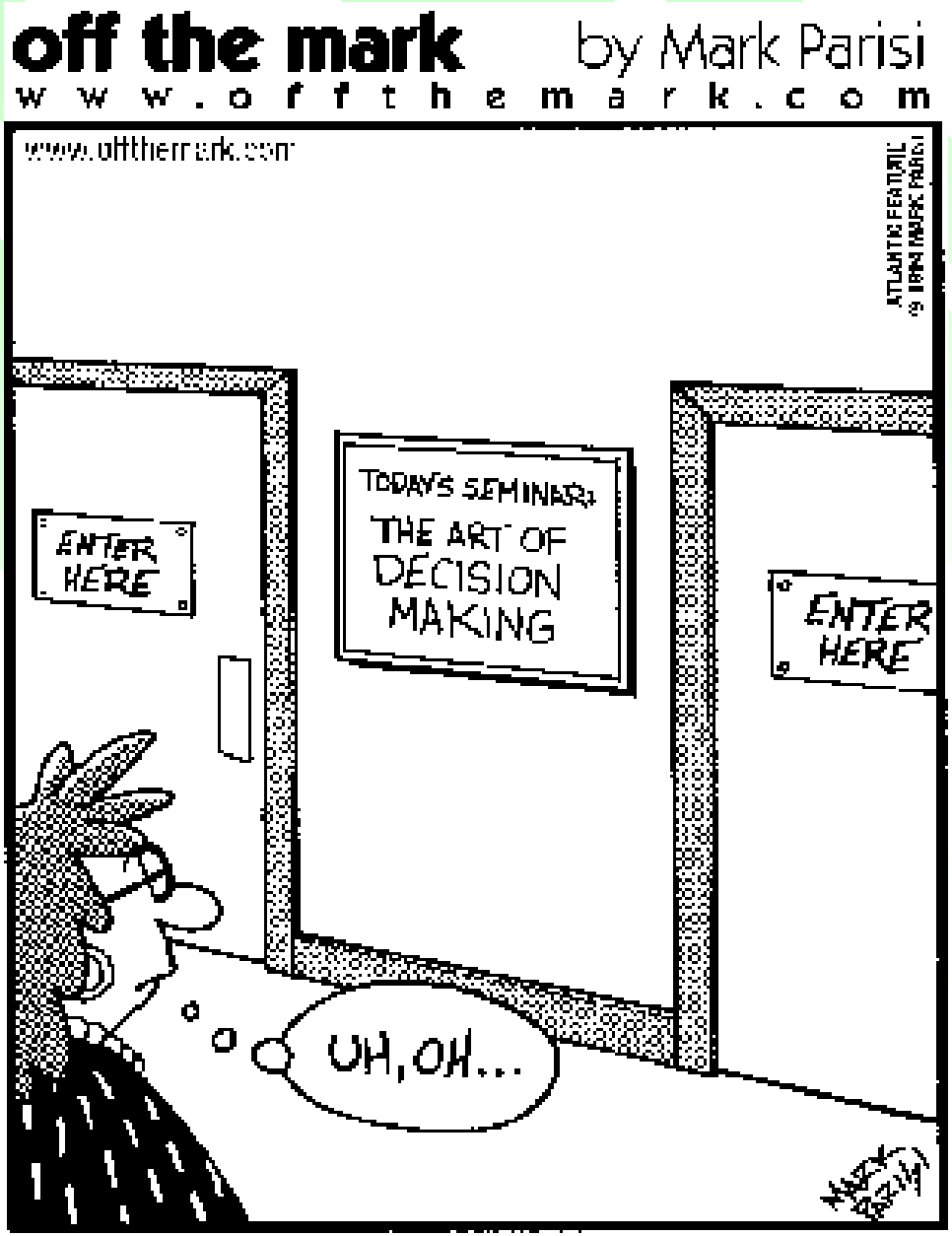
An Overview of *Decision Analysis*

Denis Bouyssou

CNRS — LAMSADE


off the mark by Mark Parisi
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TODAY'S SEMINAR:
THE ART OF DECISION MAKING
ENTER HERE
UH, OH...
MARK PARISI

