Sophisticated Preferences for Decision Aiding: from Theory to Applications

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Preferences

Why preferences for Decision Aiding (DA)? : key items for DA
(put the Decision Maker in the center of the DA process)

- Preferences are present in different decision aiding domain:
  - Group decision: social choice theory
  - Multicriteria Decision making
  - Decision under uncertainty
- Preferences are present in all the steps of the process: many research areas with them.

From theory to applications

Understand the problem
(and DM's preferences)

Model the problem
(and DM's preferences)

Solve the problem
(and the DM'a preferences)

Outline

Experimental analysis
Preference elicitation

Preference Modeling

Preference Aggregation

Industrial applications (SNCF+Ineris, ...)

Sophisticated preferences

Classical preferences?

- total orders or preorders (preference/indifference)
- too strong, not enough flexible: in many context, decision maker's preferences do not respect their properties
- do not consider incompleteness, uncertainty
- Other structures (partial o., interval o., split o., ...), valued relations, different formalisms (paraconsistent logic), ...

From theory to applications

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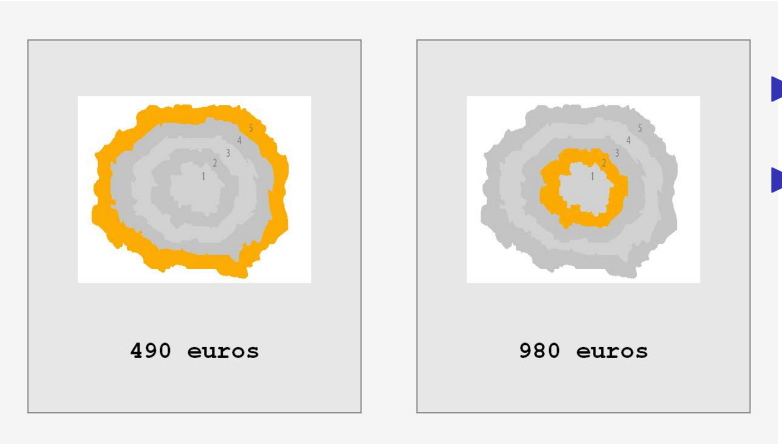
Experimental analyses in Decision Aiding

Idea

- are non classical preference relations really necessary?
- what are the advantages of working with non classical preference relations?
- what happens if I limit myself to a total or a preorder?
- Get some conclusion for preference elicitation and models to use

Experimental analyses in Decision Aiding

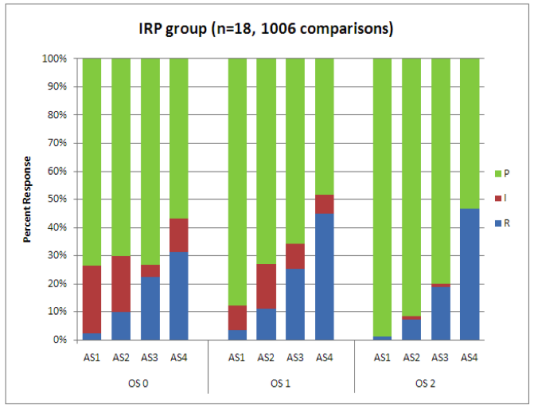


- Experiment 1: pairwise comparison
- Experiment 2: bi-matching

With S. Deparis, V. Mousseau, C. Huron and Ch. Palier In [EJOR12], [EJOR14]

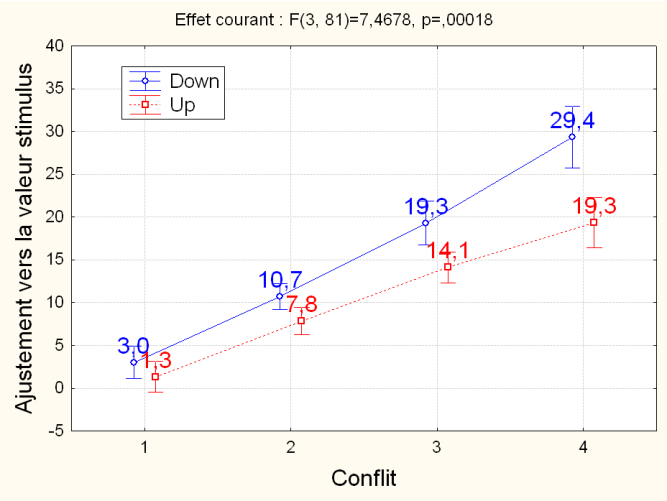
PhD thesis of Stephane Deparis with two experiments (co-advisor: V. Mousseau)

