60615A : Decision Analysis
Session 1 - Introduction to Decision Analysis

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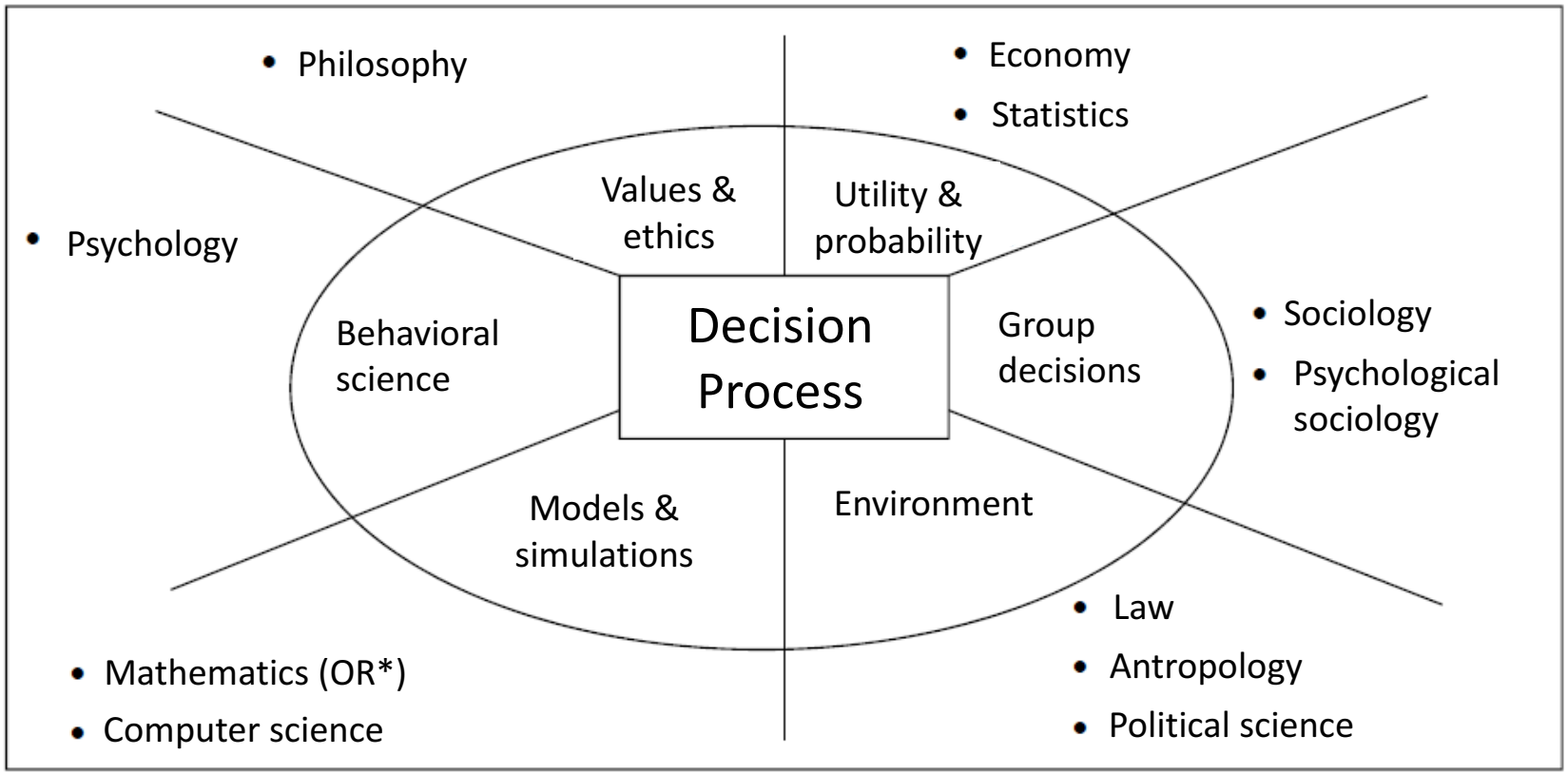
Dupont & the Ozone Layer

- During the 70s, DuPont Chemical Corporation was a firm specialized in the production of chemical products like chlorofluorocarbons (CFC).
- In June 1974, two Californians chemists announced that the emissions of CFC in the atmosphere could reduce the ozone layer by 10% in the next 50 to 80 years.
- A reduction as substantial would harm ecosystems and agricultural productions, cause dramatic climate changes, a rise in cancer rates, etc.
- In 1978, despite the interdiction of CFC in spray cans in the United States, it was permitted as a refrigerant.
- Dupont was responsible for 50% of CFC sales (450 million $)
- Should the management team of Dupont have stopped the production of CFC ?

Sources of difficulty in decision making

- Complexity of the problem : Many fields of interests can be involved (finance, environment, engineering, healthcare, public relations, ...). Consulting and assimilating experts opinions in each field.
- Uncertainty concerning key elements : the information can be incomplete, ambiguous, or even erroneous.
- Multiple and varied objectives : The evaluation of a decision can imply criteria of different natures, conflicting and sometimes even unmeasurable.
- Multiple perspectives : Need to satisfy evaluators which values differ (employees, clients, shareholders, community, etc.)
- Sensitivity of the problem : The choice of a decision is potentially greatly influenced by certain details of the problem (is the tumor malign or benign ?)

Solar system of decision sciences



OR* : Operations research

(courtesy of I. Abi-Zeid)

Different approaches

- Descriptive approach :
  - The objective is to understand how decisions are made.
  - The models must represent reality with precision.
  - Reality serves to correct and improve a descriptive model.
- Normative approach (prescriptive) :
  - The objective is to characterize how to make decisions.
  - The models must clearly describe their starting hypothesis and be justified by a logical reasoning.
  - A normative model identifies reality's incoherences and questions the reasoning that is followed.

What is decision analysis ?