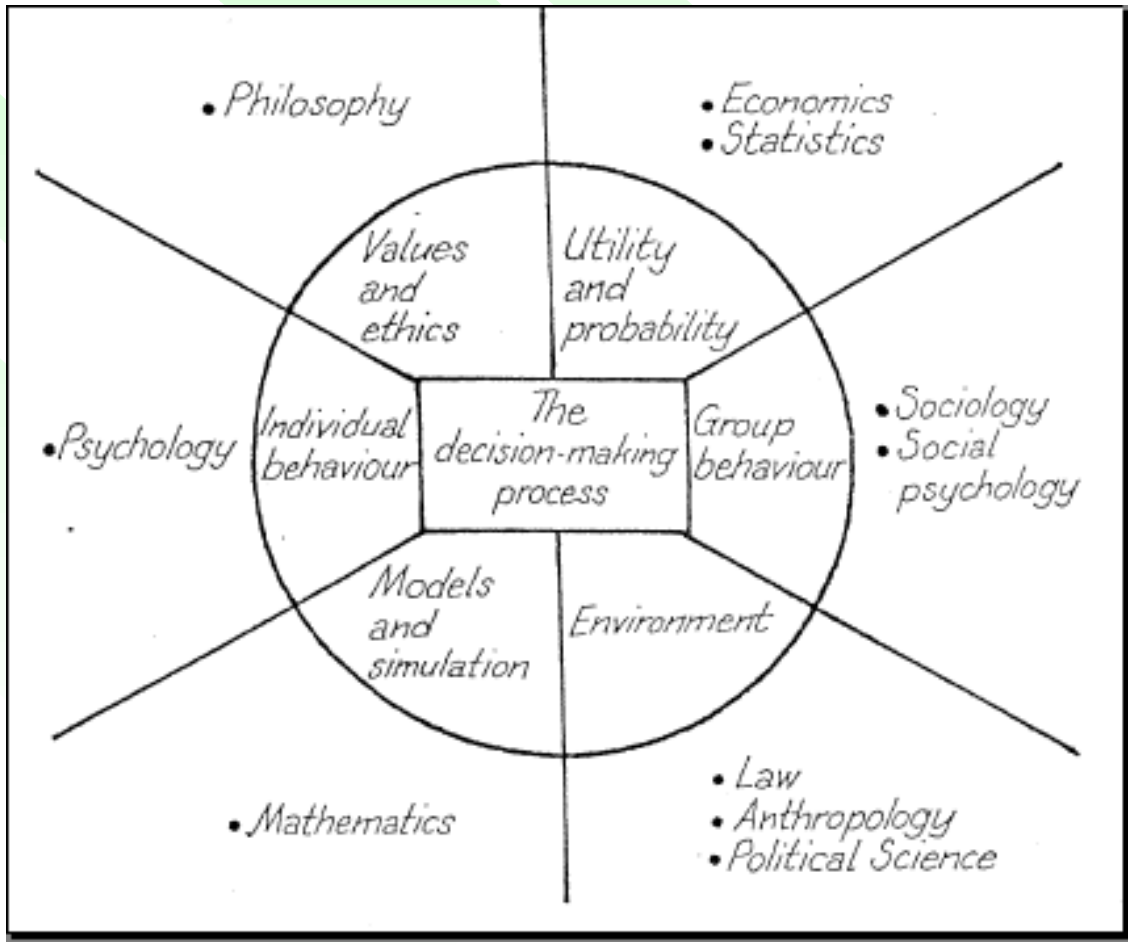
Aims of the lecture

- "Decision"
  - ⇨ Many different types
  - ⇨ Many different techniques

- Give a general framework for thinking about decision problems
- Put the various decision analysis techniques in perspective

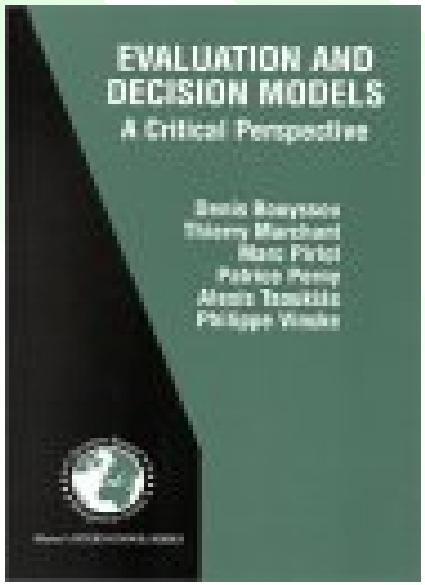
Decision

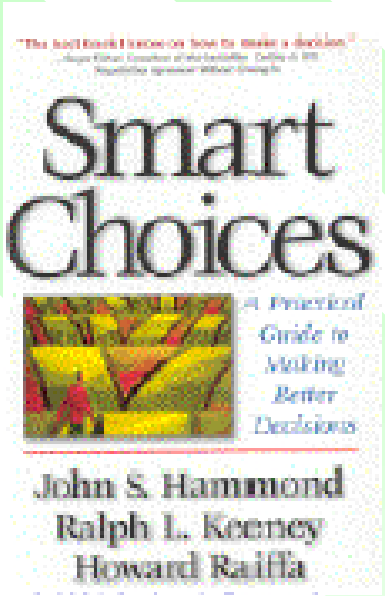
- Philosophy
- Economics
- Psychology
- Sociology
- Political Science
- Computer Science
- Operational Research
- Biology?
- Theology?

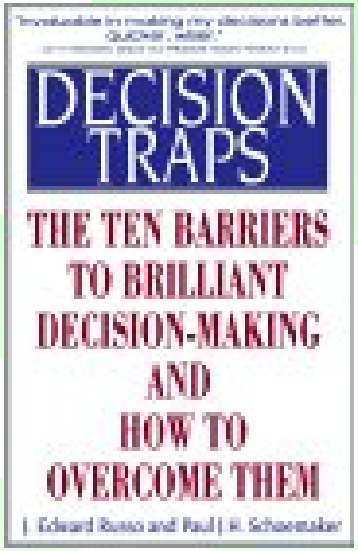


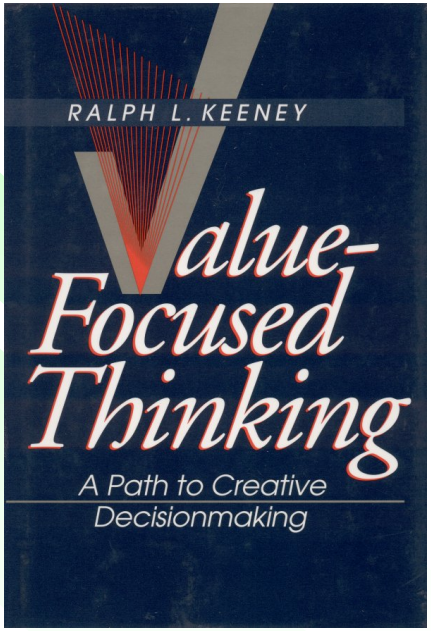
References

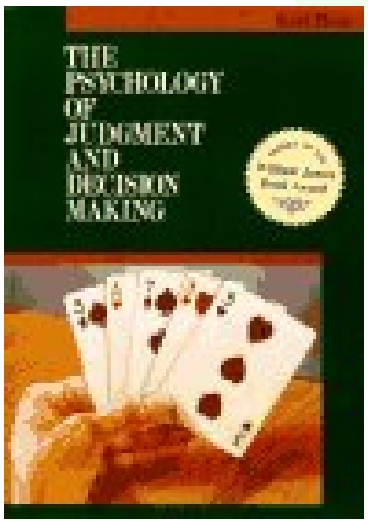
- **D. Bouyssou, Th. Marchant, M. Pirlot, P. Perny, A. Tsoukiàs and Ph. Vincke “Evaluation and Decision models: acritical Perspective”, 2000, Kluwer**

