# MCDA-ULaval software for ELECTRE methods

## Application to water source protection

**Irène Abi-Zeid[1] & Ariane Marais [2]**

**1 Professor,** Operations and Decision Systems Department

**2 Ph.D. Student**, Land Management and Regional Planning Graduate School

*irene.abi-zeid@osd.ulaval.ca*

*ariane.marais@esad.ulaval.ca*

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# Outline

- MCDA-ULaval Software

# MCDA-ULaval

- **A multicriteria decision analysis/aiding software for ranking and sorting, developed in JAVA at Laval University, Quebec, Canada**
  - ELECTRE[1] family of methods (ordinal)
- **Contains ELECTRE II and III (for ranking), and ELECTRE Tri B, Tri-C, Tri-nC, and Tri-rC (for sorting), with and without criteria interaction**
- **Freeware available for download**


1 Figueira, J. R., Greco, S., Roy, B., & Słowiński, R. (2013). An overview of ELECTRE methods and their recent extensions. Journal of Multi-Criteria Decision Analysis, 20(1-2), 61-85.

MCDA-ULaval

# Example – ranking flight tickets between Torino and Quebec City

| | CRITERIA | | | | |
|---|---|---|---|---|---|
| **Alternatives (Tickets)** | Price (Euros) (Min) | Duration (Hours) (Min) | Comfort (Max) | Arrival Time (Min) | Transportation mode (Min) |
| Air France | 824 | 15 | High (3) | 01:30 next day (4) | 2 Airplanes and 1 Bus (2) |
| United Airlines | 895 | 18 | Low (1) | 14:29 (1) | 2 Airplanes (1) |
| Lufthansa/Air Canada 1 | 875 | 13,25 | Medium (2) | 21:50 (2) | 3 Airplanes (3) |
| Lufthansa/Air Canada 2 | 880 | 14,5 | Medium (2) | 23:15 (3) | 3 Airplanes (3) |

- Comfort High : quality food, good entertainment, friendly staff, average leg room
- Comfort Medium : acceptable food, good entertainment, not very friendly staff, average leg room
- Comfort Low : very bad food, unfriendly staff, no entertainment, smaller leg room

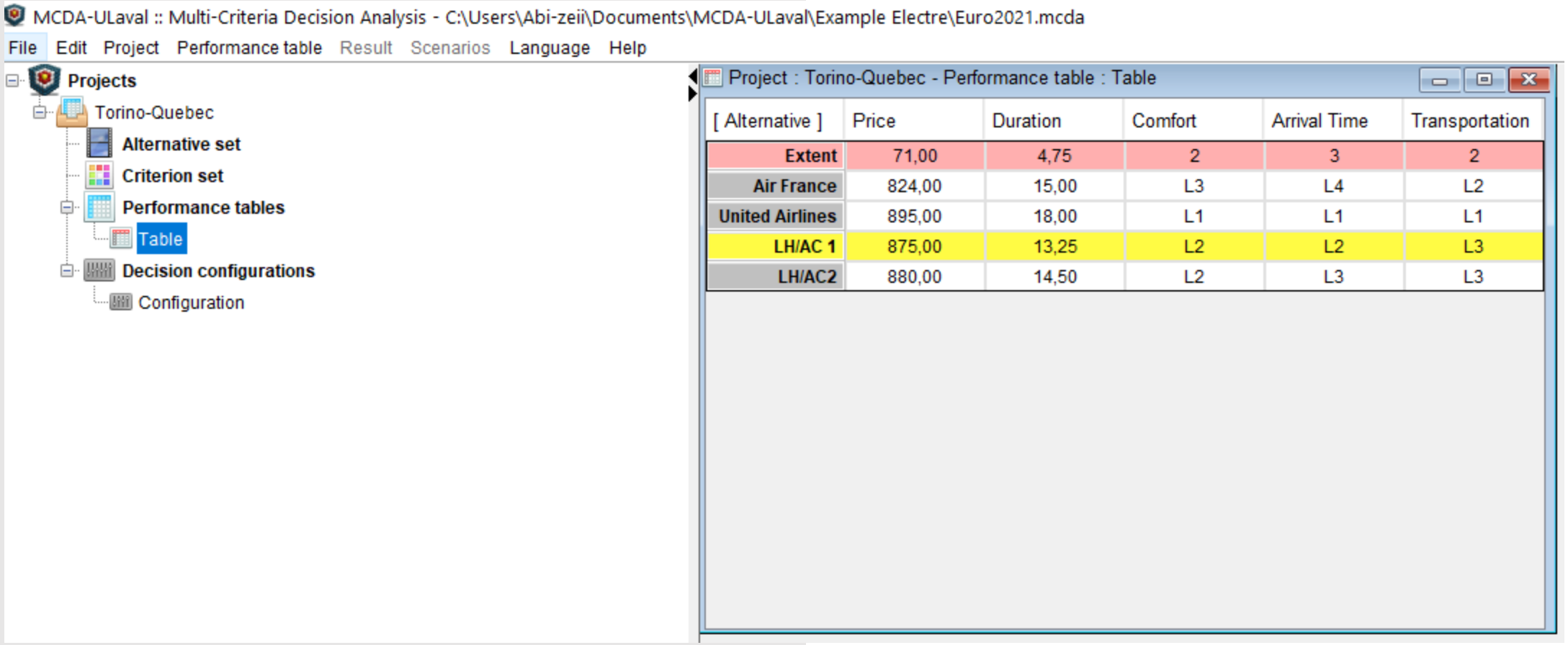
# MCDA-ULaval
# **Project**

- **A project basically contains:**
  1. A set of **alternatives**
  2. A set of **criteria**
  3. **Performance table** that can be visualized through a radar graph
  4. **Decision configuration** namely a triplet consisting of a set of alternatives, a set of criteria, and an ELECTRE method along with:
     - Criteria weights (required)
     - Criteria veto, indifference, preference thresholds (if necessary)
     - The method's technical parameters including reference profiles for the **Tri** family

# Criteria

- **Cardinal or ordinal criteria to be minimized or maximized**
- **Constant or variable thresholds for each criterion**
- **Variable thresholds**
  - For cardinal criteria: linear functions of the performances, with a choice of direct or indirect definition modes
    - For the Tri family, also linear functions of the performance of the reference profile
  - For ordinal criteria thresholds are defined for each value of the ordinal scale

