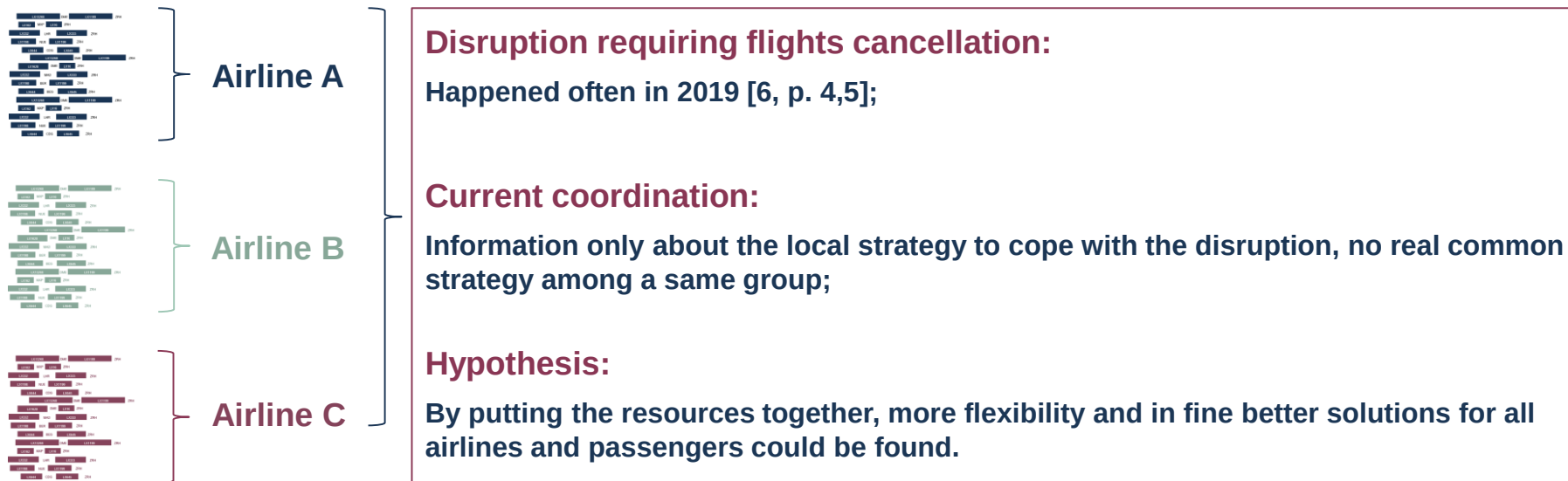
Co-authors:

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Eric Nantier, Self-Employed (Ex - Swiss International Airlines Ltd.)