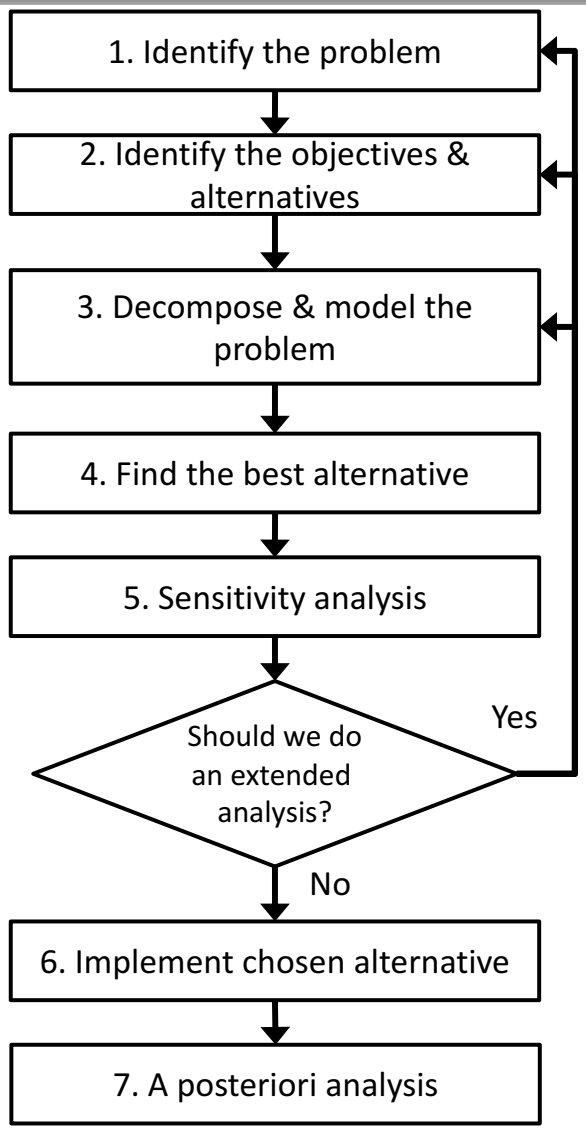
It is a normative approach destined to those who wish to engage in a serious and systematic decision-making thought process.
Decision analysis facilitates :

- A priori,
  - The organization of a decision's elements.
  - The identification of key factors.
  - The representation and management of uncertainty.
  - The management of multiple objectives.
  - The exchange process between stakeholders.
  - The coherence from a decision to another.
- A posteriori,
  - The reduction of bad surprises.
  - A better performance on average.

Analyst's responsibilities

1. Clearly define the frame of the problem.
   - Example : Should I take this course ?
   - context of the curriculum, context of your career, context of your prosperity.
2. Characterize the value system to follow.
3. Make a list of creative and implementable (i.e., deployable) alternatives.
4. Collect pertinent and reliable information.
5. Use realistic models.
6. Apply logical reasoning.
7. Ensure that the recommendation is implemented.

Decision analysis process



Steps 1 to 5 can be followed many times before reaching a satisfactory recommendation :

- The recommendation questions the representation of preferences.
- The recommendation inspires new alternatives.
- Sensitivity analysis encourages to account for new sources of uncertainty.

This course focuses on the problem decomposition and modeling.

Good decision vs. good result

It is important to differentiate the two concepts

- Good decision : Logical decision based on the decision maker's knowledge and value system.
  - A posteriori, we must be able to say that the same decision would be taken facing what was known at the moment this decision was made.
- Good result : Result that is profitable for the decision maker.
  - A posteriori, we are pleased with the outcome of our decision.

	Good Result	Bad Result
Good Decision	Success	Good will
Bad Decision	Luck	Negligence

Outline

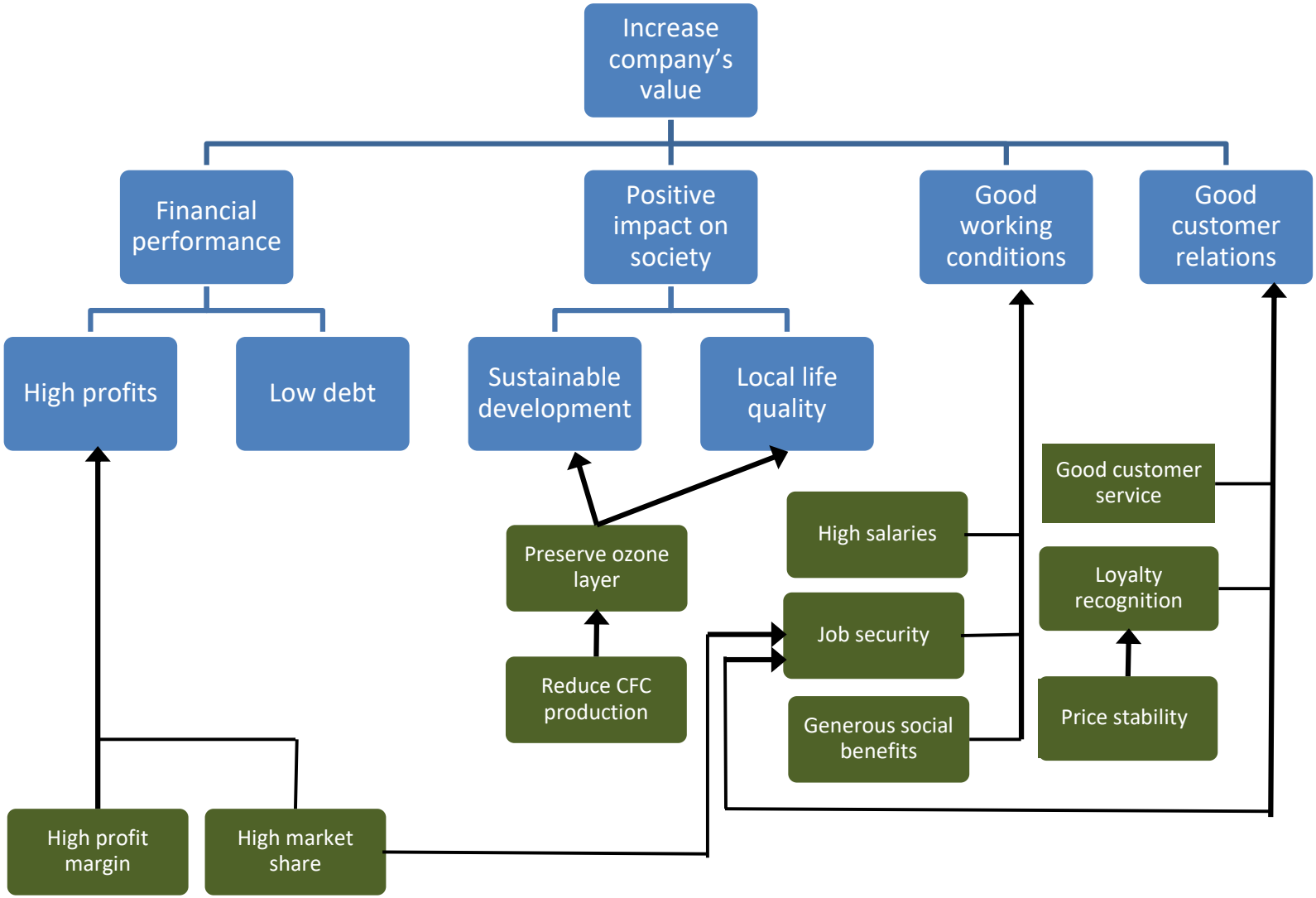
Value system and objectives - $g_1, g_2, g_3, \ldots$