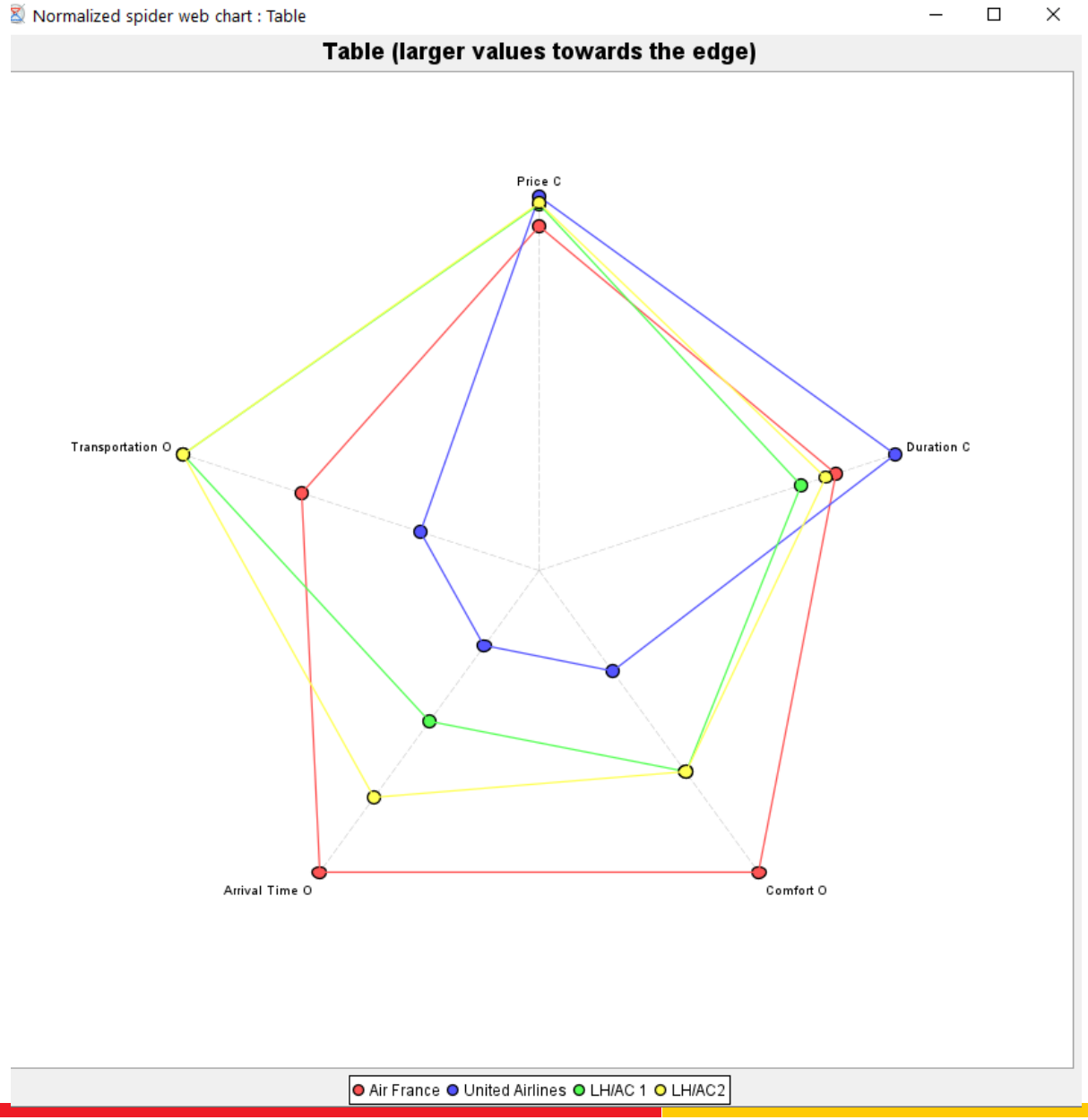
# MCDA-ULaval
# **Tree project structure**



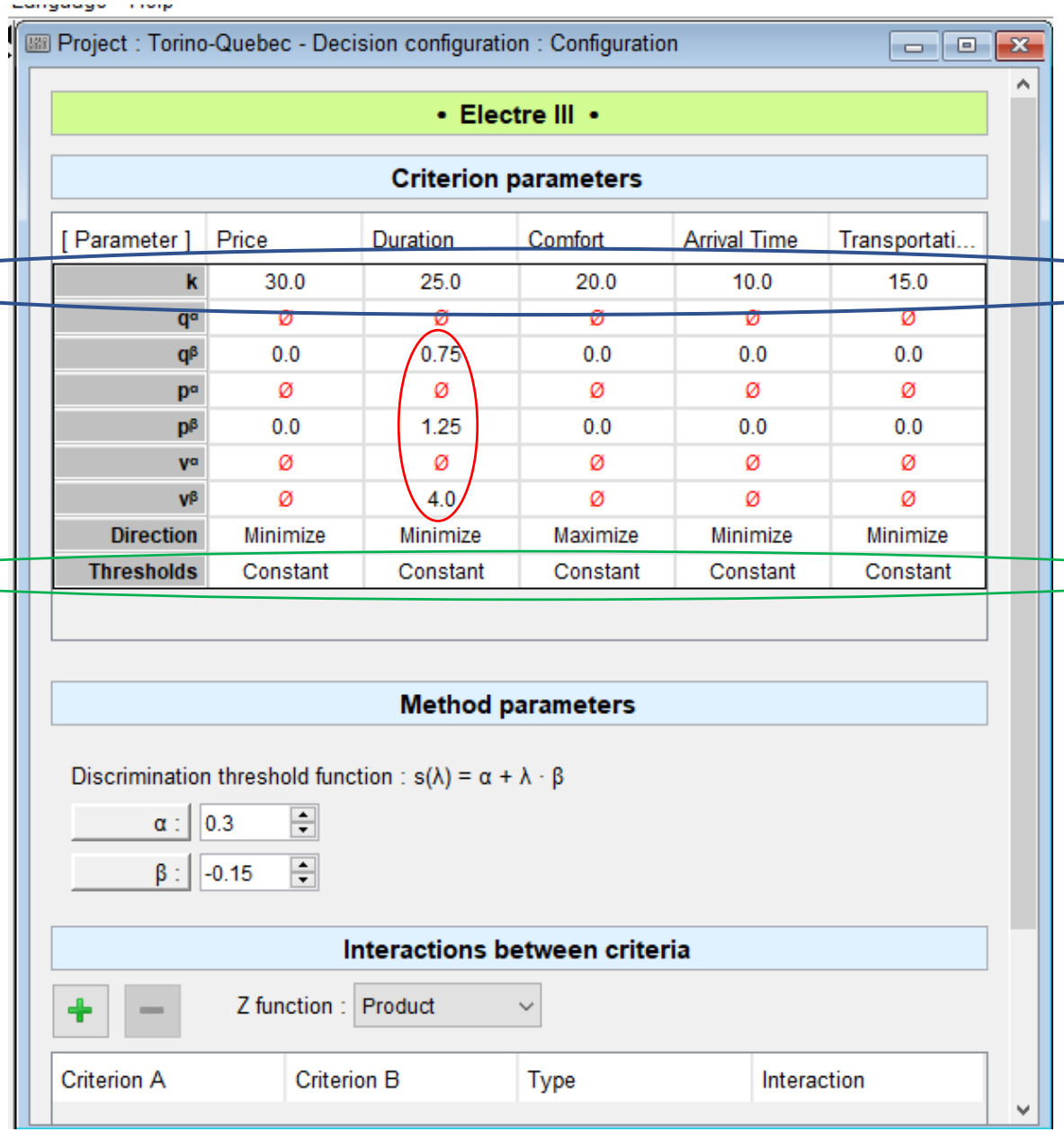
# MCDA-ULaval
# **Peformance tables**

- **Performance tables may be entered manually or imported from a file in csv dos format**