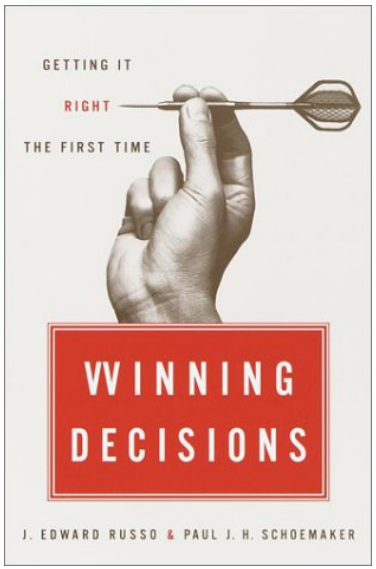



Smart Choices
A Practical Guide to Making Better Decisions
John S. Hammond
Ralph L. Keeney
Howard Raiffa


DECISION TRAPS
THE TEN BARRIERS TO BRILLIANT DECISION-MAKING AND HOW TO OVERCOME THEM

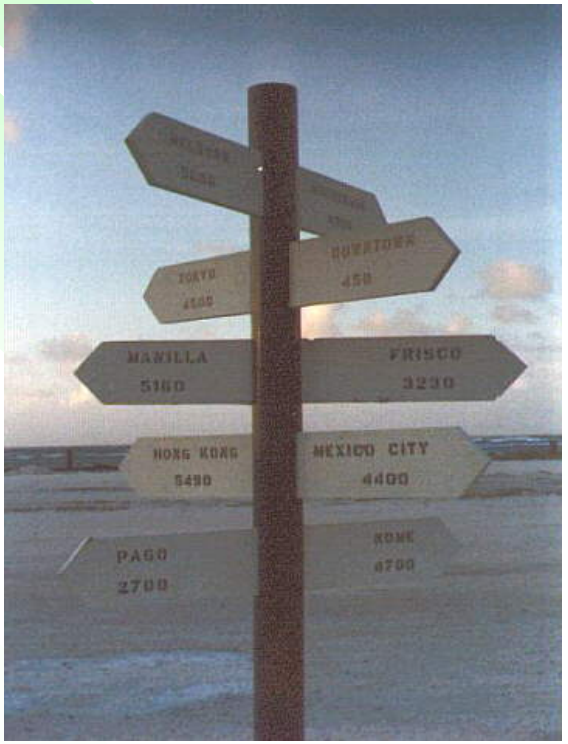

RALPH L. KEENEY
Value-Focused Thinking
A Path to Creative Decisionmaking


THE PSYCHOLOGY OF JUDGMENT AND DECISION MAKING


GETTING IT
RIGHT
THE FIRST TIME
WINNING DECISIONS
J. EDWARD RUSSO & PAUL J. H. SCHOEMAKER

Outline

- Classical view on decision
- Another view
- What can be expected?
- What should we take care of?
- What are the main types of models?



Decision ?

- Classical view (Catastrophe, Bifurcation)
  - ➪ conscious individual freely choosing between several courses of action
- Culturally biased view
- Philosophic difficulties
- Practical difficulties
  - ➪ Organization sociology, Organizational Behavior
  - ➪ Agendas of CEO and “high level executives”
  - ➪ H. Mintzberg “myths and realities”
    - The Nature of Managerial Work, Harper and Row, 1973

Difficulties with the classical view

France (CEOs)

- 15 % transports
- 5 % visits
- 5 % individuals interviews
- 30 % internal meetings
- 10 % external meetings
- 10 % meals
- 15 % telephone
- 5 % reading / writing mail
- 2 % writing
- 2 % reading
- 1 % solitary reflection (6 min./d.)
- 0 % computers