- Objective : what we want to achieve
  - Make money
  - Save lives
  - Grow our client base
  - Improve working conditions
- A value system is composed of a series of objectives.
- It is important to identify correctly all fundamental objectives.
- The objectives must be aligned with the decision's context.

Prioritization of objectives

- Fundamental objectives :
  - They form an essential objectives hierarchy.
  - At the top lies the most general objectives.
  - Under it, we list possible interpretations of the more general objectives.
- Means :
  - They form a network of objectives contributing to the achievement of fundamental objectives.
  - A mean can be used to measure another mean or a fundamental objective.

Example : Dupont & the Ozone Layer



Exploration and discovery of objectives (AI)

- Fundamentals $\downarrow$: What does this objective mean ?
- Fundamentals $\uparrow$: Of which more general objective is it an aspect ?
- Fundamentals $\rightarrow$ Means : How can we achieve this objective ?
- Fundamentals $\leftarrow$ Means : Why is this objective important ?
- Additional tip : Could two alternatives still be compared without knowing the level of performance of this objective (all others being known) ?
  - Yes = Mean
  - No = Fundamental or mean of an undiscovered fundamental objective

Decisions - x

- What are the different actions that could be applied ?
  - Ensure that we have the power to apply these actions.
- Do they limit themselves to immediate actions or should I plan other actions in the long term ?
  - Future actions can depend on past actions and events that will take place before then.
  - Only include future actions that can affect my assessment of immediate actions.
- Be creative in the quest for actions.
  - Do nothing
  - Wait to have more informations before deciding.
  - Buy insurance to be protected against bad outcomes.
  - Sub-contracting the responsibility to a third party.

Uncertainty - z

- Decisions are often taken in a context where some elements of the problem are unknown.
  - Will the temperature be nice this week-end ?
  - Will this course be hard ?
- If it is impossible to acquire more informations, this uncertainty has to be taken into account.
- The uncertain elements (parameters) can :
  - Take a limited number of values (discrete).
  - Take an infinite number of values over a region (continuous).
  - Be interdependent.
- The knowledge of these elements can evolve in time.
  - Some elements that were unknown at the time of the initial decision can be revealed before the next decision.

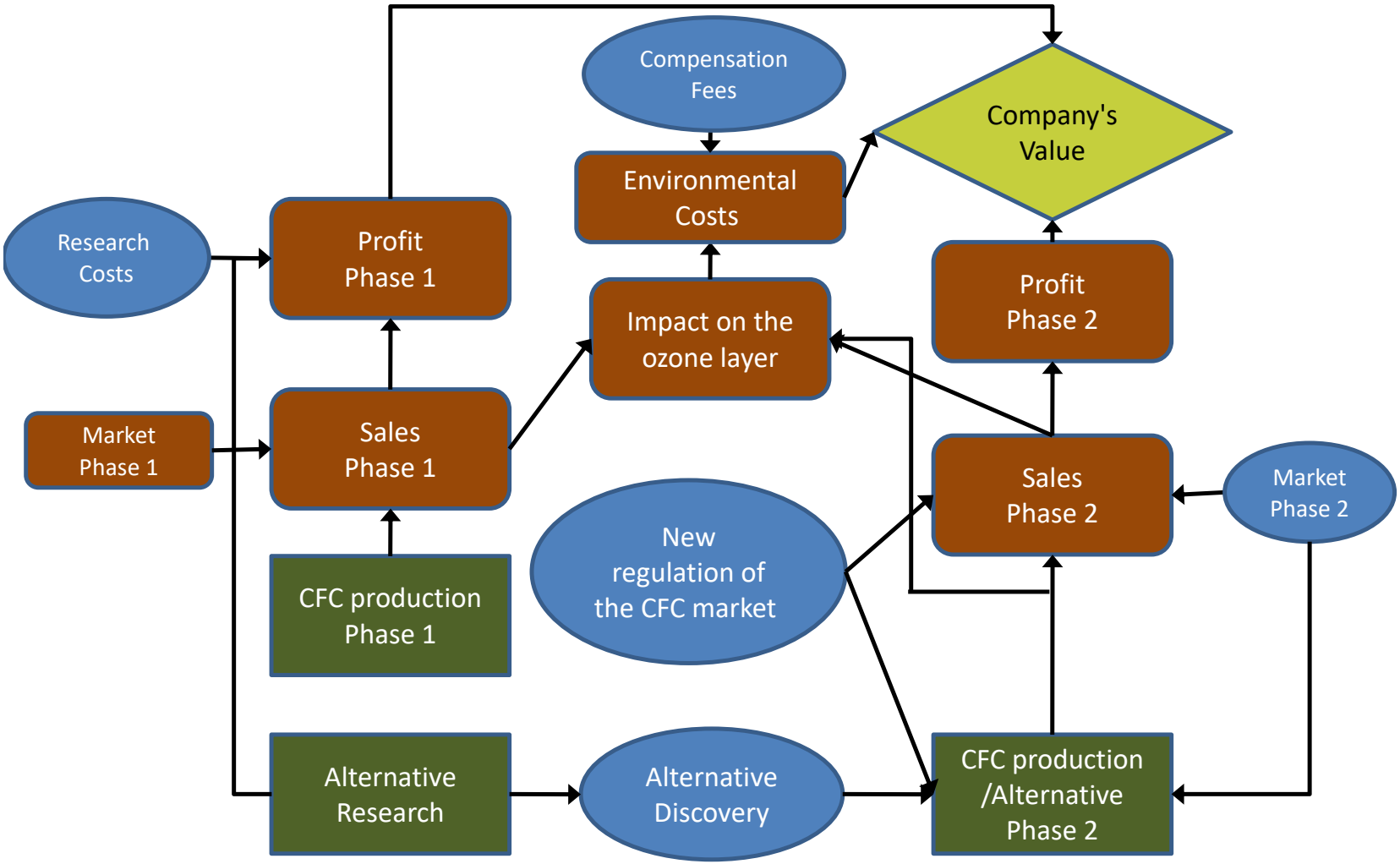
Consequences - $g_i(x; z)$, $i = 1, 2, ...$