- **Performance tables can be represented graphically as spider web (radar) charts**
  - Up to a maximum number of alternatives so it stays readable



# MCDA-ULaval
# **Configuration**



# MCDA-ULaval
## Execution

- To execute a method, user selects a decision configuration and a performance table
- Multiple decision configurations are allowed within the same project
- Subsets of alternatives, of criteria, or of both may be defined and analyzed separately

# MCDA-ULaval
# **Output**

- **Partial results: concordance, discordance and credibility matrices**
  - For sorting methods: Rho matrix
  - For ranking methods: Intermediate graphs representing the ascending and descending distillations and the direct and indirect rankings
- **Final result: Outranking matrix**
- **For ranking methods:**
  - Graphs representing the final ranking (partial pre-order), and the median ranking (total pre-order)
- **For sorting methods:**
  - Maximum and minimum categories

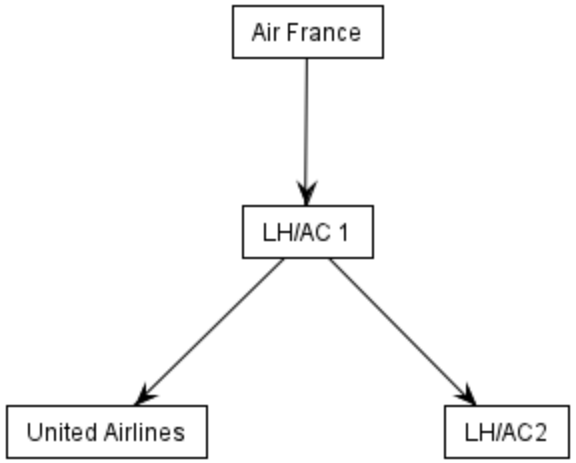
# MCDA-ULaval
# **Results**

Project : Torino-Quebec - Result : <Configuration, Table, *, Ø>

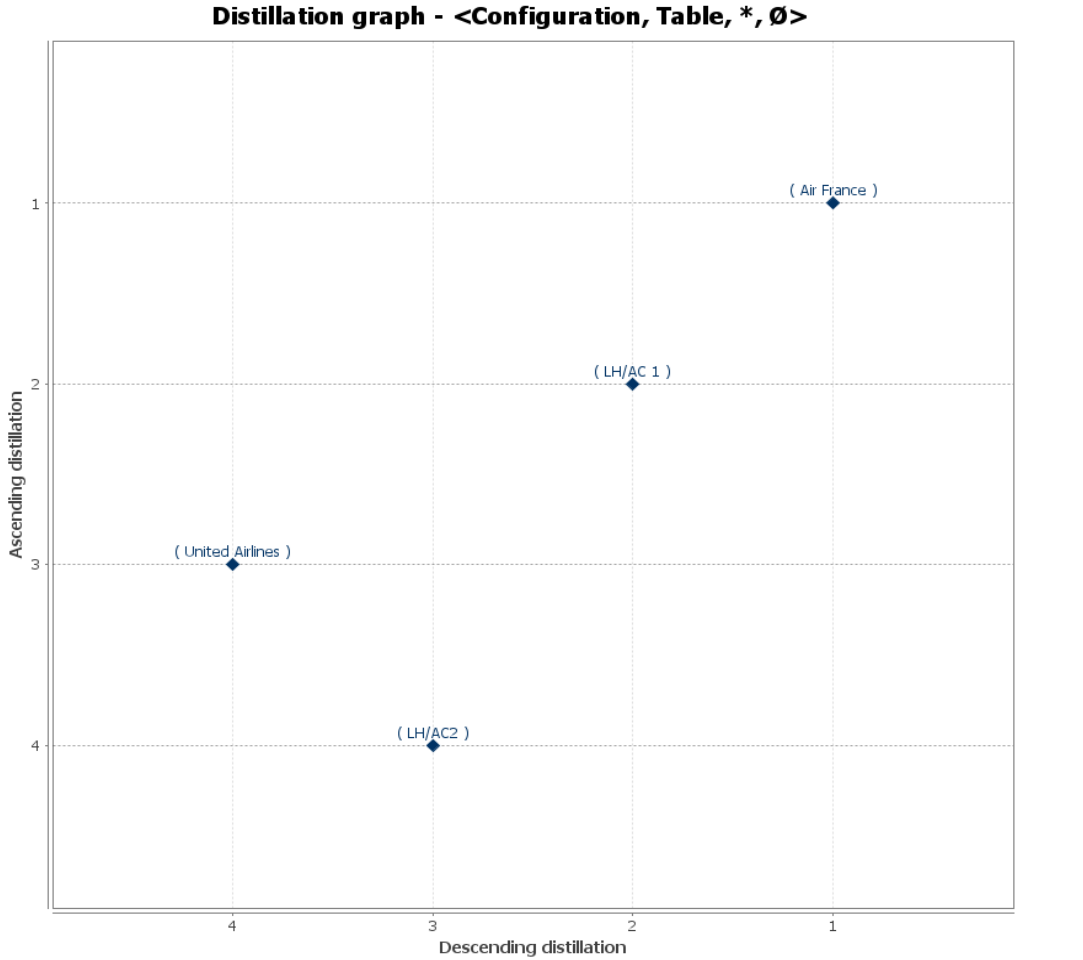
```
::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
                    RESULT <Configuration, Table, *, Ø>
::::::::::::::::::::::::::::
Ascending distillation
    1 : Air France
    2 : LH/AC 1
    3 : United Airlines
    4 : LH/AC2

Descending distillation
    1 : Air France
    2 : LH/AC 1
    3 : LH/AC2
    4 : United Airlines

Final ranking
    1 : Air France
    2 : LH/AC 1
    3 : [United Airlines, LH
```




```
Median ranking
    1 : Air France
    2 : LH/AC 1
    3 : [United Airlines, LH/AC2]
```




Project : Torino-Quebec - Configuration - Outranking

Export CSV

P+ : outranks P- : is outranked by R : incomparable I : indifferent

| [-] | Air France | United Airlines | LH/AC 1 | LH/AC2 |
|---|---|---|---|---|
| **Air France** | I | P+ | P+ | P+ |
| **United Airlines** | P- | I | P- | R |
| **LH/AC 1** | P- | P+ | I | P+ |
| **LH/AC2** | P- | R | P- | I |