# Context - General

## Airlines Coordination during Disruption

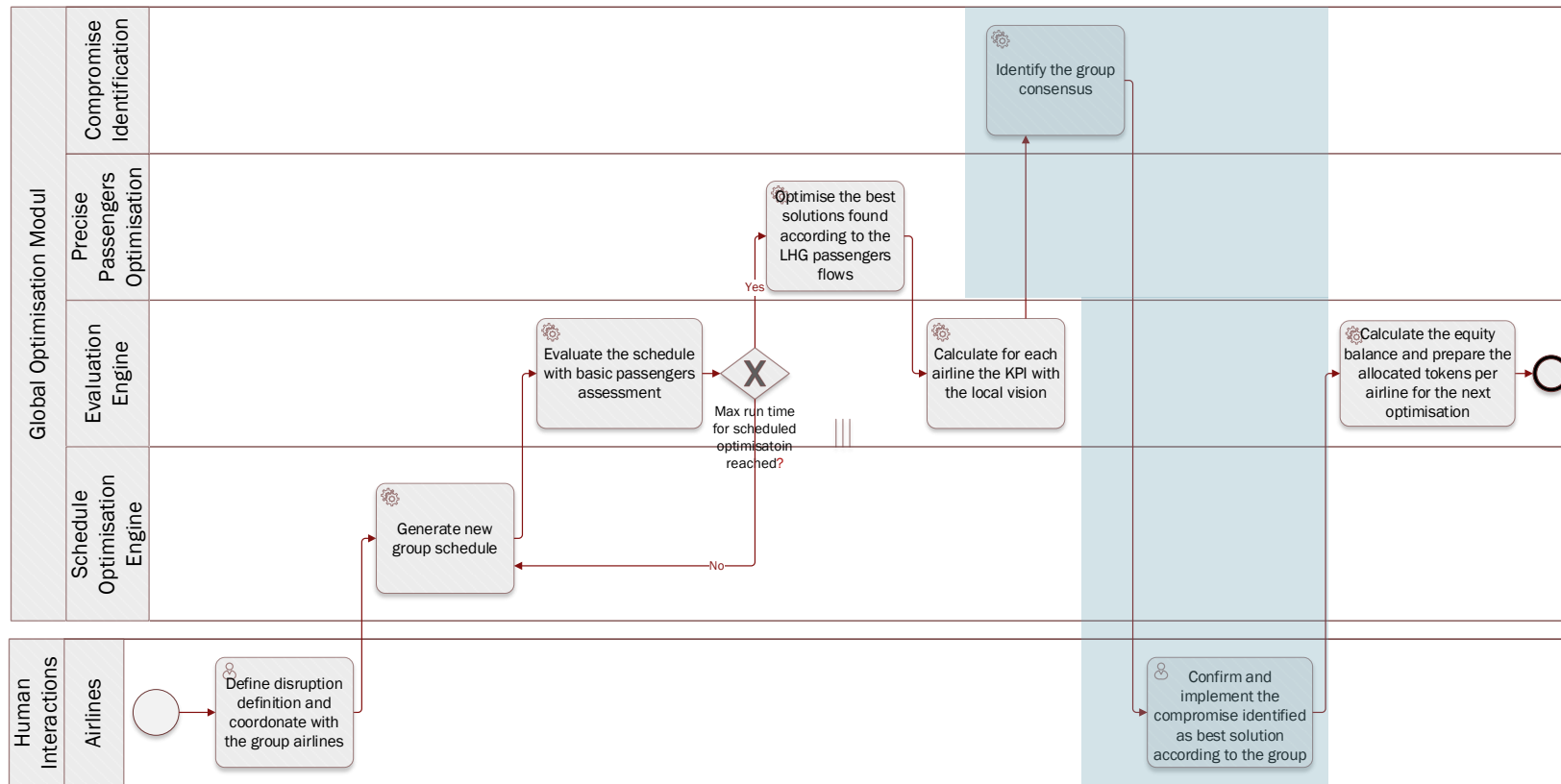


### Research question:

How to propose a multi-criteria and multi-stakeholders decision process, which ensures efficient and optimal consensus identification, accepted by all involved decision-makers within the allocated time?

# Context - General

## Business Process Model for the Global Optimisation



# Context - General

## Multi-Criteria Decision Making (MCDM)

### Main requirements:

- Multi-criteria → take into account the important criteria according to all decision-makers;
- Operational multi-stakeholders → user-friendly and intuitive method mandatory;
- Consensus identification → all decision-makers involved for acceptance of the chosen solution;
- Time constraints → limit the necessary users' inputs;

No human brain can assess efficiently the complexity of all proposed solutions

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### 2. Additive aggregation – MCDM:

- MAUT,
- TOPSIS,
- AHP,

### 3. Outranking MCDM:

- PROMETHEE,
- ELECTRE

Not intuitive nor easily understandable by non experts

Translate accurately the decision-makers preferences

BUT

Time consuming as extensive users' inputs are required

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### 4. Social voting theories:

- Majority election
- Two-rounds election
- Condorcet method
- Borda method

Not intuitive nor easily understandable by non experts

Translate accurately the decision-makers preferences

BUT

Time consuming as extensive users' inputs are required

Fast results

BUT

modelling of decision-maker not accurate enough

# Proposed Approach

## Combining Different Methods

### Mandatory:

- Multi-criteria → identify the criteria trees thanks to AHP methodology
- Accurate modelling of the decision-makers preferences
- User-friendly and intuitive and time efficient method mandatory;



### Idea:

- Combine the first step of AHP to identify the relevant criteria,
- Adapt the accurate modelling of decision-makers preferences thanks to MCDM methods.
- Take advantage of the efficient and intuitive methods from social voting theories

# Proposed Approach

## Combining Different Methods

### Borda method:

Each candidate receives points according to their ranks:

$$b_i = \sum_k (N - r_{i,k})$$

With  $r_{i,k}$  the rank of alternative  $i$  given by the  $k^{th}$  voter

Advantages:

- Always identifying a winner,
- Well established method
- Two solutions could be ranked equivalent by the voter.

If two solutions are using the ranks  $k$  and  $k+1$ , both get the average score proposed by [13]:

$$\frac{(n-k) + (n-(k+1))}{2} \text{ points.}$$

# Proposed Approach

## Combining Different Methods

**Accurate modelling of decision-makers knowledge and sensitivity through specific users' inputs :**

Let's not  $i$  a criterion,  $s$  a solution and  $g_i(s)$  the performance of solution  $s$  for criterion  $i$ .

- Indifference threshold:

$\forall i \in I, q_i$  is the indifference threshold for the criterion  $i$ .

- Acceptable interval of performances:

$\forall i \in I, O_i = [O_i^-; O_i^+]$  is the acceptable performances interval for the criterion  $i$ .

We note  $dist(g_i(s) - O_i) = \min_i(|g_i(s) - O_i^+|, |g_i(s) - O_i^-|)$  the distance between the performance of solution  $s$  for criterion  $i$  towards  $O_i$ .

# Proposed Approach

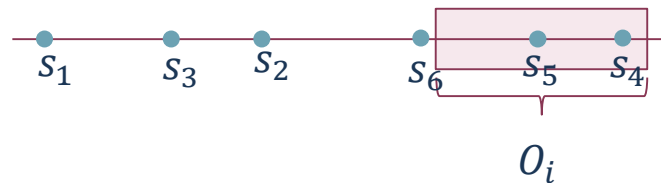
## Combining Different Methods

Accurate modelling of decision-makers knowledge and sensitivity through specific users' inputs :

1. All solutions with performances belonging to  $O_i$  get the first rank:

$$\forall s \in S, \text{ such as } g_i(s) \in O_i, r_i(s) = 1 \quad \text{Eq. 2}$$

Example for an airline A for one criterion:



| Ranking for Airline A | Solution ID | Borda Points            |
|-----------------------|-------------|-------------------------|
| 1                     | S4 & S5     | $\frac{5 + 4}{2} = 4.5$ |
| 2                     | -           | -                       |
| 3                     | ?           | 3                       |
| 4                     | ?           | 2                       |
| 5                     | ?           | 1                       |
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# Proposed Approach

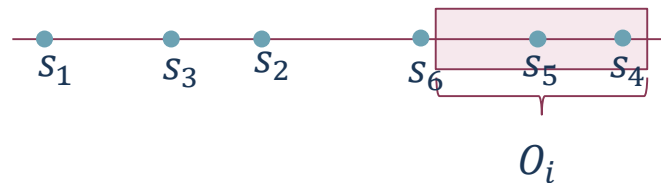
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| 3                     | S6          | 3                       |
| 4                     | ?           | 2                       |
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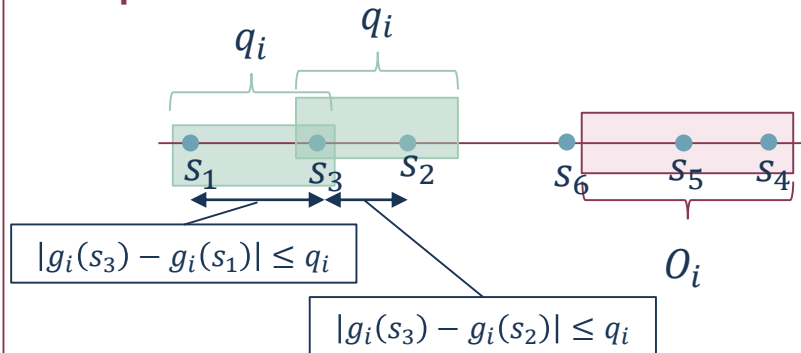
$$\forall s \in S, \text{ such as } g_i(s) \in O_i, r_i(s) = 1 \quad \text{Eq. 2}$$