Main results of Experiment 1



- Difference between Incomparability and indifference
- Incomparability increases with multicriteria conflict (%60 for maximum conflict)
- Elicitation methods using big conflict (*Ratio*, *SMART*, *Swing Weights*, ...) should be used with precaution.

Main results of experiment 2



- Elicitation methods with big conflict must be used with precaution!
- Bi-matching may be used in order to test the consistency of decision maker's answers

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Preference elicitation

	1	2	3	4	5	6	7	8	9	10
1	1	1	1	1	1	1	1	1	2	2
2	1	1	1	1	1	1	1	1	2	2
3	1	1	1	1	1	2	2	2	3	3
4	1	1	1	1	1	2	2	2	3	3
5	1	1	1	1	1	2	2	2	3	3
6	1	2	2	2	2	2	2	3	3	3
7	1	2	2	2	3	3	3	3	3	3
8	1	2	2	2	3	3	3	3	3	3
9	1	2	3	3	3	3	3	3	3	3
10	3	3	3	3	3	3	3	3	3	3

- Preference elicitation for an ordinal classification problem
- Incremental (dynamic?) preference elicitation for a group of persons

With T. Denat (PhD student, Ineris, biodiversity indicator, finished), and O. Nefla (PhD student, EmLyon, MOOCS, started in november 2017) In [DA2PL16], [ADT17]

Preference elicitation

Preference elicitation for an ordinal classification problem

- aim: given a set of assignment examples, how to classify new objects in a multiattribut context
- originality: model free + non deterministic procedure (Monte Carlo) + based on monotonicity principle
- some theoretical results (convergence, etc.) and simulation results

Preference elicitation

Incremental (dynamic?) preference elicitation for a group of persons : new subject

- aim: to learn preference parameters of individuals in a dynamic way
- context: MOOCs, ordinal classification
- originality : dynamic aspect, how to improve a personal information using what we learned on other persons, integrate the model in a multiagent system