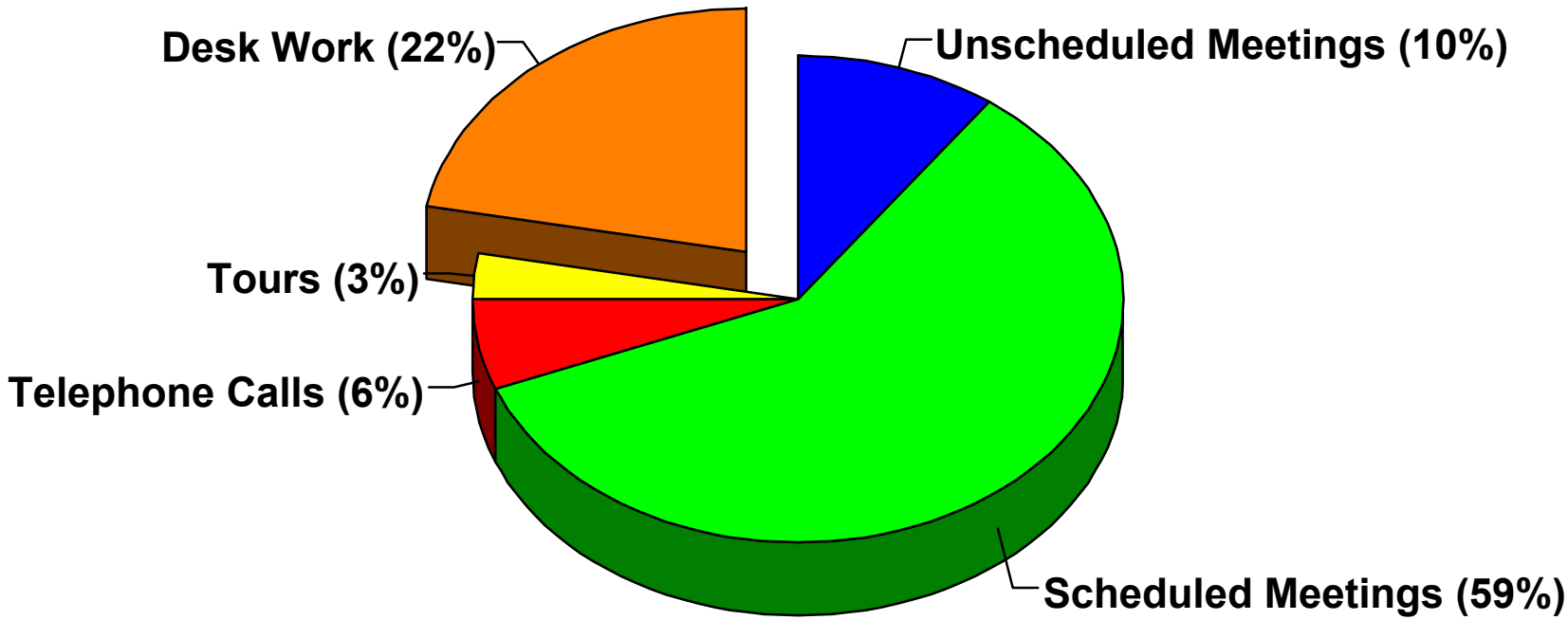
Transport 20 %

Meetings 55 %

Individual work 25 %

Managers

- 160 managers UK
  - 1 period every two days in which they work continuously on the same subject for 30 minutes
  - 1 verbal contact in 398 deals with organization / planning
  - on average 583 different activities within 8 hours
    - 0,82 min per activity



H. Mintzberg (1973), The Nature of Managerial Work

Mintzberg's Studies of Managers

- **Myth #1**: The manager is a reflective systematic planner.
  - **Fact**: Study after study shows managers work at an unrelenting pace, that their activities are characterized by brevity, variety, and discontinuity, they are strongly oriented toward action, and dislike reflective activities.
- **Myth #2**: The effective manager has no regular duties to perform.
  - **Fact**: Managerial work involves performing a number of regular duties, including ritual and ceremony, negotiations, and processing of soft information that links the organization with its environment

Mintzberg's Studies of Managers

- **Myth #3**: The senior manager needs aggregated information, which a formal management information system best provides.
  - ⇨ Fact: Managers strongly favor verbal media, telephone calls, and meetings over documents.

Myth #4: Management is, or at least is quickly becoming, a science and a profession.

- ⇨ **Fact**: The managers' programs - to schedule time, process information, make decisions, and so on-remain locked deep inside their brains.

Decision

- *Provisional definition* [R. Howard]: “Decision-making is what you do when you do not know what to do”
- Criteria: Anxiety, Fear, Hyper-vigilance
- Symptoms
  - ⇨ Scribbling on a sheet of paper / worksheet
  - ⇨ multiplication of meetings
  - ⇨ Procrastination
  - ⇨ Depression / Enthusiasm
- Complexity
  - ⇨ High / complex stakes
  - ⇨ Uncertainty / Time horizon / Multiples objectives

Real Decisions

Three classical attitudes

- **Omen**
  - ➪ **Intuition / Charismatic leader / Expert / Authority**
- **Ritual Sacrifices**
  - ➪ **René Girard "Things Hidden Since the Foundation of the World", "The Scapegoat"**
- **Consulting study**

ANDERSEN

KPMG

Deloitte Touche Tohmatsu

⇒ **Let someone else carry your anxiety**

Decision Analytic tools = Tools for managing anxiety

What Decision Analysis is not!

- **A general method for taking "good decisions"**

  Example

  - ⇨**Choice 1: [Heads] 1000 € [Tails] 0 €**
  - ⇨**Choice 2: [Heads Heads] 5000 € [Otherwise] 0 €**

  Example

  - ⇨**Choice of new job, medical decision, etc.**

- **What is a "good decision"?**
  - ⇨**Good for whom, according to what criteria, at which moment in time?**
- **Good decision process *vs.* good decisions**
  - ⇨**Japanese shoemaker**

What Decision Analysis is not!

- A description on how “wise people” decide
  - ⇨ Expert systems
  - ⇨ Doctors / Politicians
    - Prevention vs. First Aid
    - Nuclear Industry vs. Road safety
      - ⇨ 5 000 000 vs. 140 000 (USD 1978)
- How do you recognize “wise people”?
  - ⇨ Luck vs. Wisdom
- What can we do then?

Example: rolling a dice

	1	2	3	4	5	6
a	0	100	200	300	400	500
b	100	200	300	400	500	0

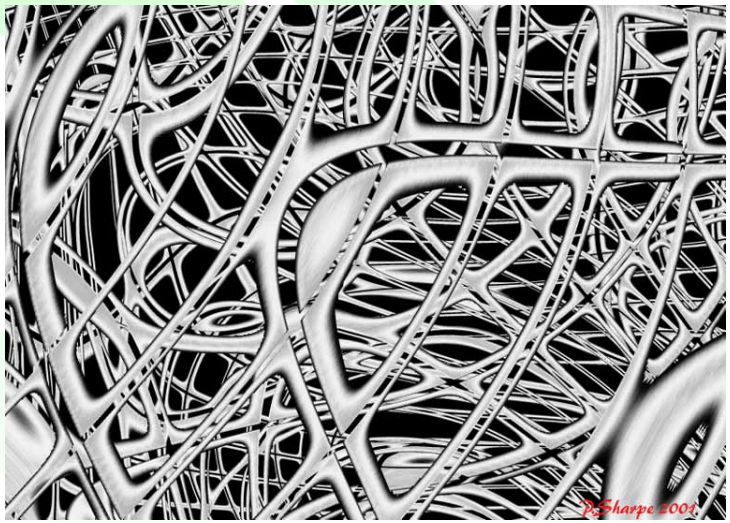
	1	2	3	4	5	6
a	10	110	210	310	410	510
b	100	200	300	400	500	0