2. For all other solutions:

a. Solutions equivalent:

$$\begin{aligned} &\forall s, s' \in S, g_i(s) \notin O_i \text{ and } g_i(s') \notin O_i, \\ &\text{if } |g_i(s) - g_i(s')| \leq q_i \text{ then } r_i(s) = r_i(s') \quad \text{Eq. 3} \end{aligned}$$

**Example for an airline A for one criterion:**



$$s_1 \sim s_3, s_3 \sim s_2 \text{ BUT } s_1 \not\sim s_2$$

| Ranking for Airline A | Solution ID | Borda Points            |
|-----------------------|-------------|-------------------------|
| 1                     | S4 & S5     | $\frac{5 + 4}{2} = 4.5$ |
| 2                     | -           | -                       |
| 3                     | S6          | 3                       |
| 4                     | ?           | 2                       |
| 5                     | ?           | 1                       |
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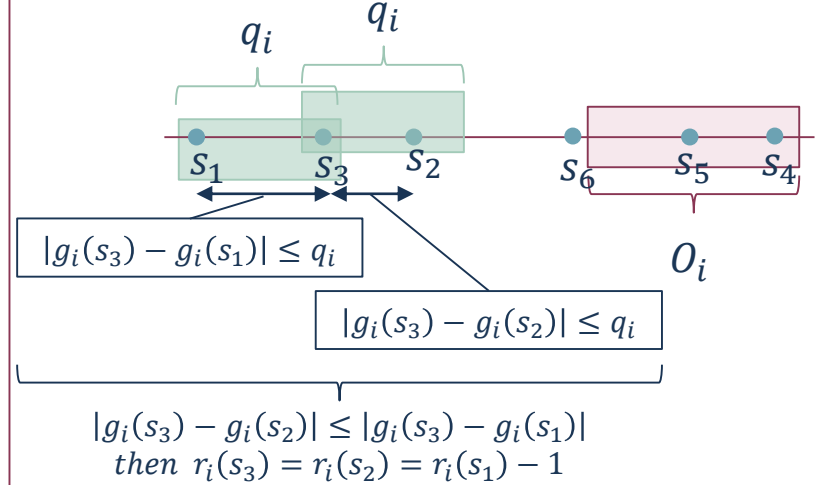
b. Equivalence conflicts:

$$\begin{aligned} &\forall s, s', s'' \in S, g_i(s) \notin O_i, g_i(s') \notin O_i, g_i(s'') \notin O_i \\ &\quad \text{such as} \\ &\text{dist}(g_i(s) - O_i) \leq \text{dist}(g_i(s') - O_i) \leq \text{dist}(g_i(s'') - O_i) \\ &\quad \text{and} \\ &|g_i(s) - g_i(s')| \leq q_i \text{ and } |g_i(s') - g_i(s'')| \leq q_i \text{ and } |g_i(s) - g_i(s'')| > q_i \end{aligned}$$

*Then:*

$$\begin{aligned} &\text{If } |g_i(s) - g_i(s')| \leq |g_i(s') - g_i(s'')| \text{ then } r_i(s) \\ &\quad \geq 1 \text{ and } r_i(s) = r_i(s') = r_i(s'') - 1 \\ &\text{Else } r_i(s) \geq 1 \text{ and } r_i(s) + 1 = r_i(s') = r_i(s'') \quad \text{Eq. 4} \end{aligned}$$