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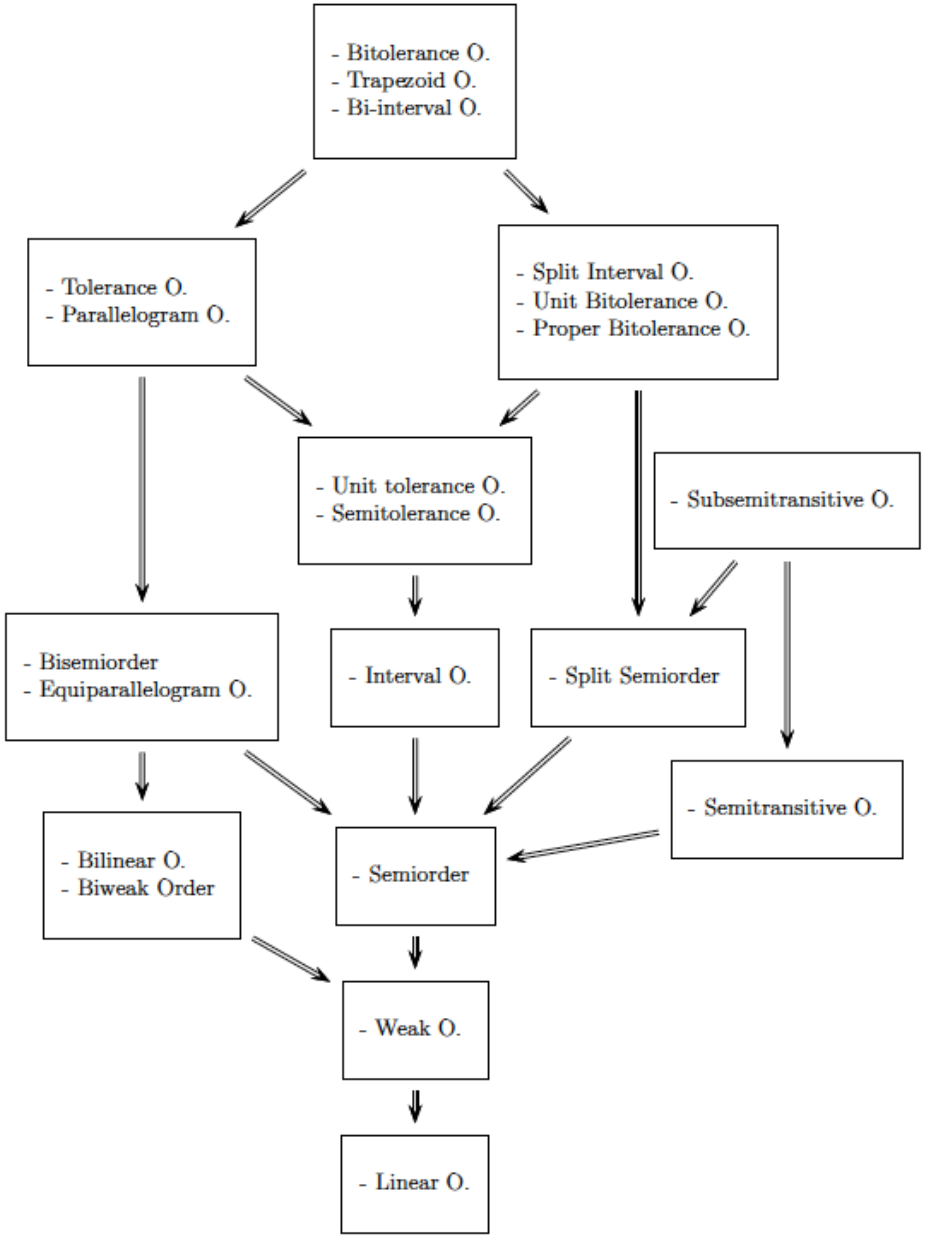
Preference Modeling

- General framework with n-point intervals
- Valued relations for intervals
- Compact representation for interval orders

With S. Moretti, P. Marquis, M. Pirlot, A. Tsoukias and Ph. Vincke In [AOR08], [MSS09], [AIJ11], [FSS14], [JMP17], [chapter14]

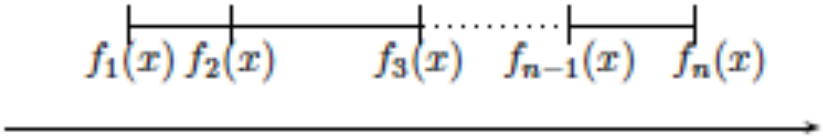
Preference Modeling: general framework



Preference Modeling: general framework

Idea

Proposing a general framework with a numerical representation by n ordered points.



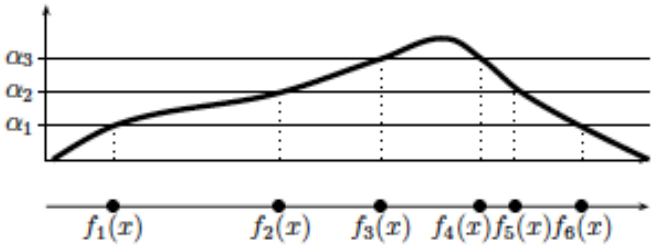
Preference Modeling: general framework

Originality:

- Axiomatization (P and I, only relative positions, very simple and basic properties)
- Systematic analysis of different comparison rules

Main results:

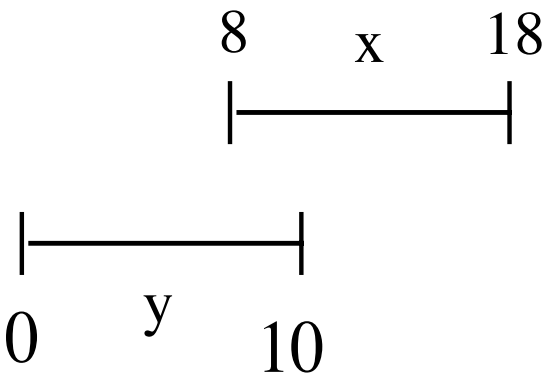
- Common language for a big number of preference structures
- Study of structures with 3 -4 ordered points : old structures but also new ones
- Relation with comparison of fuzzy numbers: our comparisons cover comparisons with possibility/necessity relations