- A consequence is only interesting based on what it implies for our objectives.
- Consequences are evaluated once all uncertainties are revealed.
- The horizon of planning must be :
  - Sufficiently restricted for the sake of clarity.
  - Sufficiently extended to include the consequences that could affect our immediate decision.
  - Examples :
    - The value of a company - fiscal year
    - The environment - Many generations

Influence Diagram

- An influence diagram is used to represent the relation between decisions, the uncertain elements, and the consequences.
  - A rectangle = a decision element.
  - A circle = an element of uncertainty.
  - A rectangle with rounded corners = a constant or the calculation of an intermediate consequence.
  - A diamond = the final consequence.
  - An arrow indicates a relation of influence.

Example : Dupont & the Ozone Layer

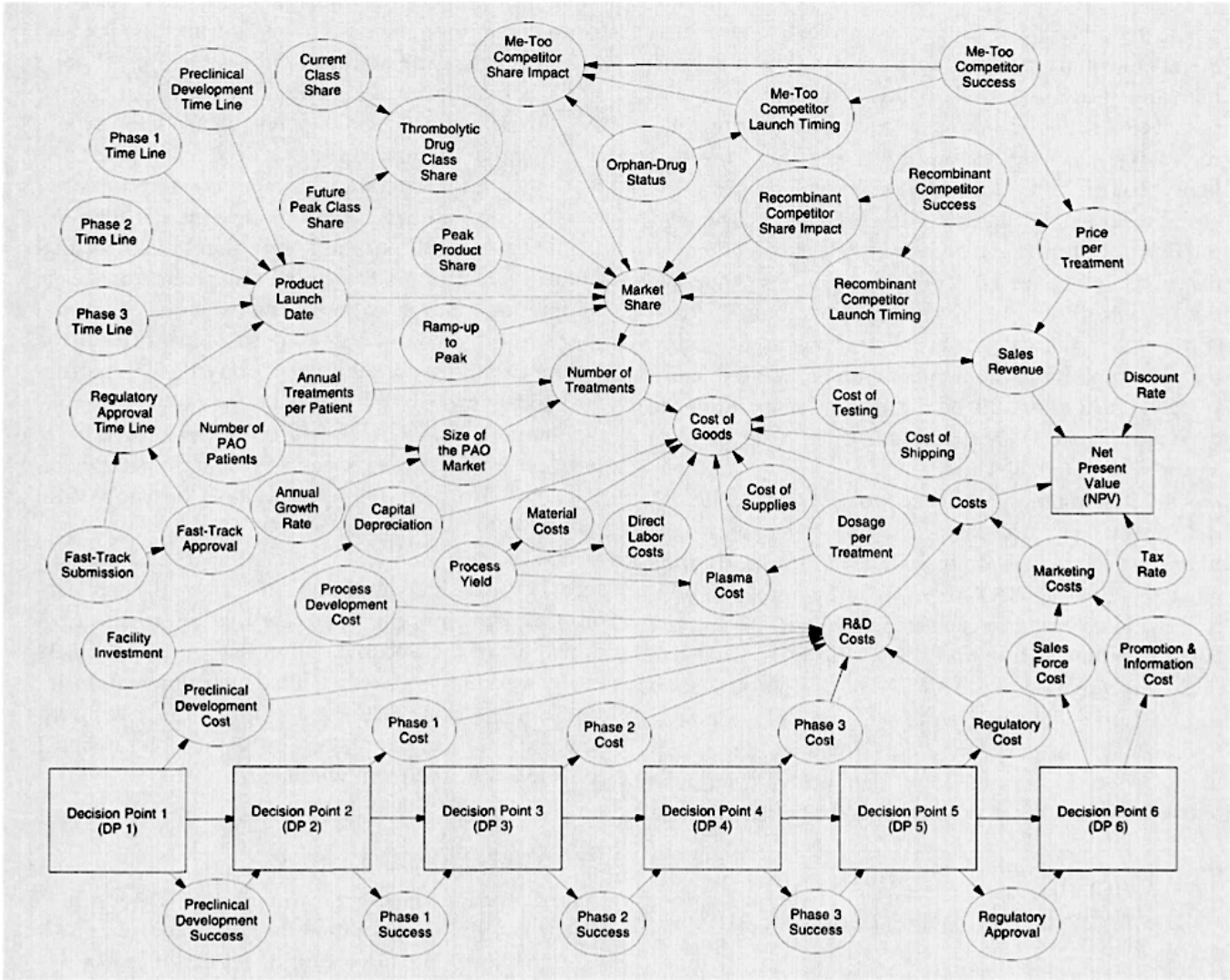


Influence Diagram II

- A diagram must be completed by describing the function of each node.
  - Decision node : what are the different options.
  - Element of uncertainty node : What are the possibilities, the probability of each and how this probability is influenced by influent variables.
  - Consequence node : How to compute the consequence based on influent variables.

- Clarity test (Howard 1988)
  - Imagine a clairvoyant person capable of answering each question regarding future events.
  - Would this person be able to evaluate every consequence described for each possible future realization, without applying any personal judgment ?