**Example for an airline A for one criterion:**

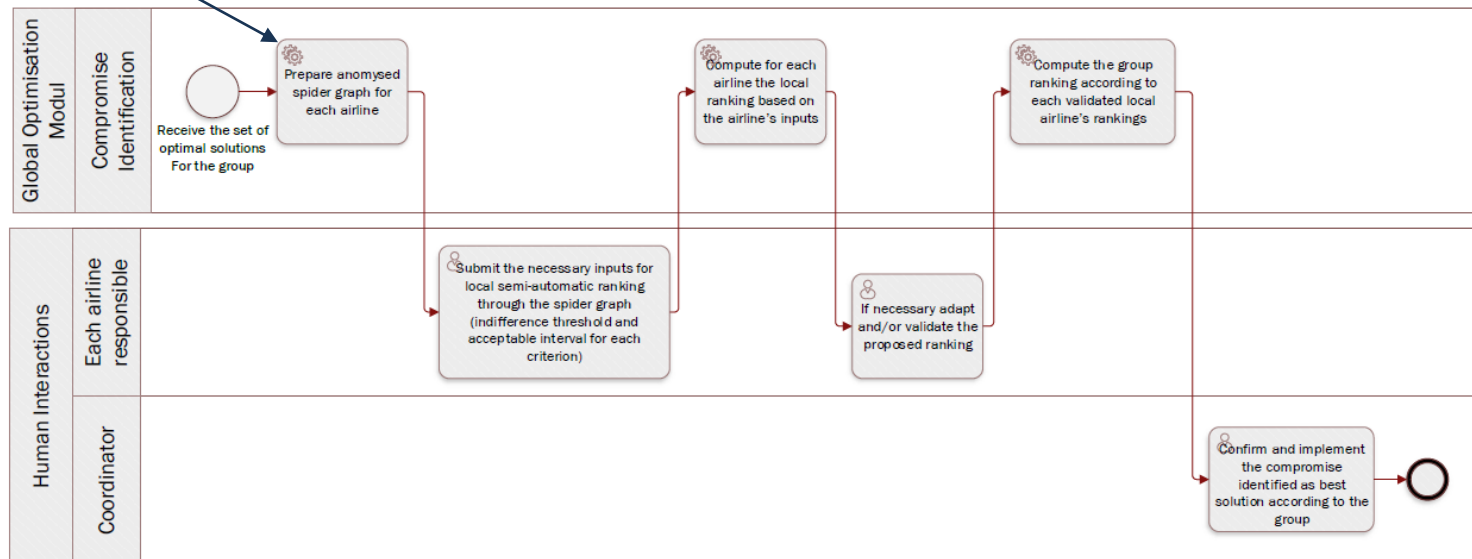


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| 1                     | S4 & S5     | $\frac{5+4}{2} = 4.5$ |
| 2                     | -           | -                     |
| 3                     | S6          | 3                     |
| 4                     | S2 & S3     | $\frac{3+2}{2} = 2.5$ |
| 5                     | -           | -                     |
| 6                     | S1          | 0                     |

# Proposed Approach

## Business Process Model for the Consensus Identification

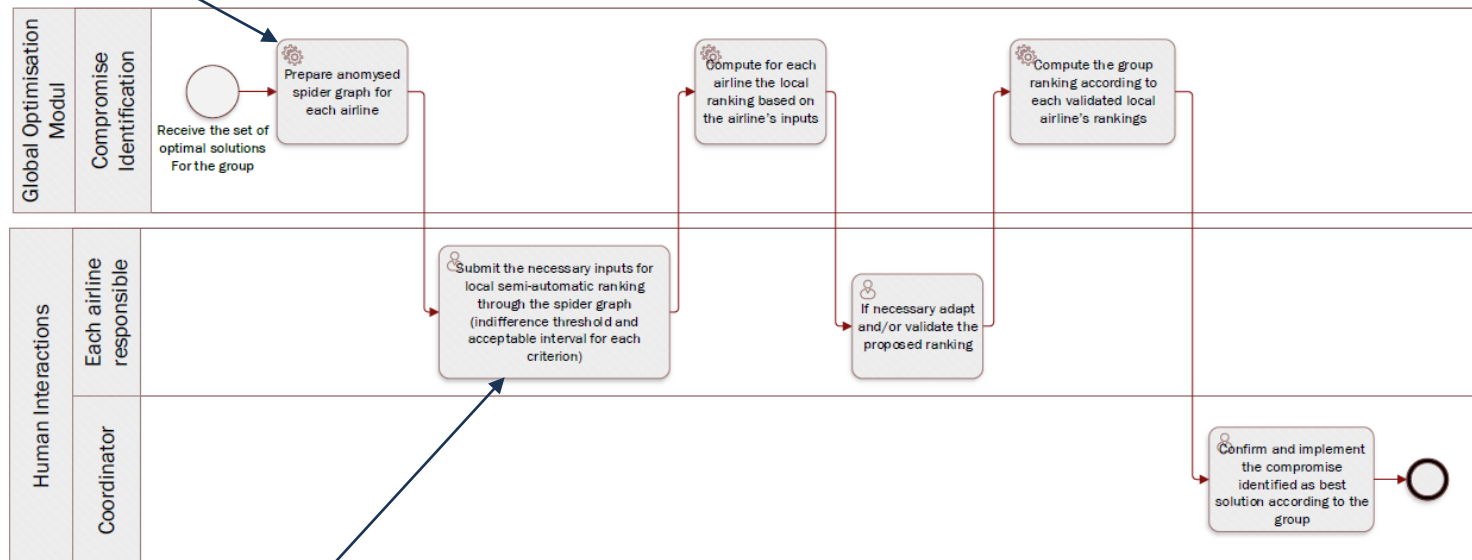
Spider graph to present the solutions performance with a users friendly approach



# Proposed Approach

## Business Process Model for the Consensus Identification

Spider graph to present the solutions performance with a users friendly approach



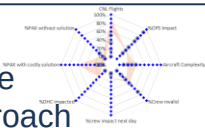
Each airline provides for each criterion:

- Indifference threshold
- Acceptable interval of performances

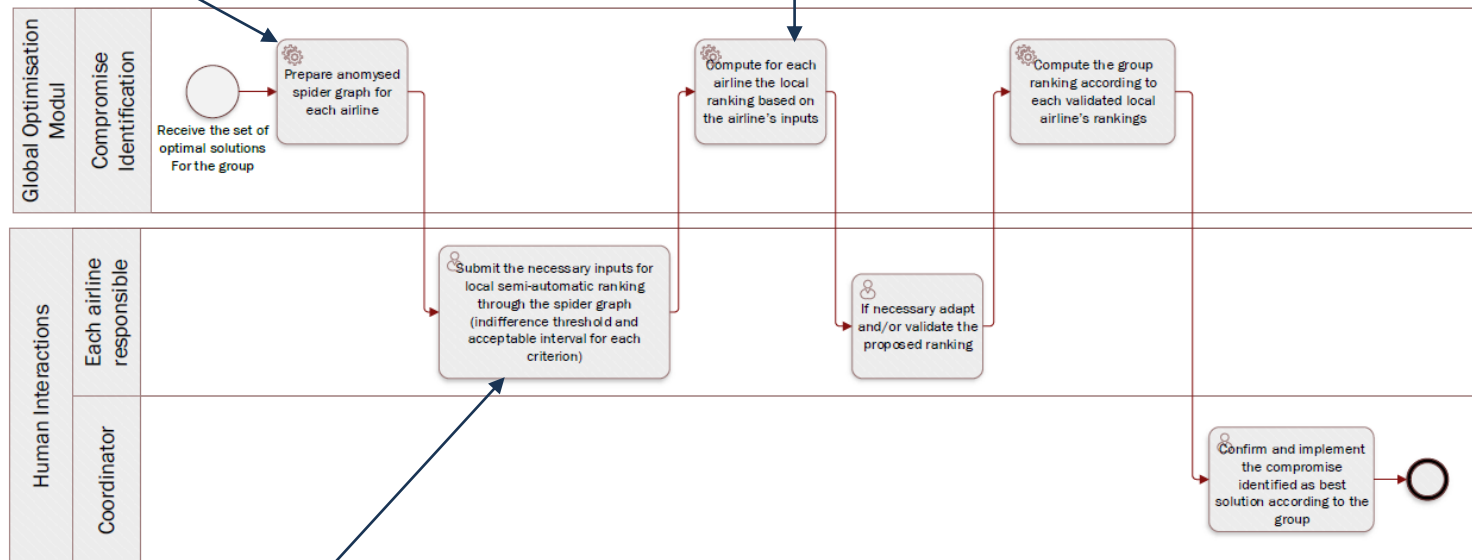
# Proposed Approach

## Business Process Model for the Consensus Identification

Spider graph to present the solutions performance with a users friendly approach



First Borda Round for local ranking with decision-makers preferences and sensitivity modelled (1criterion=1voter)



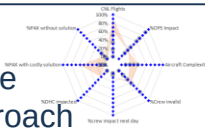
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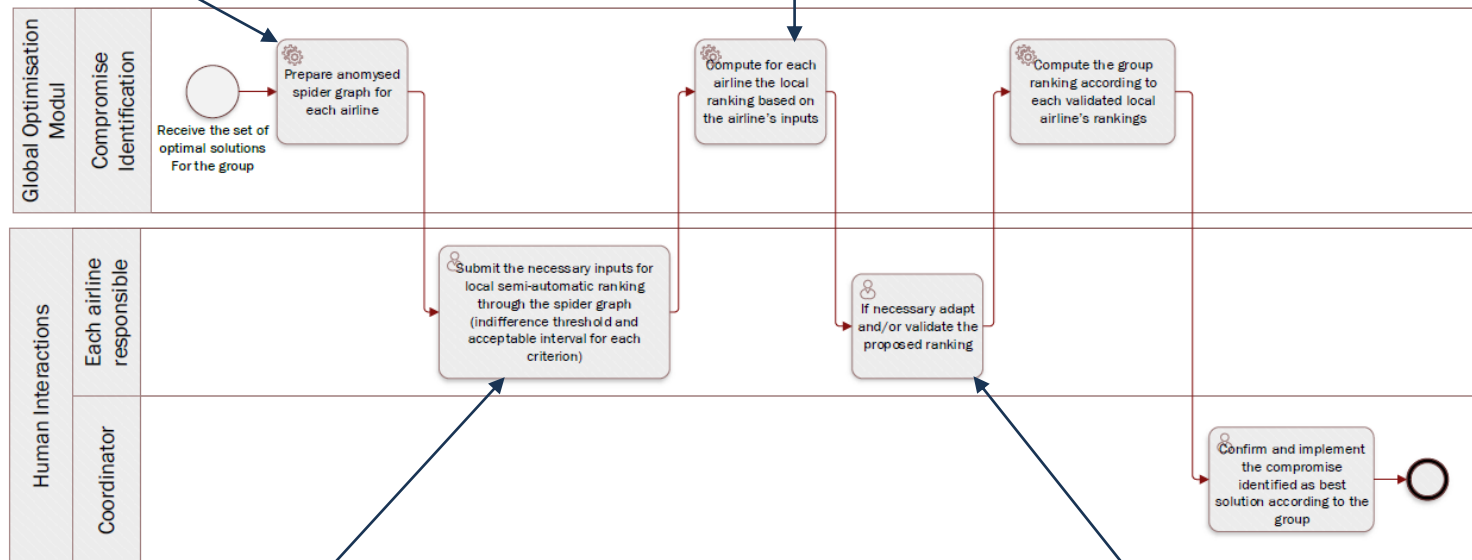
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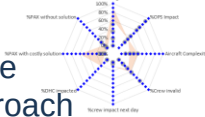
- Indifference threshold
- Acceptable interval of performances

Each airline can adapt their local ranking according to their operations knowledge and awareness

# Proposed Approach

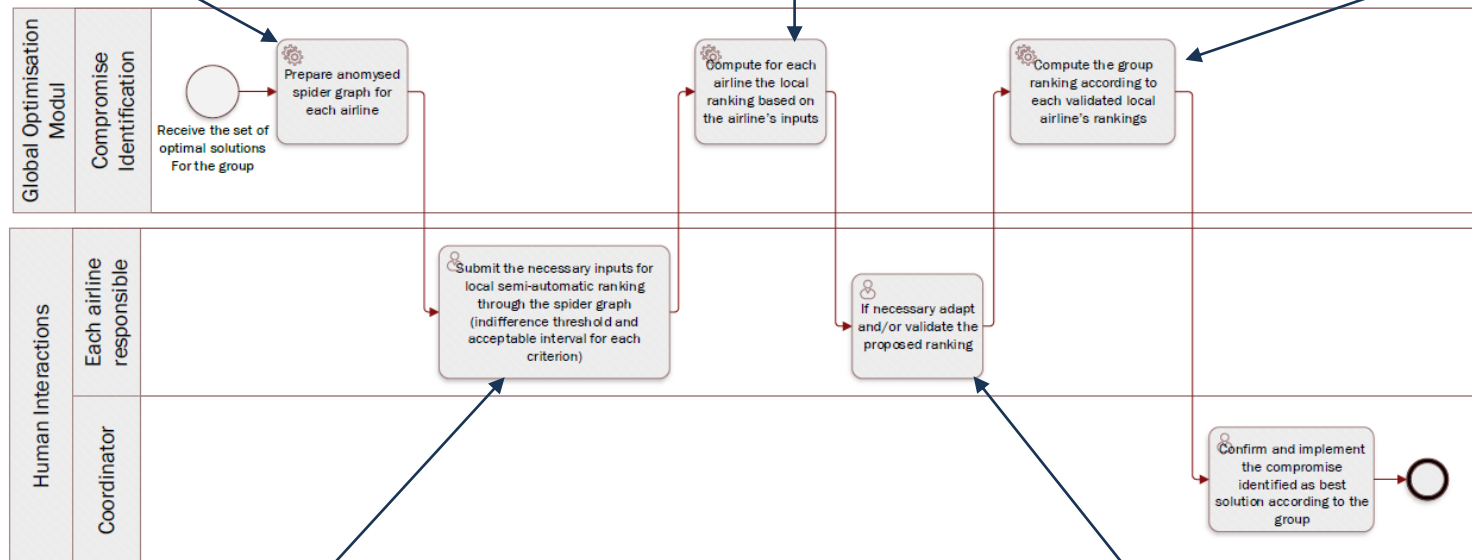
## Business Process Model for the Consensus Identification