Decision Analysis

- **Definition (B. Roy): "consists in trying to provide *answers* to questions raised by actors involved in a *decision process* using a *model*"**
- ***Decision process*: strategy of intervention (aid, communication, justification, etc.**
  - ⇨ **Many different ways to provide decision-aid**

Decision Process

- Time
- Multiple actors
- Organization
  - ➪ links with other processes
  - ➪ power
- Milestones
  - ➪ alternatives created / rejected
  - ➪ fragments of decisions



Decision Making

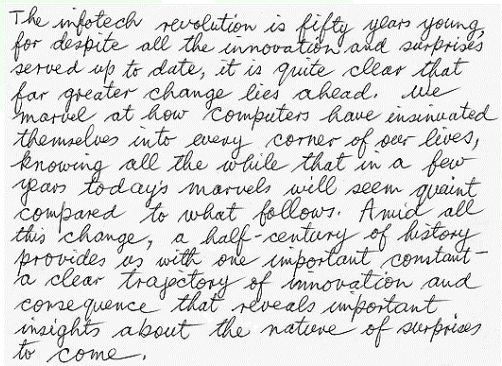
- Decision Making ≠ "Solving" a well-defined problem
- Intervention in a decision process
  - imagine compromises
  - communicate
  - coordinate
  - control
  - motivate
  - conduct change
- Importance of "final choice"?

Decision Analysis

- **Definition (B. Roy): "consists in trying to provide *answers* to questions raised by actors involved in a *decision process* using a *model*"**
- ***Answers*: "Optimal solution" or "Good decision" is absent**
- ***Models*: formalized or not**

Examples of models

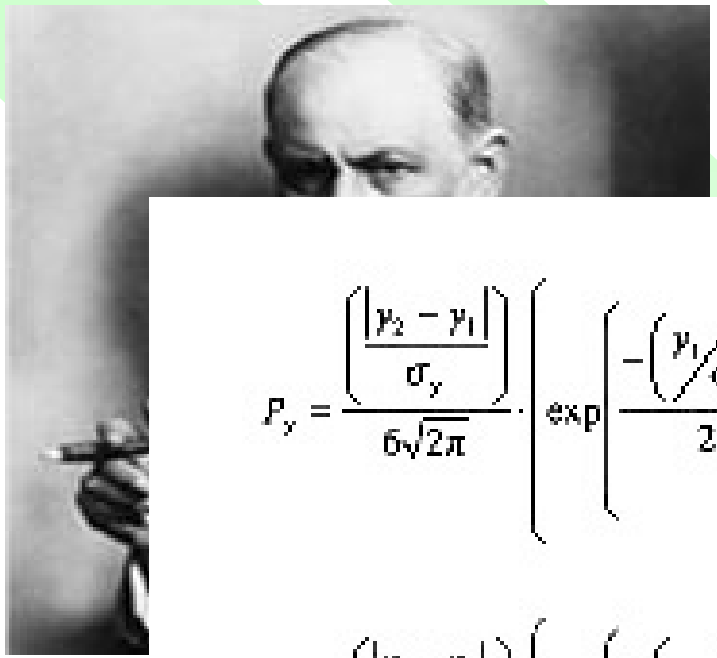
- **Astrology**
  - ⇨ **the astrologer "provide *answers* to questions raised by his/her client using a *model*"**
- **Graphology**
- **Psycho-analysis**


The infotech revolution is fifty years young, for despite all the innovation and surprises served up to date, it is quite clear that far greater change lies ahead. We marvel at how computers have insinuated themselves into every corner of our lives, knowing all the while that in a few years todays marvels will seem quaint compared to what follows. Amid all this change, a half-century of history provides us with one important constant - a clear trajectory of innovation and consequence that reveals important insights about the nature of surprises to come.

- **Decision analysis makes use of *explicit* and *formalized* models**

$$P_y = \frac{\left(\frac{|y_2 - y_1|}{\sigma_y}\right)}{6\sqrt{2\pi}} \cdot \left[\exp\left[-\frac{\left(y_1/\sigma_y\right)^2}{2} \right] + 4 \cdot \exp\left[-\frac{\left(\frac{y_1 + y_2}{2\sigma_y}\right)^2}{2} \right] + \exp\left[-\frac{\left(y_2/\sigma_y\right)^2}{2} \right] \right]$$

$$P_x = \frac{\left(\frac{|x_2 - x_1|}{\sigma_x}\right)}{6\sqrt{2\pi}} \cdot \left[\exp\left[-\frac{\left(\frac{x_1}{\sigma_x}\right)^2}{2} \right] + 4 \cdot \exp\left[-\frac{\left(\frac{(x_1 + x_2)}{2\sigma_x}\right)^2}{2} \right] + \exp\left[-\frac{\left(\frac{x_2}{\sigma_x}\right)^2}{2} \right] \right]$$



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Formalized Models

- **Drawbacks**
  - ⇨ **Complex**
  - ⇨ **Opaque**
- **Advantages**
  - ⇨ **Provide a clear language**
    - **communication tool**
  - ⇨ **Capture the essence of a situation**
    - **structuration tool**
  - ⇨ **Answers "what-if" questions (sensitivity, robustness)**
    - **Exploration tool**
- **Example: choosing a bottle of wine**

Possible Objections

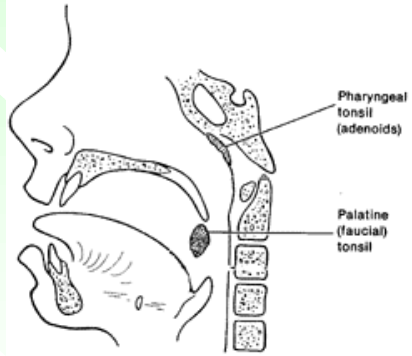
- ***We*** **do not need such tools because *we* know how to decide**
- **Let's organize a high-level *meeting* to discuss it**
- ***Intuition*** **is often enough**

I do not need it

- **OK but:**
  - **How will you convince your Boss?**
  - **How will you avoid being a scapegoat?**

Intuition?