Example : Influence Diagram at Bayer



[Stonebraker, J.S. (2002) : How Bayer makes decisions to develop new drugs]

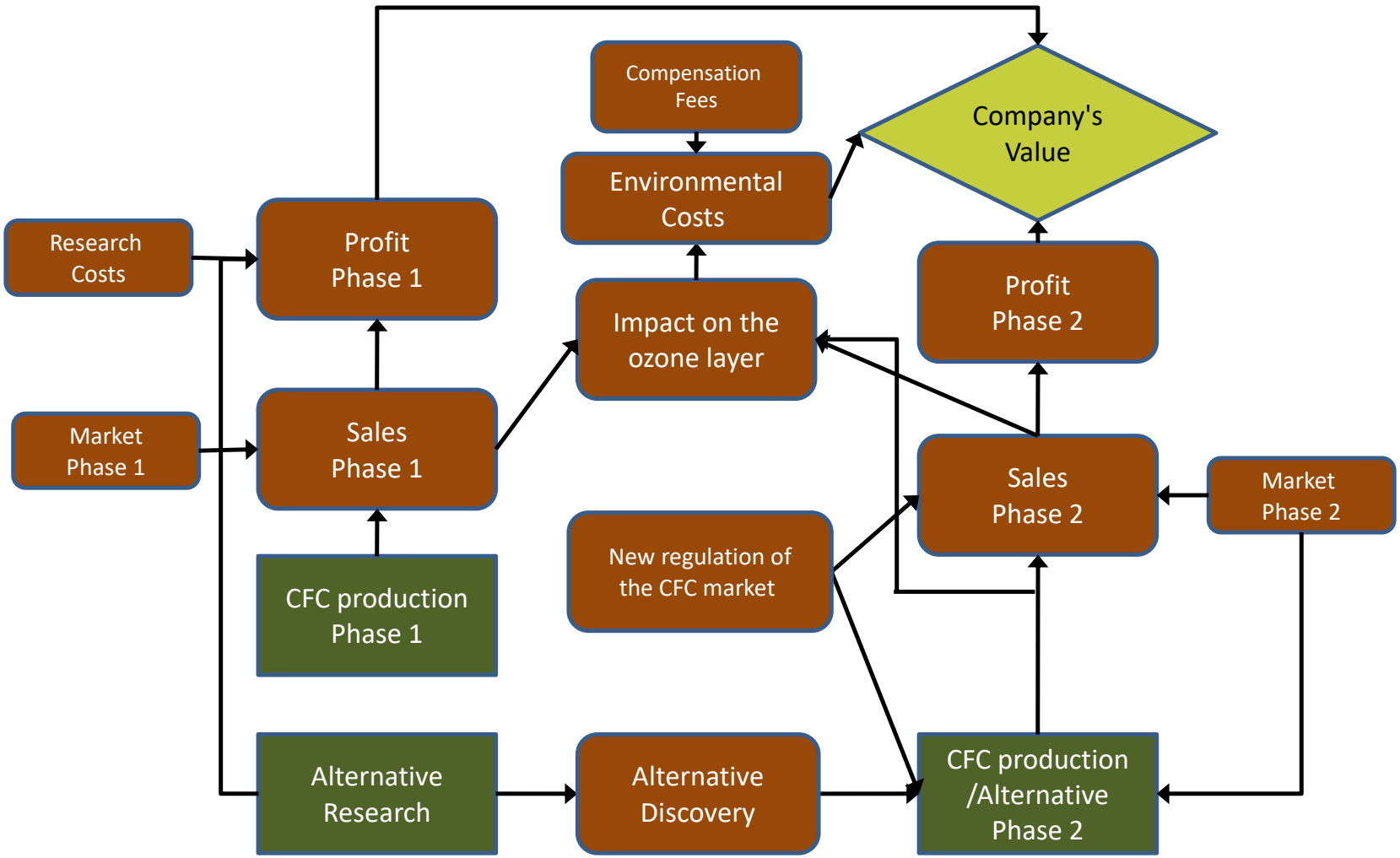
Are we done ?

- Once the diagram has been completed, it is normally possible to determine mathematically the best decision given this context.
- Regardless of the tool used, the suggested decision will always intimately depend :
  - On the list of chosen alternatives.
  - On the values chosen for each parameter (probabilities, revenues, magnitude of each consequence)
  - On the choice of compromise (i.e., tradeoff) between conflicting or competing fundamental objectives.
- This is why it is important to study the sensitivity of our decision and the forecasted performance regarding these choices.

Outline

Example : Dupont & the Ozone Layer (Excel file)

Let's study the deterministic model :



Example : Dupont & the Ozone Layer

Unfortunately, those estimates aren't exact.

Parameter	Estimated value	Confidence interval
Environment costs (in $ by g)	0,75	$[0, 1,5]$
Market in Phase 1 (in tons)	10	$[7, 11]$
Research costs (in M$)	16	$[14, 20]$
Success of research	Yes	$\{$Yes, No$\}$
Market in Phase 2 (in tons)	28	$[20, 30]$
CFC market shares	60%	$[0\%, 100\%]$