Spider graph to present the solutions performance with a users friendly approach



First Borda Round for local ranking with decision-makers preferences and sensitivity modelled (1 criterion=1 voter)

Second Borda Round for global ranking with each airline being an elector



Each airline provides for each criterion:

- Indifference threshold
- Acceptable interval of performances

Each airline can adapt their local ranking according to their operations knowledge and awareness

# Illustration and Discussion

## On a Simple Basic Use-Case

S1 gets 7 points from Airline C

S1 gets 5 points from Airline B  
as ranked equivalent to S3 and  
S7

S1 gets 5 points from Airline A

S1 gets 17 points globally

TABLE IV RANKINGS FOR THE THREE PARTICIPATING AIRLINES

| <i>Rank</i> | <i>Ranking for<br/>Airline A</i> | <i>Ranking for<br/>Airline B</i> | <i>Ranking for<br/>Airline C</i> |
|-------------|----------------------------------|----------------------------------|----------------------------------|
| 1           | S2                               | S2                               | S1                               |
| 2           | S3                               | S1 S3 S7                         | S2                               |
| 3           | S1                               | -                                | S7                               |
| 4           | S7                               | -                                | S3                               |
| 5           | S8                               | S8                               | S5                               |
| 6           | S4                               | S4                               | S8                               |
| 7           | S5                               | S5                               | S4                               |
| 8           | S6                               | S6                               | S6                               |

S2 gets 14 points as ranked twice first  
by Airline A and B

S2 gets 6 points as ranked second by  
Airline C

S2 gets 20 points globally

TABLE V RANKING OF THE GROUP VISION WITH ALL AIRLINES VOTES

| <i>Global Ranking</i> | <i>Solution ID</i> | <i>Borda Points</i> |
|-----------------------|--------------------|---------------------|
| 1                     | S2                 | 20                  |
| 2                     | S1                 | 17                  |
| 3                     | S3                 | 15                  |
| 4                     | S7                 | 14                  |
| 5                     | S8                 | 8                   |
| 6                     | S4 S5              | 5                   |
| 7                     | -                  | -                   |
| 8                     | S6                 | 0                   |

# Illustration and Discussion

## On Very Different Users' Rankings

TABLE VI: ILLUSTRATION OF VERY DIFFERENT RANKING

| <i>Rank</i> | <i>Ranking for<br/>Airline A</i> | <i>Ranking for<br/>Airline B</i> | <i>Ranking for<br/>Airline C</i> |
|-------------|----------------------------------|----------------------------------|----------------------------------|
| 1           | S1                               | S6                               | S8                               |
| 2           | S4                               | S7                               | S5                               |
| 3           | S6                               | S2                               | S3                               |
| 4           | S3                               | S3                               | S2                               |
| 5           | S2                               | S4                               | S7                               |
| 6           | S8                               | S1                               | S1                               |
| 7           | S5                               | S8                               | S4                               |
| 8           | S7                               | S5                               | S6                               |

S3 ranked averagely by all airlines

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| 1                     | S3                 | 13                  |
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| 3                     | -                  | 12                  |
| 4                     | S1                 | 11                  |
| 5                     | S4 S8              | 10                  |
| 6                     | -                  | 10                  |
| 7                     | S7                 | 9                   |
| 8                     | S5                 | 7                   |

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| 1           | S1                               | S6                               | S8                               |
| 2           | S4                               | S7                               | S5                               |
| 3           | S6                               | S2                               | S3                               |
| 4           | S3                               | S3                               | S2                               |
| 5           | S2                               | S4                               | S7                               |
| 6           | S8                               | S1                               | S1                               |
| 7           | S5                               | S8                               | S4                               |
| 8           | S7                               | S5                               | S6                               |

S3 ranked averagely by all airlines

S1 ranked first by airline A but on the 6<sup>th</sup> position by airlines B and C

TABLE VII RANKING FOR THE GROUP VISION WITH ALL AIRLINES VOTES

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| 2           | S4                               | S7                               | S5                               |
| 3           | S6                               | S2                               | S3                               |
| 4           | S3                               | S3                               | S2                               |
| 5           | S2                               | S4                               | S7                               |
| 6           | S8                               | S1                               | S1                               |
| 7           | S5                               | S8                               | S4                               |
| 8           | S7                               | S5                               | S6                               |

S3 ranked averagely by all airlines

S6 ranked first by airline B but third by A and last by C

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| 1           | S1                               | S6                               | S8                               |
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| 3           | S6                               | S2                               | S3                               |
| 4           | S3                               | S3                               | S2                               |
| 5           | S2                               | S4                               | S7                               |
| 6           | S8                               | S1                               | S1                               |
| 7           | S5                               | S8                               | S4                               |
| 8           | S7                               | S5                               | S6                               |