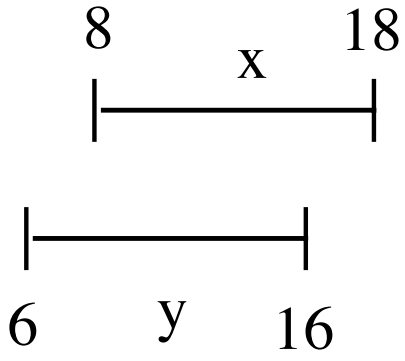
Preference Modeling: valued relations

Idea

Compare real intervals (distance!) with a preference modeling point of view: a valued Ferrers relation.



i(x,y)=0,15



i(x,y)=0,8

Preference Modeling: valued relations

Definition (Outranking relation for intervals)

Let r be a valued binary relation on $A \times A$ then it is an outranking relation for intervals iff $\forall x, y$

$$r(x,y) = \min\left(1, \max\left(\frac{u(x)-u(y)}{u(x)-l(x)}, 0\right) + \max\left(\frac{l(x)-l(y)}{u(y)-l(y)}, 0\right) + \max\left(\frac{x \cap y}{u(x)-l(x)}, 0\right)\right).$$

Our outranking relation r satisfies the definitions 1, 2, 3, 4, 6, 7, 8, 9 and 10 of the following Figure.

Preference Modeling: valued relations

Different ways to define valued Ferrers relation (*t-norms*)

1) $T_{min}(r(x,y), r(z,t)) \leq S_{max}(r(x,t), r(z,y))$

2) $T_{min}(p(x,y), p(z,t)) \leq S_{max}(p(x,t), p(z,y))$

3) $\forall\lambda\ R_\lambda$ Ferrers

4) $\forall\lambda\ (P_\lambda, I_\lambda)$ Ferrers

5) $p \circ_{T_{min}} i \circ_{T_{min}} p \subseteq p$

6) $T_L(r(x,y), r(z,t)) \leq S_L(r(x,t), r(z,y))$

7) $T_L(p(x,y), p(z,t)) \leq S_L(p(x,t), p(z,y))$

8) $r \circ_{T_L} r^d \circ_{T_L} r \subseteq r$

9) $p \circ_{T_L} p^d \circ_{T_L} p \subseteq p$

10) $p \circ_{T_L} i \circ_{T_L} p \subseteq p$

Preference Modeling: compact representation

Idea

Represent in a "compact" way an interval order : propositional logic

- propositional logic because it is simple, expressive, has nice space efficiency

Preference Modeling: compact representation

- Each object is a truth value
- Each object satisfies some formula of the weighted base
- The aggregation of the intervals of these formula give the interval of the object

Example

alternative	2^{PS}	$I_B^{\cap}$
a	000	$[30, 60]$
b	001	$[30, 80]$
c	010	$[30, 60]$
d	011	$[30, 80]$
e	100	$[20, 40]$
f	101	$[20, 40]$
g	110	$[20, 60]$
h	111	$[50, 100]$

Let $PS = \{x, y, z\}$ ordered in this way. Let S be the scale $[0, 100]$.
$B = \{(\neg x, \geq, 30, \leq, 80), (\neg z, \geq, 20, \leq, 60), (x \wedge \neg y, \geq, 20, \leq, 40),$
$(x \wedge y \wedge z, \geq, 50, \leq, 100)\}$ is a weighted base.

Preference Modeling: compact representation

Main results

- Simple and modular representation
- Our representation is more compact than both the explicit representation and the interval representation
- Expressiveness: total orders, preorders, semiorders and interval orders
- Complexity: several key decision problems (comparison, feasibility, ...) remain tractable while some others (equivalence, non dominance, ...) become NP-hard: the price to pay for the gain in spatial efficiency offered by our representation languages).