# Stability and scenario analyses

To understand the impact of parameter variation on the results

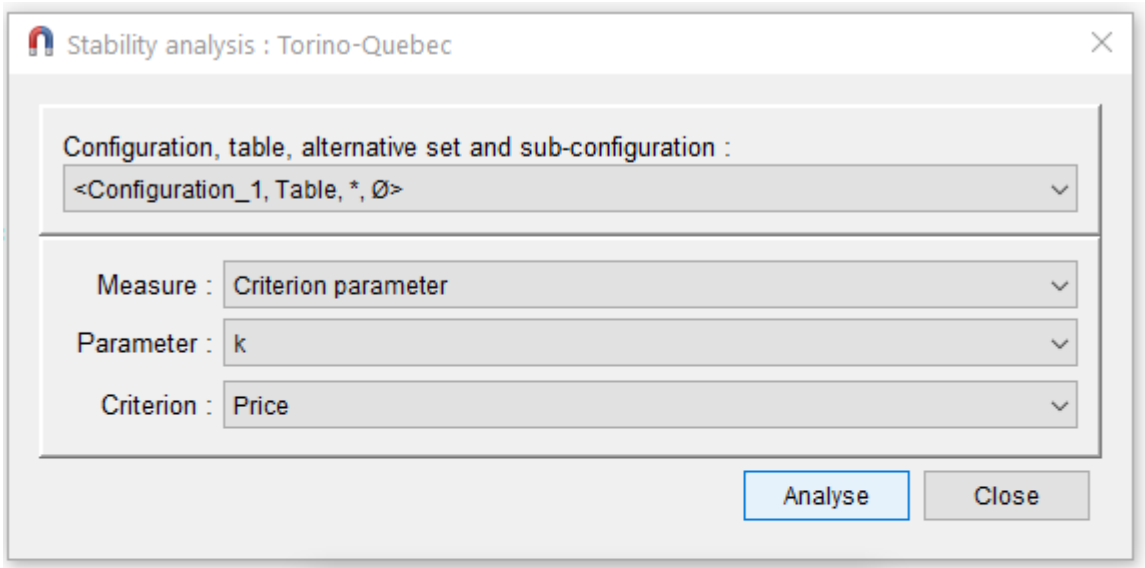
# MCDA-ULaval
## **Stability analysis**

- **The Stability Analysis module computes, for a single parameter, the range within which the initial solution obtained (ranking or sorting) remains stable**
  - Weights of criteria
  - Method’s technical parameters

# MCDA-ULaval
## **Stability analysis**

- **An interval for a parameter within which the results do not change**

- **Here the weight of the Price criterion (initially at 30%) can vary between 20,92% and 55,46% without changing the results**



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# Scenario Analysis

- **A scenario analysis essentially consists of executing a decision configuration with different combinations of parameter values**
  - Robustness analysis
- **User chooses the parameters to vary, the range of variation and the number of sub-intervals**
- **MCDA-ULaval then executes for each combination of parameter values**
- **The resulting decision is presented for each combination of parameter values**

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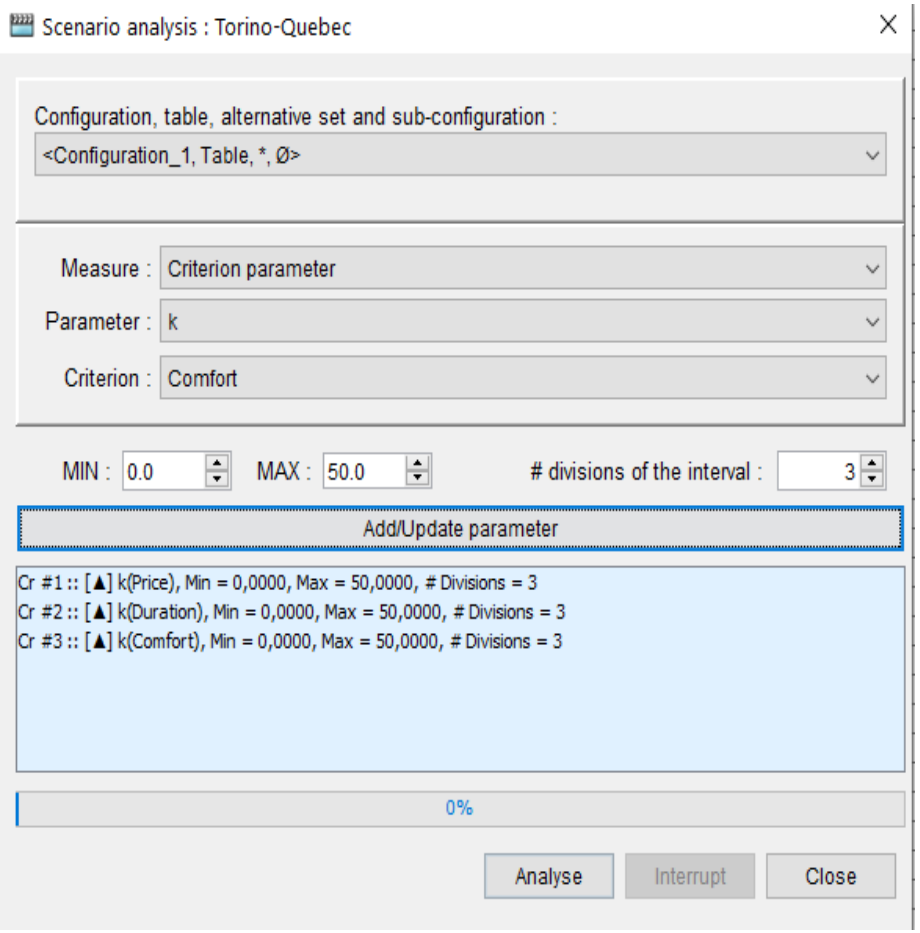
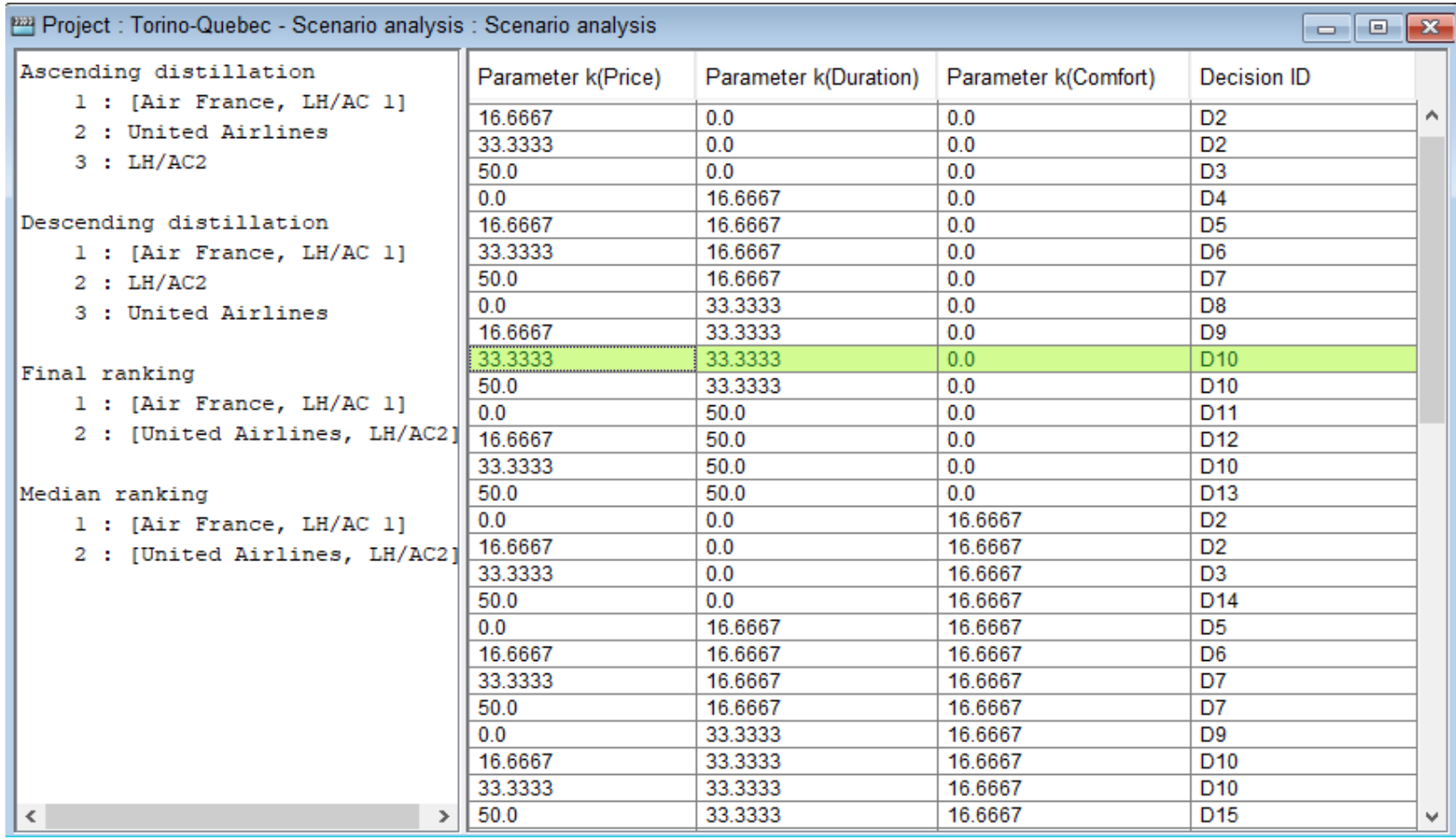
# Scenario Analysis