- Doctors
- New England Journal of Medicine
  - ➪ Tonsillectomy
  - ➪ Experts + Clinical Tableaus



389 child

- 45 % Yes
- 55 % No
  - 46 % Yes
  - 54 % No
    - 44 % Yes
    - 56 % No

Do-it-yourself Example

You are confronted with the *double* decision problem:

***Problem 1*. Choose between**

- **Option A = sure gain of 1200 €**
- **Option B = gain of 5000 € with probability 25%, no gain with probability 75%**

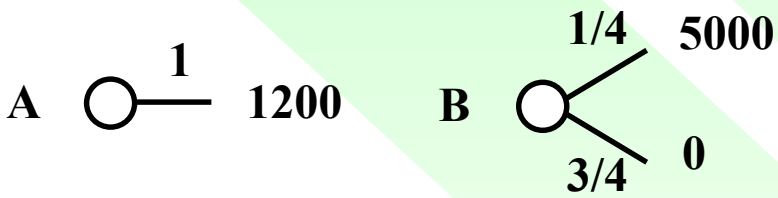
***Problem 2*. Choose between:**

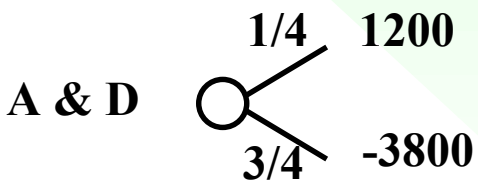
- **Option C = sure loss of 3750 €**
- **Option D = loss of 5000 € with proba. 75 %, no loss with proba. 25%**

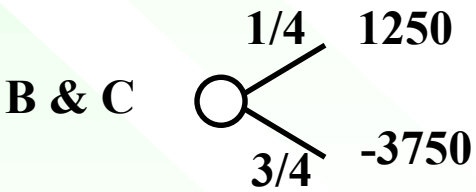
- **Make your own choices!**

Results (D. Kahneman / A. Tversky)

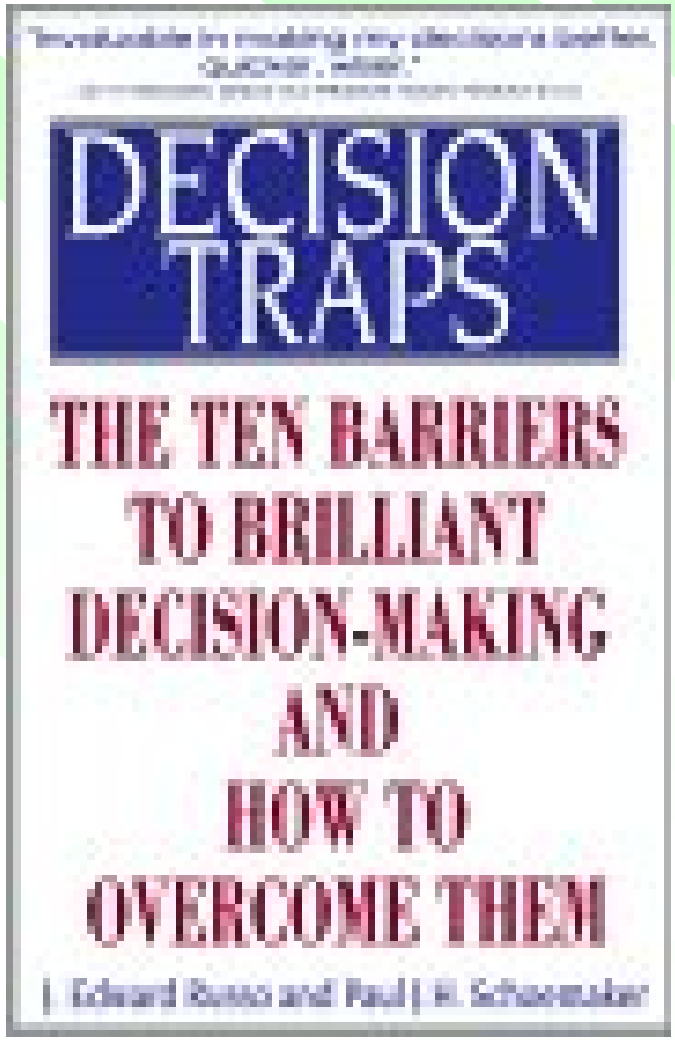
- **Modal choice = A & D (73%)**







Daniel Kahneman


DECISION TRAPS
THE TEN BARRIERS TO BRILLIANT DECISION-MAKING AND HOW TO OVERCOME THEM

Trap # 6

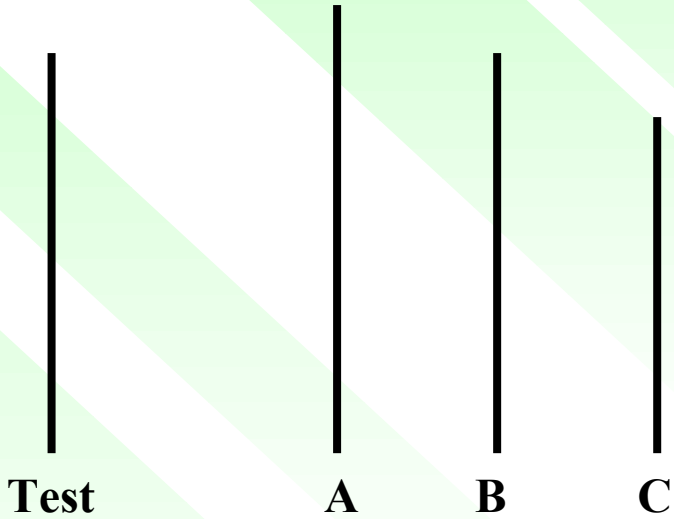
Shooting from the hip

- **"Believing that you can keep straight in your head all the information you've discovered, and therefore "winging it" rather than following a systematic procedure when making the final choice"**