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Preference aggregation

- Formalism: paraconsistent logic
- Aggregation with propositional optimisation
- Single-peaked preferences
- Social ranking (ordinal power relation)

With B. Escoffier, J. Lang, D. Le Berre, P. Marquis, S. Moretti, A. Tsoukias and E. Turunen In [DSS07], [ECAI08], [IJIS08], [ADT09], [FSS10], [ADT17]

Preference aggregation: paraconsistent logic

Idea

Represent bipolar reasoning in Decision Aiding

Bipolarity: ideal/anti-ideal solutions, examples/counterexamples, concordance/discordance, ...

$\Longrightarrow$ Separation of negative and positive reasons (R^- and R^+) in the sense that they are treated separately in an independent way.

$\Longrightarrow$ Paraconsistent logics like Belnap four values (T, F, U, K)

Main results

- A fuzzyfication of Belnap values by using different t-norms
- How to use them in preference aggregation

Preference aggregation: with propositional optimisation

Idea

Aggregate interval orders based on Kemeny distance

Aggregation with Kemeny distance: to find an interval order which minimizes the total Kemeny distance (number of disagreements in pairwise comparisons) to the profile.

problem: It is NP-hard.

Formulation/tool: to translate it into a propositional optimization problem (Binate Covering Problem), then to solve the latter using a MAX-SAT solver.

Preference aggregation: with propositional optimisation

- Analyze the properties of the aggregation
- Create a simple software: `http://sat4j.ow2.org/`
- Test our method for ranking solvers participating at SAT RACE 2006.

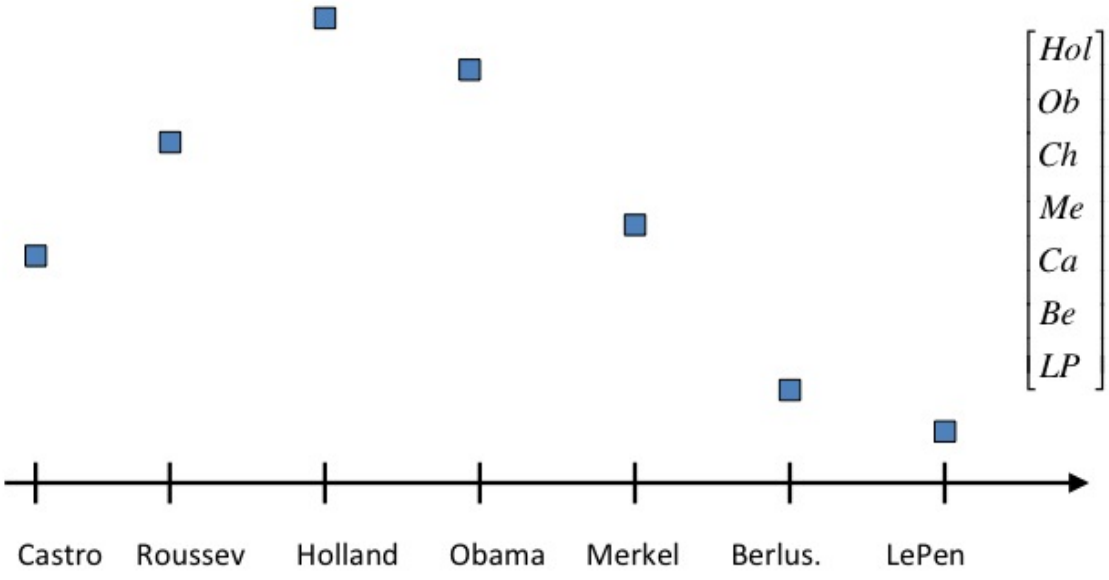
Preference aggregation: single-peaked preferences

Idea

Study some restrictions on the domain of decision makers' preferences: single peaked preferences

Preference aggregation: single-peaked preferences

Who must be the president of the world?



Main results

- Propose an algorithm, in $O(m, n)$, checking if a given profile is single-peaked and if so, determining one of the possible axes

Preference aggregation : social ranking

- aim: how to rank individuals given a ranking over groups formed by them?

$$\{1,2,3\} \succcurlyeq \{3\} \succcurlyeq \{1,3\} \succcurlyeq \{2,3\} \succcurlyeq \{2\} \succcurlyeq \{1,2\} \succcurlyeq \{1\} \succcurlyeq \emptyset$$

- originality : new subject, property driven approach (axiomatization), many virgin study subjects...