- **Computes up to 64 different combinations in the scenario analysis**




| Parameter k(Price) | Parameter k(Duration) | Parameter k(Comfort) | Decision ID |
|---|---|---|---|
| 16.6667 | 0.0 | 0.0 | D2 |
| 33.3333 | 0.0 | 0.0 | D2 |
| 50.0 | 0.0 | 0.0 | D3 |
| 0.0 | 16.6667 | 0.0 | D4 |
| 16.6667 | 16.6667 | 0.0 | D5 |
| 33.3333 | 16.6667 | 0.0 | D6 |
| 50.0 | 16.6667 | 0.0 | D7 |
| 0.0 | 33.3333 | 0.0 | D8 |
| 16.6667 | 33.3333 | 0.0 | D9 |
| 33.3333 | 33.3333 | 0.0 | D10 |
| 50.0 | 33.3333 | 0.0 | D10 |
| 0.0 | 50.0 | 0.0 | D11 |
| 16.6667 | 50.0 | 0.0 | D12 |
| 33.3333 | 50.0 | 0.0 | D10 |
| 50.0 | 50.0 | 0.0 | D13 |
| 0.0 | 0.0 | 16.6667 | D2 |
| 16.6667 | 0.0 | 16.6667 | D2 |
| 33.3333 | 0.0 | 16.6667 | D3 |
| 50.0 | 0.0 | 16.6667 | D14 |
| 0.0 | 16.6667 | 16.6667 | D5 |
| 16.6667 | 16.6667 | 16.6667 | D6 |
| 33.3333 | 16.6667 | 16.6667 | D7 |
| 50.0 | 16.6667 | 16.6667 | D7 |
| 0.0 | 33.3333 | 16.6667 | D9 |
| 16.6667 | 33.3333 | 16.6667 | D10 |
| 33.3333 | 33.3333 | 16.6667 | D10 |
| 50.0 | 33.3333 | 16.6667 | D15 |