S3 ranked averagely by all airlines

S6 ranked first by airline B but third by A and last by C

S1 ranked first by airline A but on the 6<sup>th</sup> position by airlines B and C

S8 ranked first by C but 6<sup>th</sup> by A and 7<sup>th</sup> by B

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| 2           | S4                               | S7                               | S5                               |
| 3           | S6                               | S2                               | S3                               |
| 4           | S3                               | S3                               | S2                               |
| 5           | S2                               | S4                               | S7                               |
| 6           | S8                               | S1                               | S1                               |
| 7           | S5                               | S8                               | S4                               |
| 8           | S7                               | S5                               | S6                               |

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| 5                     | S4 S8              | 10                  |
| 6                     | -                  | 10                  |
| 7                     | S7                 | 9                   |
| 8                     | S5                 | 7                   |

→ Outlines the Borda behavior aiming at finding a consensus rather than following the majority of voters' rankings.

# Illustration and Discussion

## On Very Imbalanced Rankings

TABLE VIII: ILLUSTRATION OF A VERY IMBALANCED SITUATION

S1 ranked first by A but last by B and 2<sup>nd</sup> by C

S8 ranked first by C but 4<sup>th</sup> by B and 7<sup>th</sup> by C

| <i>Rank</i> | <i>Ranking for Airline A</i> | <i>Ranking for Airline B</i> | <i>Ranking for Airline C</i> |
|-------------|------------------------------|------------------------------|------------------------------|
| 1           | S1                           | S6                           | S8                           |
| 2           | S3                           | S7                           | S1                           |
| 3           | S5                           | S2                           | S7                           |
| 4           | S4                           | S8                           | S5                           |
| 5           | S2                           | S3                           | S2                           |
| 6           | S6                           | S4                           | S3                           |
| 7           | S8                           | S5                           | S4                           |
| 8           | S7                           | S1                           | S6                           |

TABLE IX RANKING OF THE GROUP VISION WITH ALL AIRLINES VOTES

| <i>Global Ranking</i> | <i>Solution ID</i> | <i>Attributed Borda Points</i> |
|-----------------------|--------------------|--------------------------------|
| 1                     | S1                 | 13                             |
| 2                     | S8                 | 12                             |
| 3                     | S2                 | 11                             |
| 4                     | S3                 | 11                             |
| 5                     | S7                 | 11                             |
| 6                     | S5                 | 10                             |
| 7                     | S6                 | 9                              |
| 8                     | S4                 | 7                              |

→ Borda can identify a controversial solution, but which is still preferred by more airlines than the other solutions.

# Illustration and Discussion

## On Very Imbalanced Rankings

TABLE VIII: ILLUSTRATION OF A VERY IMBALANCED SITUATION

S1 ranked first by A but last by B and 2<sup>nd</sup> by C

S8 ranked first by C but 4<sup>th</sup> by B and 7<sup>th</sup> by C

| <i>Rank</i> | <i>Ranking for<br/>Airline A</i> | <i>Ranking for<br/>Airline B</i> | <i>Ranking for<br/>Airline C</i> |
|-------------|----------------------------------|----------------------------------|----------------------------------|
| 1           | S1                               | S6                               | S8                               |
| 2           | S3                               | S7                               | S1                               |
| 3           | S5                               | S2                               | S7                               |
| 4           | S4                               | S8                               | S5                               |
| 5           | S2                               | S3                               | S2                               |
| 6           | S6                               | S4                               | S3                               |
| 7           | S8                               | S5                               | S4                               |
| 8           | S7                               | S1                               | S6                               |

Compensation mechanism must be introduced to ensure long-term balance in equity and trust in the consensus system by all stakeholders

TABLE IX RANKING OF THE GROUP VISION WITH ALL AIRLINES VOTES

| <i>Global<br/>Ranking</i> | <i>Solution<br/>ID</i> | <i>Attributed<br/>Borda Points</i> |
|---------------------------|------------------------|------------------------------------|
| 1                         | S1                     | 13                                 |
| 2                         | S8                     | 12                                 |
| 3                         | S2                     | 11                                 |
| 4                         | S3                     | 11                                 |
| 5                         | S7                     | 11                                 |
| 6                         | S5                     | 10                                 |
| 7                         | S6                     | 9                                  |
| 8                         | S4                     | 7                                  |

→ Borda can identify a controversial solution, but which is still preferred by more airlines than the other solutions.

# Illustration and Discussion

## On Borda with Weights

TABLE VIII: ILLUSTRATION OF A VERY IMBALANCED SITUATION

| <i>Rank</i> | <i>Ranking for<br/>Airline A</i> | <i>Ranking for<br/>Airline B</i> | <i>Ranking for<br/>Airline C</i> |
|-------------|----------------------------------|----------------------------------|----------------------------------|
| 1           | S1                               | S6                               | S8                               |
| 2           | S3                               | S7                               | S1                               |
| 3           | S5                               | S2                               | S7                               |
| 4           | S4                               | S8                               | S5                               |
| 5           | S2                               | S3                               | S2                               |
| 6           | S6                               | S4                               | S3                               |
| 7           | S8                               | S5                               | S4                               |
| 8           | S7                               | S1                               | S6                               |

Airline A was slightly advantaged during the last global optimisation  
→ weight = 0.9

Airline B was slightly disadvantaged during the last global optimisation  
→ weight = 1.1

Airline C was reaching the perfect equilibrium with equity toward the other airlines  
→ weight = 1

- Compensation mechanism must be introduced to ensure long-term balance in equity and trust in the consensus system by all stakeholders
- If Borda does rank two solutions on the first rank in the global assessment, Condorcet could identified the most preferred solution:
  - S1 preferred once to S8
  - S8 preferred twice to S1  
→ S8 is the consensus.