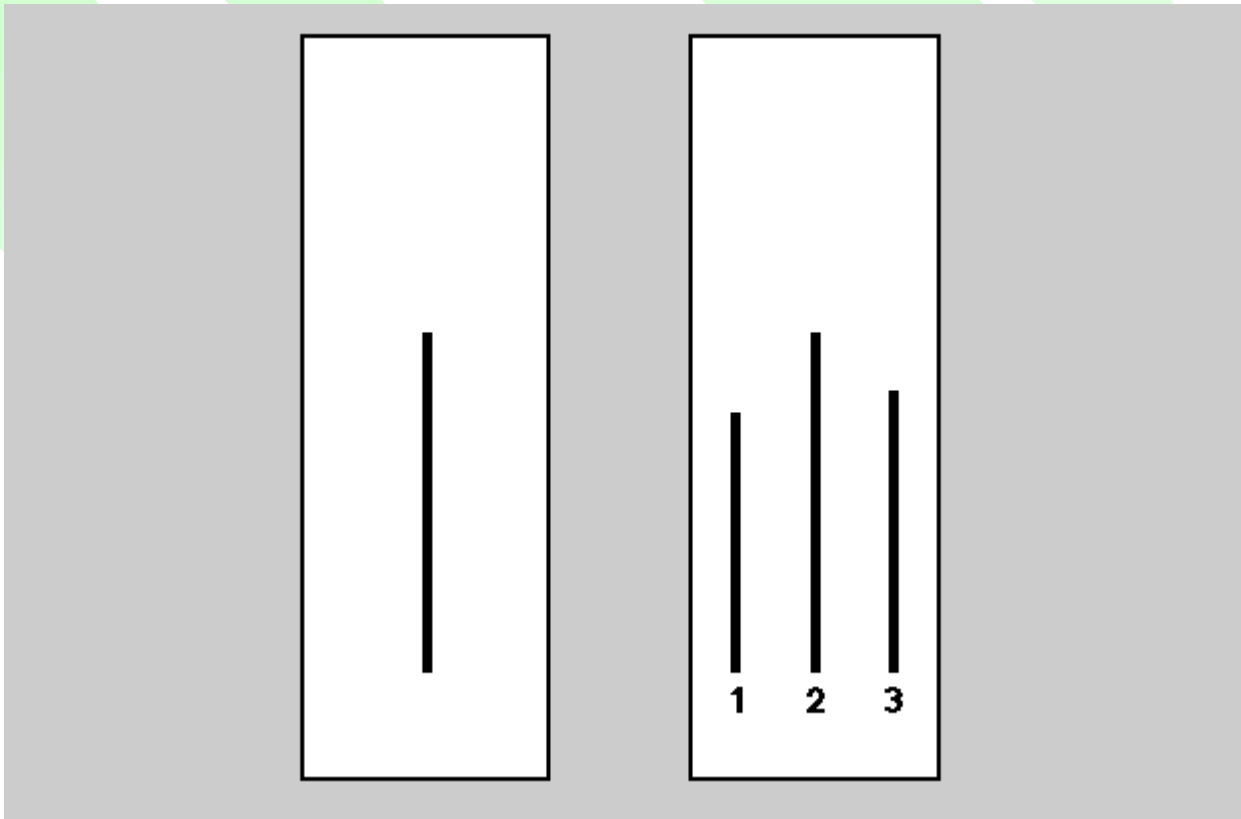
Russo & Shoemaker

Meetings

- **Asch experiment**



- **99% correct answers**
  - ⇨ **1 person says A** — **error rate = 3%**
  - ⇨ **2 person say A** — **error rate = 13 %**
  - ⇨ **3 person say A** — **error rate = 33 %**
  - ⇨ **Bonus for correct consensus** — **error rate = 47 %**


1
2
3

Trap # 7

Group failure

- **"Assuming that with many smart people involved, good choices will follow automatically, and therefore failing to manage the group decision-making process"**