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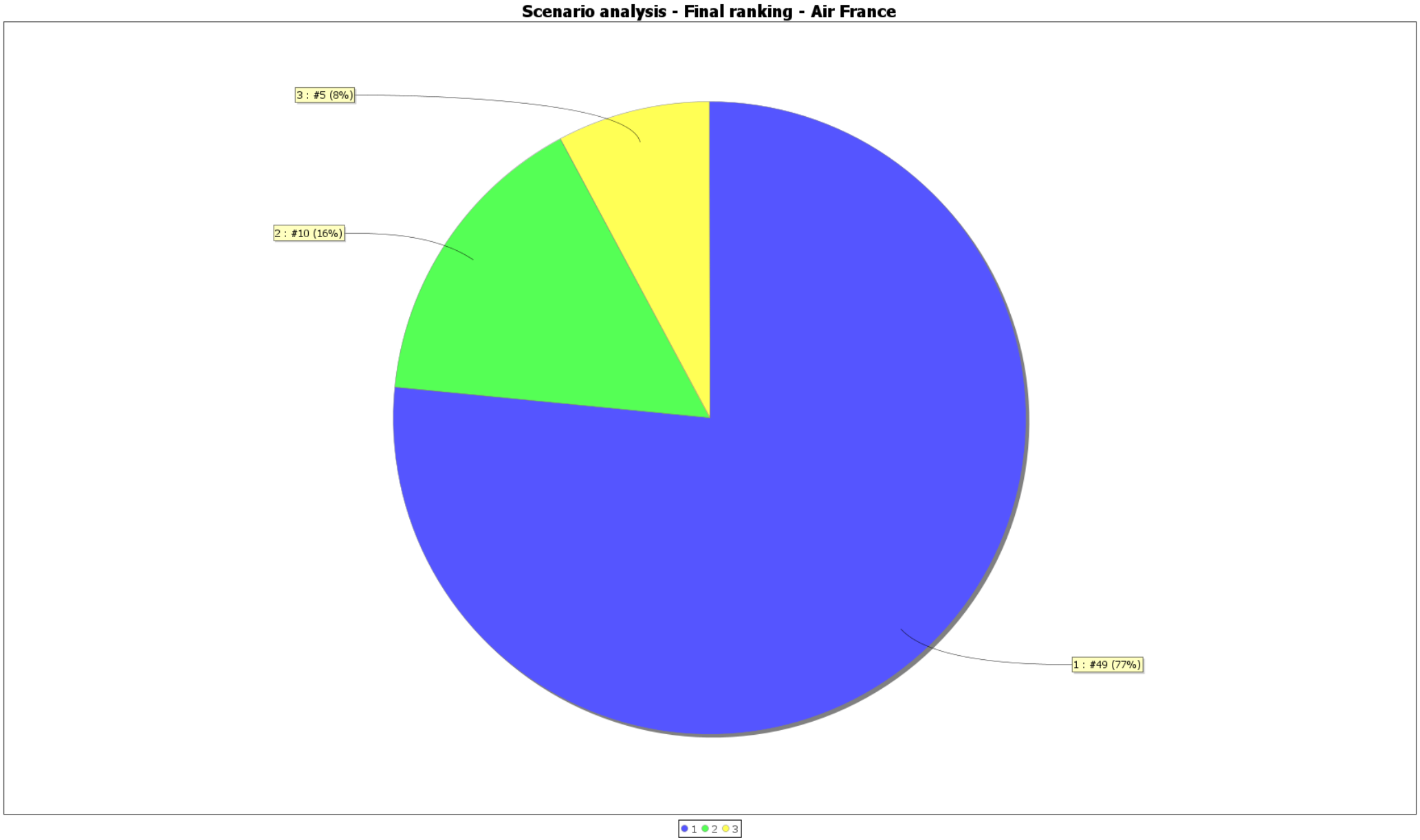
# Scenario analysis - Distribution of ranks of Air France – Pie chart



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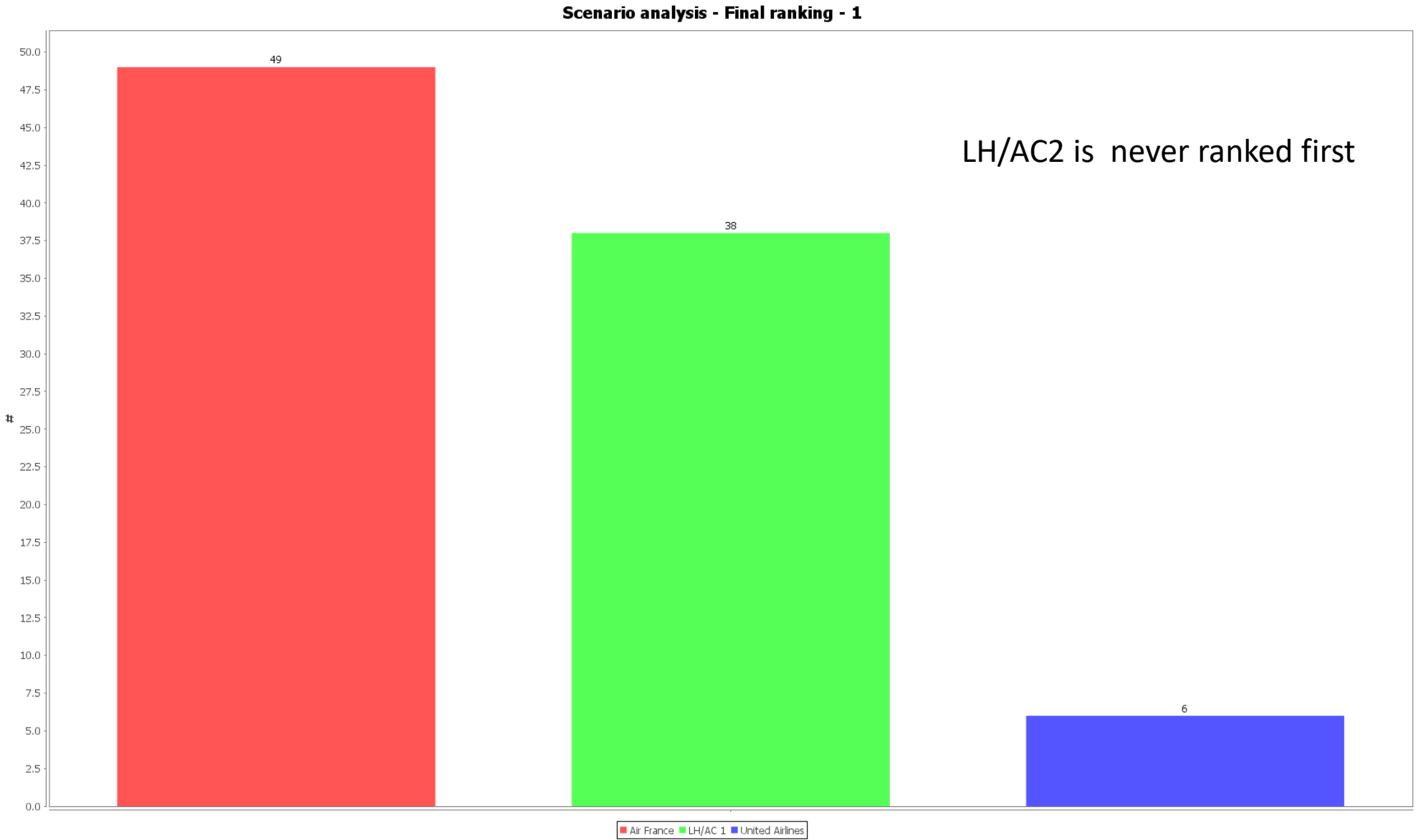
# Scenario analysis - Distribution of first rank – Bar chart




LH/AC2 is never ranked first

MCDA-ULaval
## Many useful features

- Multiple projects can be simultaneously edited through the multi-document interface.
- French and English versions
- The numerical precision of the cardinal criteria can be set by the user
- Ordinal criteria have an arbitrary number of levels, defined by the user
- The interface is of the multi-document type, i.e. it can display many windows at the same time
- Results can be exported to csv files and the figures copied and saved

# Application – Drinking water source protection in Quebec, Canada

Project completed in December 2018

# Application
# **Water source protection actions**

- **All actions intended to protect the quality of groundwater and surface water before disinfection**

- **For example, we can delineate perimeters around wells and streams where different activities are forbidden, or encourage persons living near a stream or a lake to enhance the quality of the riparian buffers**

# Application
# **Regulations**

- **Province of Quebec (Canada): since 2014, it is mandatory for municipalities to identify what are the sources of contamination around drinking water sources**