TABLE X RANKING OF THE GROUP VISION WITH ALL AIRLINES VOTES

| <i>Global Ranking</i> | <i>Solution ID</i> | <i>Borda Points</i> |
|-----------------------|--------------------|---------------------|
| 1                     | S8                 | 12.3                |
| 2                     | S1                 | 12.3                |
| 3                     | S7                 | 11.6                |
| 4                     | S2                 | 11.2                |
| 5                     | S3                 | 10.7                |
| 6                     | S5                 | 9.6                 |
| 7                     | S6                 | 9.5                 |
| 8                     | S4                 | 6.8                 |

→ The weights influence the Borda calculations (4<sup>th</sup> rank of S8 slightly more important due to  $Weight_B = 1.1$  and 7<sup>th</sup> rank slightly less important due to  $Weight_A = 0.9$ )

→ S1 ~ S8

# Identification of a Consensus in a Multi-criteria Decision Process involving several Decision-Markers

## Conclusion

### Goal and contribution of this research article:

- Presentation of a two-steps approach to identify quickly and efficiently a consensus among optimal solutions with conflictive opinions from the different decision-makers;
- Model the human sensitivity (indifference threshold) as well as the preferences (interval of acceptable performances) of each decision-maker;
- Ensuring quick and efficient decision-making based on the preferences of relevant stakeholders could only have positive effect on the European ATM;
- Considering the priorities of airlines and reaching a consensus involving all stakeholders would result in an enhanced travel experience through Europe (less delay and passengers centric approach), a decrease of the environmental impact of aviation (less high speed and holdings needed).

# Identification of a Consensus in a Multi-criteria Decision Process involving several Decision-Markers

## Conclusion

### Further research path arisen:

- This approach must be complemented with a transparent and reliable long-term monitoring of the balances between the stakeholders (First definitions and steps in [5]);
- This approach could be adapted and applicable on an ATM level and not only on an airlines group level;
- Set the path for further research towards long-term equity guarantee to enable more flexibility and better global solution, even if at time  $t$  the inequity is high (weights attribution or other mechanisms).

# References

- [1] G. Yannis, A. Kopsacheili, A. Dragomanovits, and V. Petraki, “State-of-the-art review on multi-criteria decision-making in the transport sector,” *J. Traffic Transp. Eng. Engl. Ed.*, vol. 7, no. 4, pp. 413–431, Aug. 2020, doi: 10.1016/j.jtte.2020.05.005.
- [2] EUROCONTROL Airport CDM Team, “Airport CDM Implementation Manual,” EUROCONTROL, Mar. 2017.
- [3] A. Jardines, M. Soler, A. Cervantes, J. García-Heras, and J. Simarro, “Convection indicator for pre-tactical air traffic flow management using neural networks,” *Mach. Learn. Appl.*, vol. 5, Sep. 2021, doi: 10.1016/j.mlwa.2021.100053.
- [4] N. Pilon, L. Guichard, Z. Bazso, G. Murgese, and M. Carré, “User-Driven Prioritisation Process (UDPP) from advanced experimental to pre-operational validation environment,” *J. Air Transp. Manag.*, vol. 97, Oct. 2021, doi: 10.1016/j.jairtraman.2021.102124.
- [5] M. Carré, E. Nantier, S. Durieux, and L. Piétrac, “Equity within Air Transportation Management – an Analysis of Inequity Index for Multi-Stakeholders Optimisation,” in *ATM Seminar 2021*, Sep. 2021, p. 10.
- [6] EUROCONTROL, “CODA Digest All-causes delay and cancellations to air transport in Europe,” Annual report for 2019, Apr. 2020.
- [7] G. D. Pelegrina, L. T. Duarte, M. Grabisch, and J. M. T. Romano, “The multilinear model in multicriteria decision making: The case of 2-additive capacities and contributions to parameter identification,” *Eur. J. Oper. Res.*, vol. 282, no. 3, pp. 945–956, May 2020, doi: 10.1016/j.ejor.2019.10.005.
- [8] M. Grabisch and C. Labreuche, “A decade of application of the Choquet and Sugeno integrals in multi-criteria decision aid,” *Ann. Oper. Res.*, vol. 175, no. 1, pp. 247–286, Mar. 2010, doi: 10.1007/s10479-009-0655-8.
- [9] S. Greco, A. Ishizaka, M. Tasiou, and G. Torrisi, “The ordinal input for cardinal output approach of non-compensatory composite indicators: the PROMETHEE scoring method,” *Eur. J. Oper. Res.*, vol. 288, no. 1, pp. 225–246, Jan. 2021, doi: 10.1016/j.ejor.2020.05.036.
- [10] L. B. Anderson, “Chapter 16 Voting theory,” in *Handbooks in Operations Research and Management Science*, vol. 6, Elsevier, 1994, pp. 561–584. doi: 10.1016/S0927-0507(05)80097-0.
- [11] H. P. Young, “An axiomatization of Borda’s rule,” *J. Econ. Theory*, vol. 9, no. 1, pp. 43–52, 1974, doi: [https://doi.org/10.1016/0022-0531\(74\)90073-8](https://doi.org/10.1016/0022-0531(74)90073-8).
- [12] C. Herrero and A. Villar, “Group decisions from individual rankings: The Borda–Condorcet rule,” *Eur. J. Oper. Res.*, vol. 291, no. 2, pp. 757–765, Jun. 2021, doi: 10.1016/j.ejor.2020.09.043.
- [13] N. Narodytska and T. Walsh, “The Computational Impact of Partial Votes on Strategic Voting,” Prague, May 2014.
- [14] B. Roy, “The outranking approach and the foundations of electre methods,” *Theory Decis.*, vol. 31, no. 1, pp. 49–73, Jul. 1991, doi: <https://doi.org/10.1007/BF00134132>.



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## Thank you