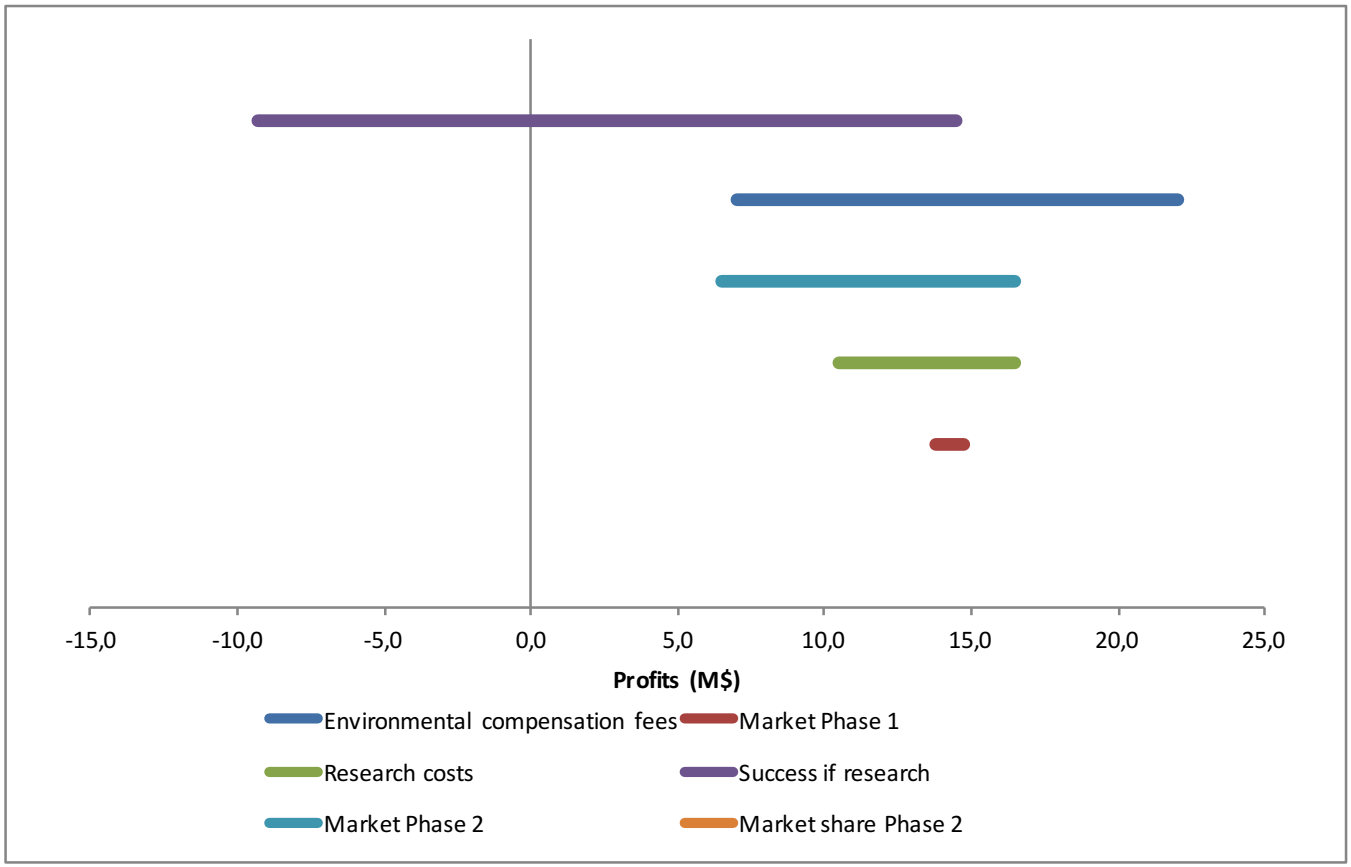
Type of Sensitivity analysis

- Objective sensitivity :
  - What is the impact of a change of parameter on the performance achieved by our decision ?
- Decision sensitivity :
  - What is the impact of a change of parameter on our choice decision ?
- Unidirectional analysis :
  - Study of the impact of a change of a single parameter when all other parameters are fixed to their estimated value.
- Bidirectional analysis :
  - Study of the impact of a simultaneous change of impact of two parameters when the other parameters are fixed to their estimated value.

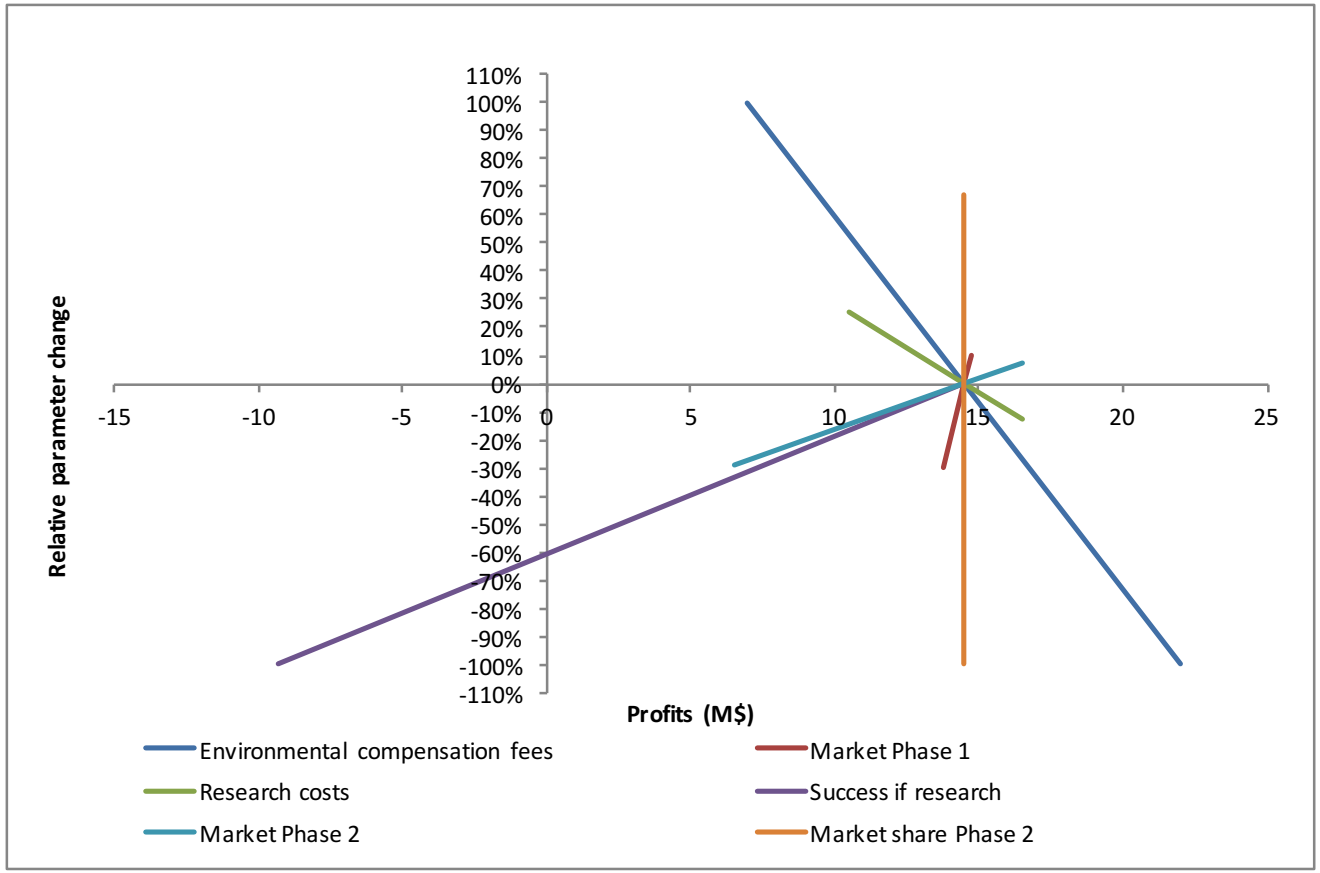
Tornado Diagram

- It presents in a compact way the objective sensitivity to unidirectional changes.
- Method (execute in Excel file) :
  1. Describe a confidence interval for each parameter.
  2. For each parameter, find the maximal and minimal objective value when this parameter varies on the interval (while maintaining the others fixed)
  3. Rank the parameters according to the magnitude of the difference between the objective max and min.
  4. (Optional) Find the values of the parameters and the objective for which the decision would change (decision sensitivity).