- **Municipalities have to produce water protection plans starting in 2021**

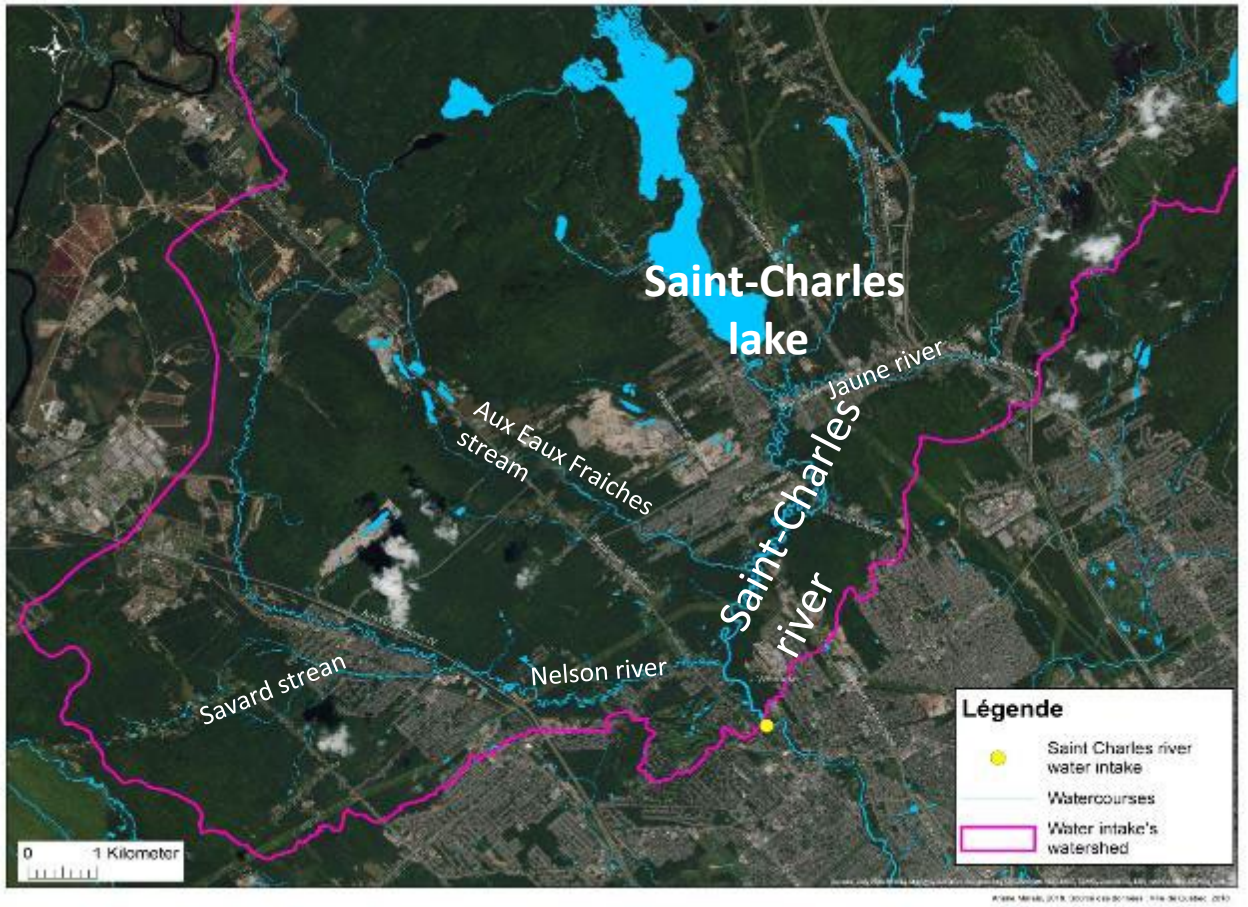
# Application
# **Quebec City, Canada**



**Supplies 300 000 persons**
**Total population: 514 000 persons**

# Application
# **Quebec City, Canada**

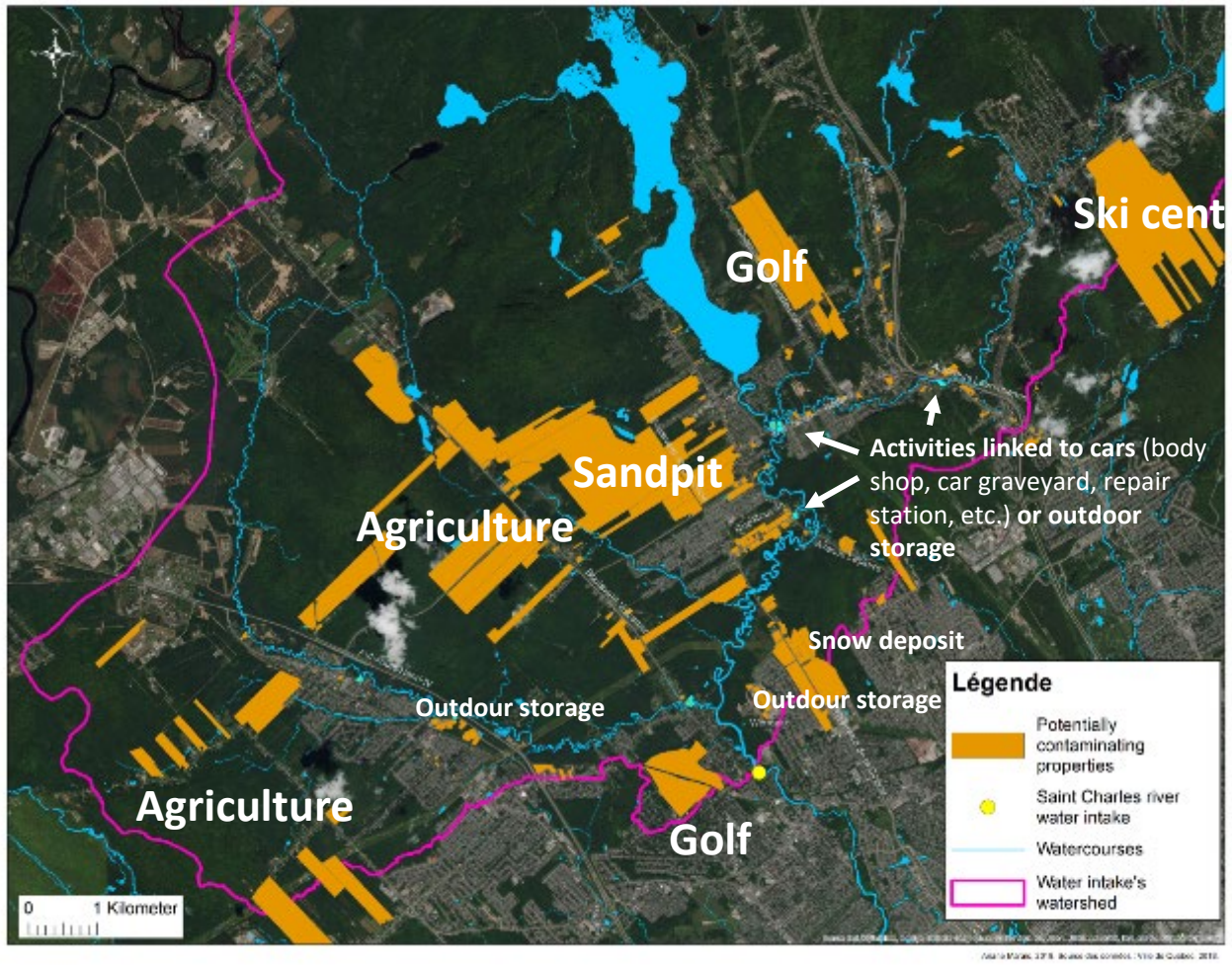
- Quebec City regulation on the protection of water intakes
  - « Upstream of a water supply intake, it is forbidden to store hazardous materials, de-icing salts, dirty snow, residual materials, manure or artifical fertilizers, within a 300 meters buffer around watercourses»
- The City identified 47 potentially contaminating activities located in 207 properties