PhD thesis of Hossein Khani started in 2017 (co-advisor: S. Moretti)

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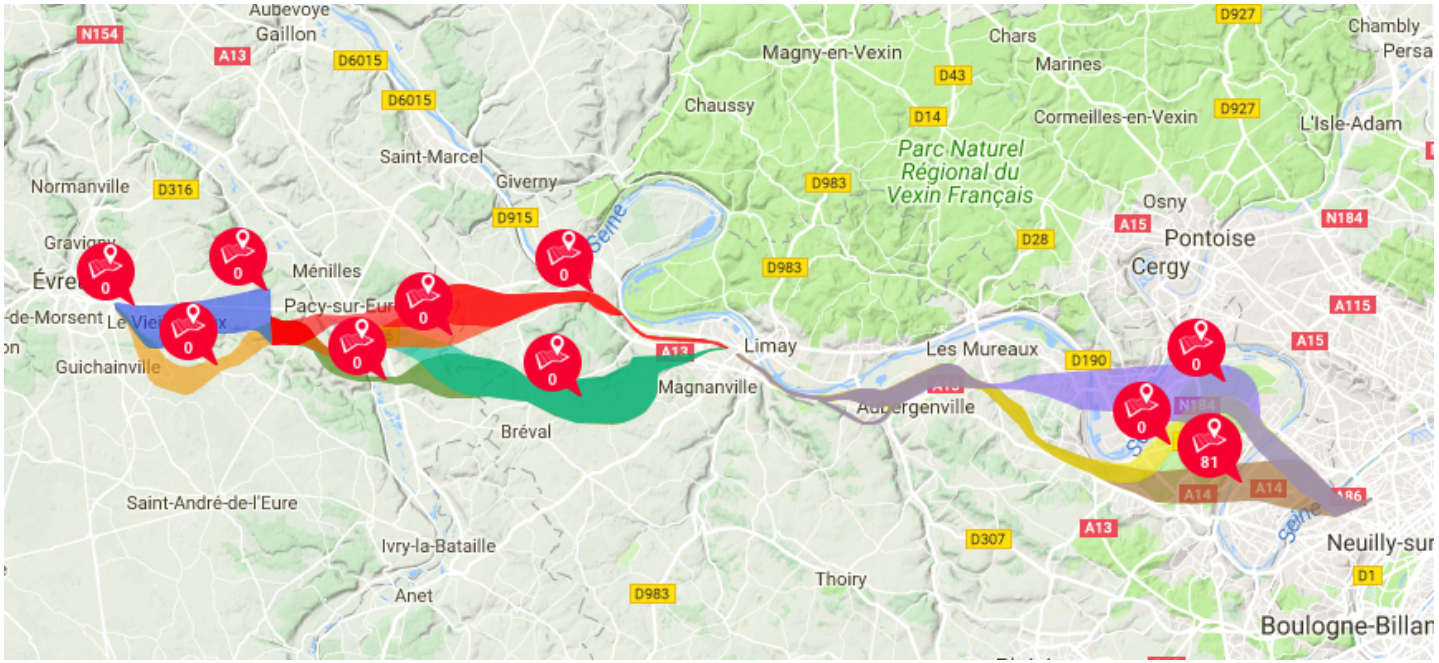
Industrial Applications