Dupont & the Ozone - Tornado Diagram



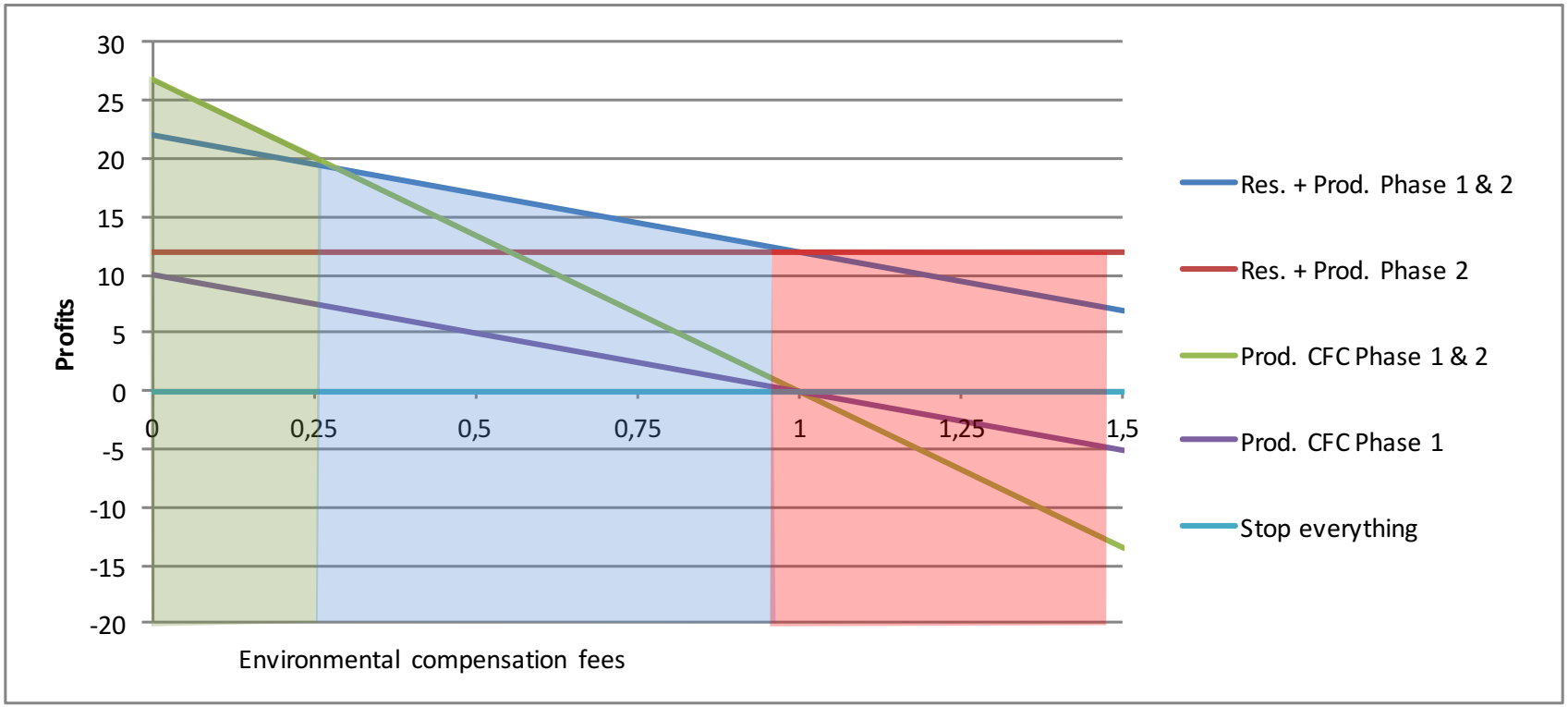
Dupont & the Ozone - Spider Diagram



Optimality Preserving Interval

- Present unidirectional analysis of the decision sensitivity
  - i.e. : Presents the range of values a parameter can take without affecting the optimality of a decision.
- Method :
  1. Describe a confidence interval for each parameter.
  2. Choose a parameter.
  3. Fix the other parameters to their estimated value.
  4. Sample the parameter's interval (ex. : uniformly).
  5. Evaluate the optimal decision and the objective value for each sample.
  6. Present the observations on a figure.