# Application
# **Quebec City, Canada**

- **Objective of the project:**

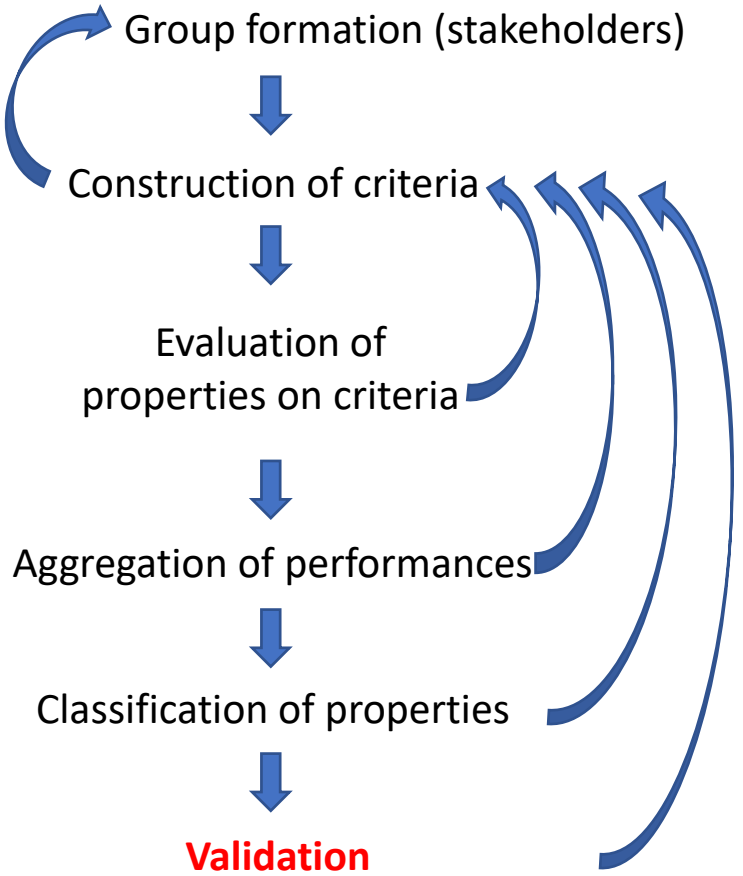
  To **rank** potentially contaminating properties located in the Saint Charles river water supply intake's watershed according to **their level of incompatibility** with the water intake's quality



# Application
## **Facilitated group decision process**

- **STAKEHOLDERS : 9 all along the process + 6 who participated occasionally**

- **MEETINGS : 7 meetings + 7 submeetings over 7 months**



Application

# Ranking of 207 properties and defining 4 categories

## 1 ALTERNATIVES

207 properties

## 2 CRITERIA

- Activity's impact (1 to 4)
- Travel time (1 to 3)
- Proximity (1 to 4)
- Runoff (1 to 5)
- Wetlands (1 to 4)
- Riparian buffers (1 to 5)
- Floodability (1 to 5)

## 3 PERFORMANCE TABLE

## 4 PREFERENCE PARAMETERS

| Criteria | Parameters | |
|---|---|---|
| | Weight *k* | Veto treshhold |
| Impact | 25% | None |
| Time | 20% | None |
| Proximity | 20% | 2 |
| Runoff | 15% | None |
| Wetlands | 9% | None |
| RB | 4% | None |
| Floodability | 7% | None |

ELECTRE III in MCDA-ULaval

| Incompatibilty level | Number of properties |
|---|---|
| Low (ranks 37-49) | 45 |
| Moderate (ranks 25-36) | 61 |
| High (ranks 13 à 24) | 66 |
| Very high (ranks 1 to 12) | 35 |

Application

# Constructing the criterion Activity's impact

1 **ALTERNATIVES**

588 combinations (pollutant x frequency x concentrations)

2 **CRITERIA**

- Ecological Health (1 to 5)
- Human Health (1 to 5)
- Functionality (1 to 3)
- Perception (1 to 3)
- Treatability (1 to 4)

**3 PERFORMANCE TABLE** →

**4 PREFERENCE PARAMETERS and REFERENCE PROFILES**

↓

ELECTRE Tri-nC in MCDA-ULaval

↓

| Activity's impact |
|---|
| Very Low |
| Low |
| Moderate |
| High |
| Very high |

# Application
## Excerpts from a letter by the Director of Planning and Land Use Coordination

- “This analysis was very useful for the City of Quebec as it helped to develop a strategy for activities that are incompatible with the protection of the drinking water intake and to prioritize the actions to be taken. “
- “… it was difficult at the outset of the project to target properties for analysis in the first phase. “
- “Your contribution allowed us to reconcile different objectives that can traditionally be in conflict and to clearly define the relevant criteria for prioritization.”

# Application
## Excerpts from a letter by the Director of Planning and Land Use Coordination

- “As a result, the City of Québec is able to more easily identify properties that present the greatest potential for incompatibility … and can make informed choices about the prioritization of its actions with respect to the supervision of incompatible activities.”

- “Finally, this study will continue to be a reference in the coming years.”

# Conclusion

- **MCDA-ULaval is available for download at no charge, for research and teaching purposes**
  - Has been used in Germany, France, Italy, Portugal, Greece, Switzerland, United Kingdom and Canada
  - It comes with a user guide and a few projects based on examples taken from the literature

- **We use it in various real-life applications**

- **Special Acknowledgments: Oscar Nilo, research professionnal at Université Laval**

# Merci !


Register and download at: mcda.fsa.ulaval.ca