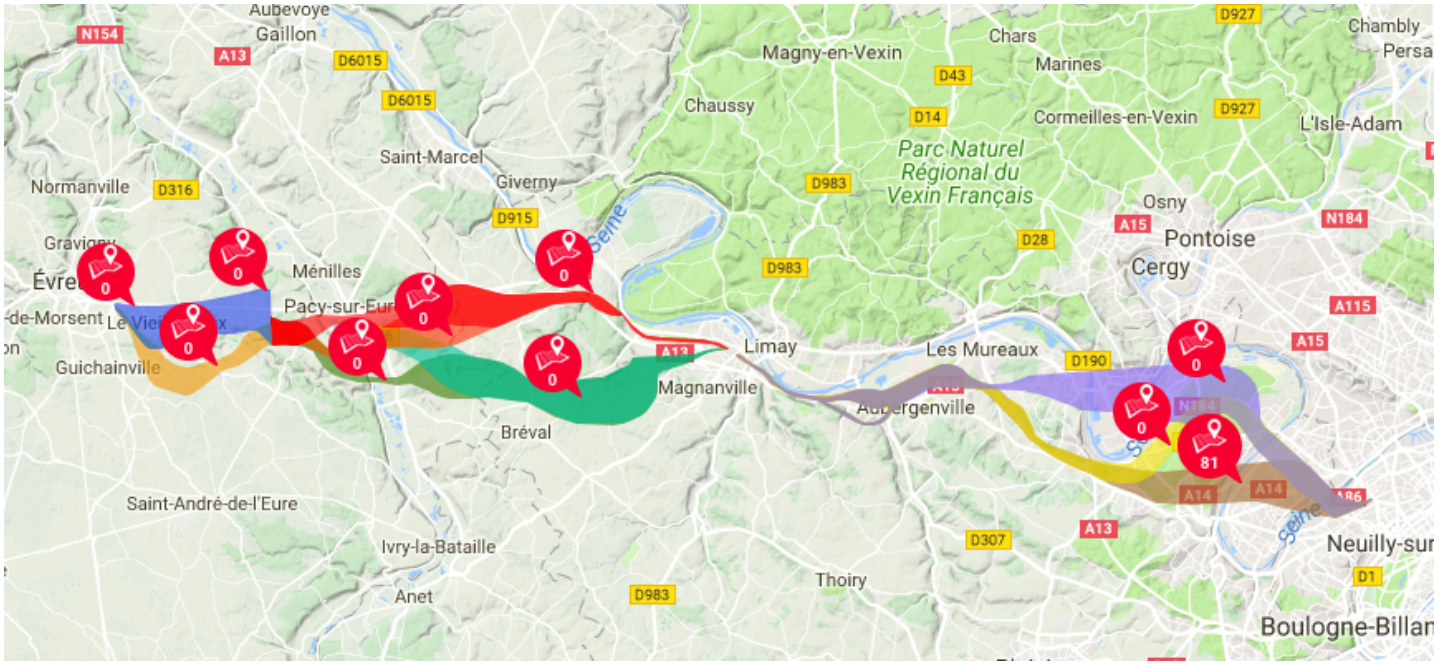
- Industrial applications
- Projet LNPN with SNCF : *Ligne nouvelle Paris-Normandie*

With D. Bouyssou, O. Cailloux, C. Galais, S. Guerrand, L. Mammeri, B. Mayag, V. Mousseau, S. Segretain, C. Talotte In [Ineris11], [DA2PL12], [chapter14]

Industrial Applications

- Determination of the train line Paris-Normandie *Ligne nouvelle Paris-Normandie*, SNCF
- Biodiversity severity index to evaluate the risks of accidental pollutions in the industry : PhD thesis of Tom Denat, INERIS, co-advisor: Denis Bouyssou.
- Evaluation of comfort on the train : PhD thesis of Lounes Mammeri, SNCF, co-advisor: Denis Bouyssou.
- Hierarchy of toxic substances : project with Vincent Mousseau and Olivier Cailloux (research contract with Ineris)
- Evaluation of purification technics for liquid waste : master 2 thesis of Audrey Pfister, Ineris, co-advisor: Denis Bouyssou.

Industrial Applications: LNPN



Idea

Use a MCDA approach in order to evaluate different possibilities for Paris-Normandie train line?

Industrial Applications: LNP

A complex problem : multi experts (multi decision makers??), multicriteria, uncertainty, politic pression, ...

Aggregation methods :

- Different aggregation methods in each nodes: logical rules, Electre methods, Choquet integrals, ranking+classifying
- Procedure to choose the method (type of data, dependence between criteria, compensation, veto, number of criteria, expected result type)
- Indirected elicitation procedure: experts answering some questions...

Industrial Applications: LNP

Where are we now?

- three possible "*zone de passage (3km)*" are identified
- we are looking for political decisions...

Industrial Applications: LNPN