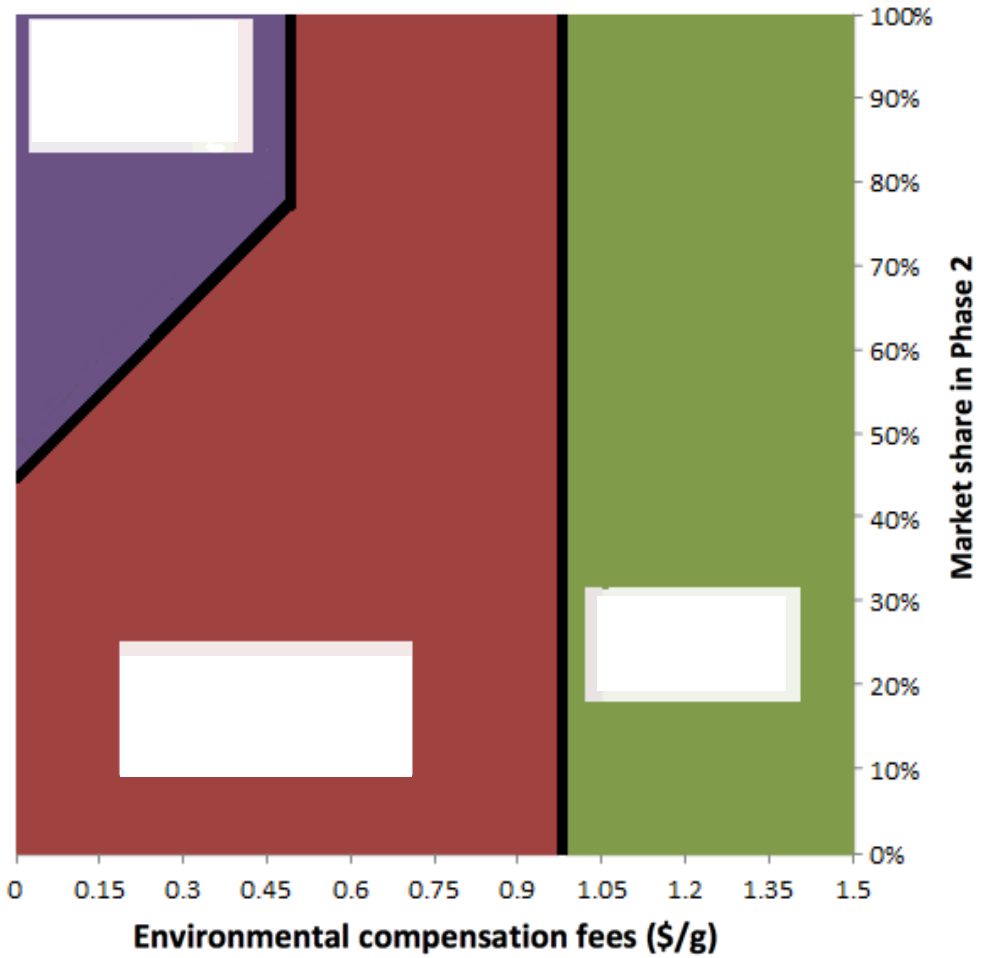
Decision sensitivity



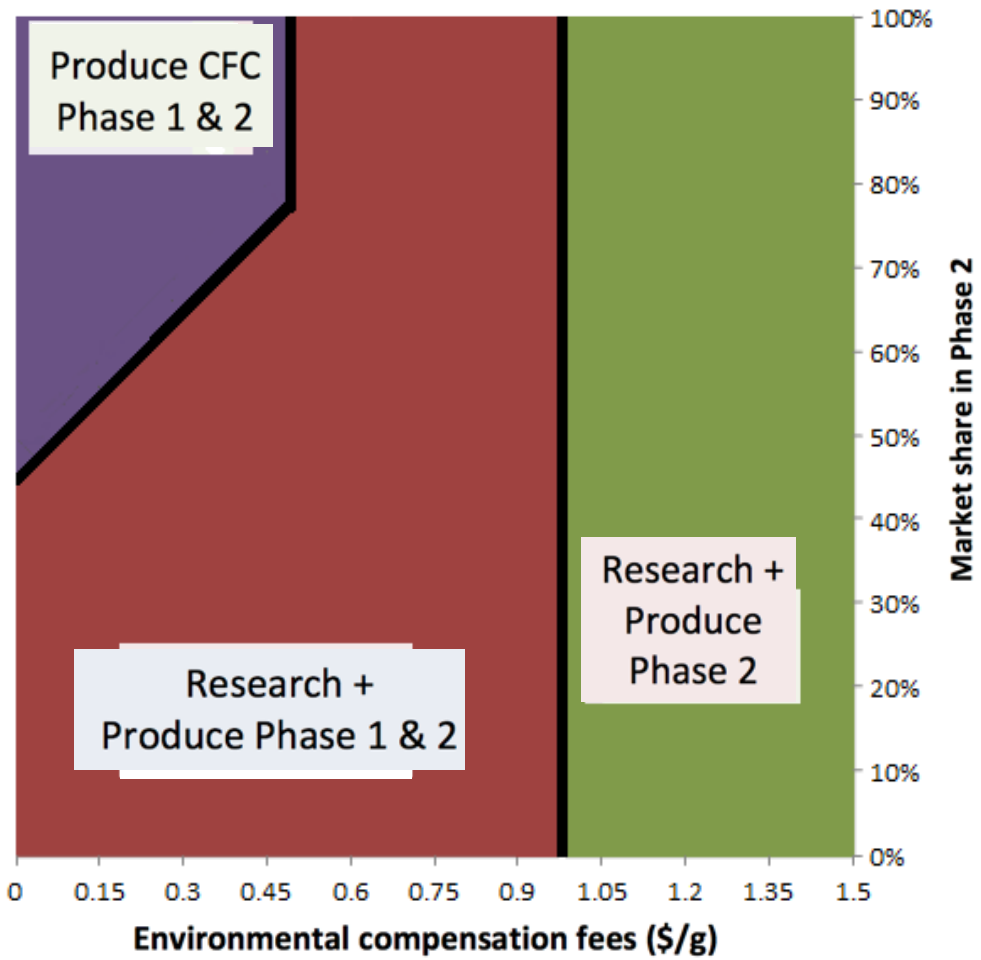
Optimality Preserving Region

- Presents the bidirectional analysis of the decision sensitivity (harder to obtain).
  - i.e. : Presents the region of values two parameters can take without affecting the optimal character of a decision.
- Method :
  1. Describe a confidence interval for each parameter.
  2. Choose two parameters
  3. Fix the other parameters to their estimated value.
  4. Sample the joint region of the possible values of the two parameters (ex. : grid).
  5. Evaluate the optimal decision for each sample.
  6. Present on a figure the set of samples where the original decision remains optimal.

Decision Sensitivity - Bidirectional



Decision Sensitivity - Bidirectional



Dupont & the Ozone - Analysis Conclusion

- Immediate decision (Phase I) based on the estimated values :
  - Continue to produce CFC.
  - Invest in alternative research.
- The company's value is greatly affected by the compensation fees (i.e. compromise between environment and profits)
  - The optimality of our decision won't be affected by the value of these fees if they remain between 0,25 \$/g & 1\$/g.
- Two other parameters have a significant impact on profit :
  - The success of the research in the case where it is subsidized.
  - The size of the market in Phase II.
- The optimality of the decision seems sensitive, which justifies :
  - Treating some parameters as uncertain.
  - Confirming their value by consulting an expert.