Russo & Shoemaker

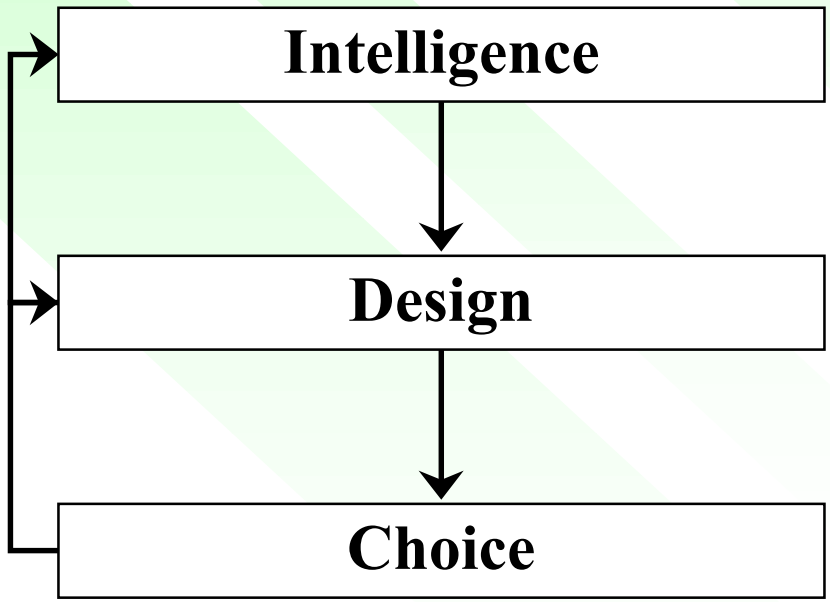
Optical Illusions

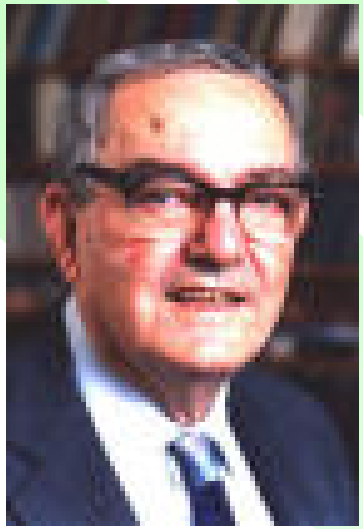
What can be expected?

- Separate “facts” and “values”
- Separate “robust” from “fragile” conclusions
- Improve communication
- Foster consistent reasoning
- Draw attention to counter-intuitive and perverse effects
- Promote open debate and discussion
- Promote partial agreements
- Promote reflection on objectives

Simple Decision Process Model

Herbert A. Simon

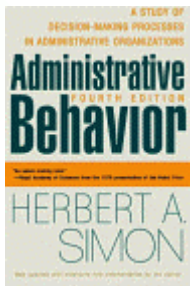




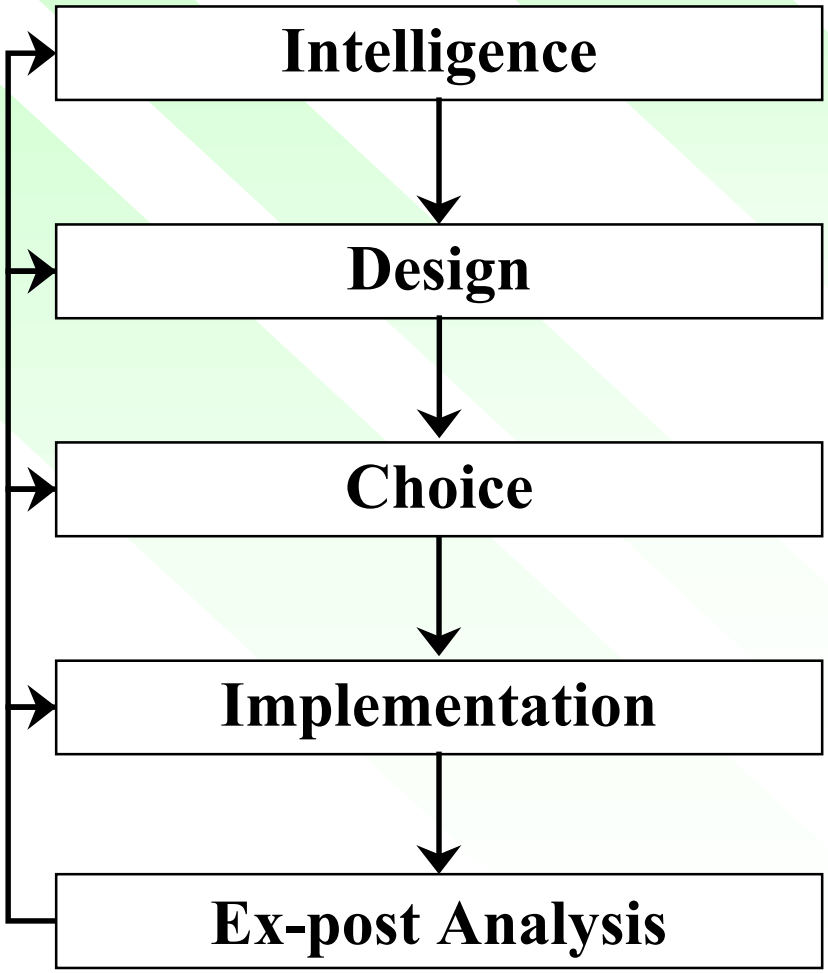
Herbert A. Simon

- **Nobel Prize in Economics (1978)**

  "for his pioneering research into the decision-making process within economic organizations"



Decision process



Trap # 1

Plunging In

- **“Beginning to gather information and reach conclusions without taking first a few minutes to think about the crux of the issue you’re facing or to think how you believe decisions like this one should be made”**

Russo & Shoemaker

Trap # 10

Failure to audit your decision process

- **“Failing to create an organized approach to understanding your own decision-making, so you remain constantly exposed to all other nine decision traps”**

Russo & Shoemaker

Intelligence

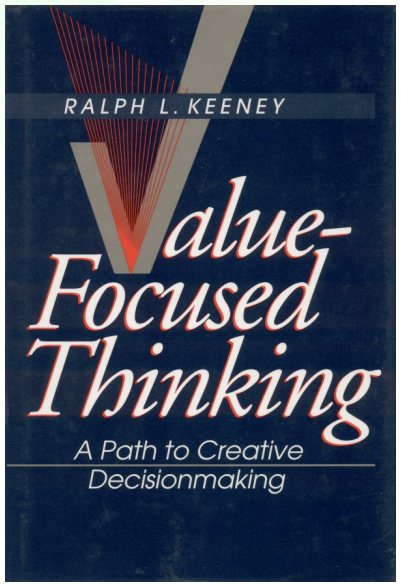
- Triggering the “decision situation”
  - ⇨ having the right triggers
- Values - Objectives
- Frontier of the system
- Possible actions on the system
  - ⇨ N. Maier: “do not propose solutions until the problem has been thoroughly discussed without suggesting any”

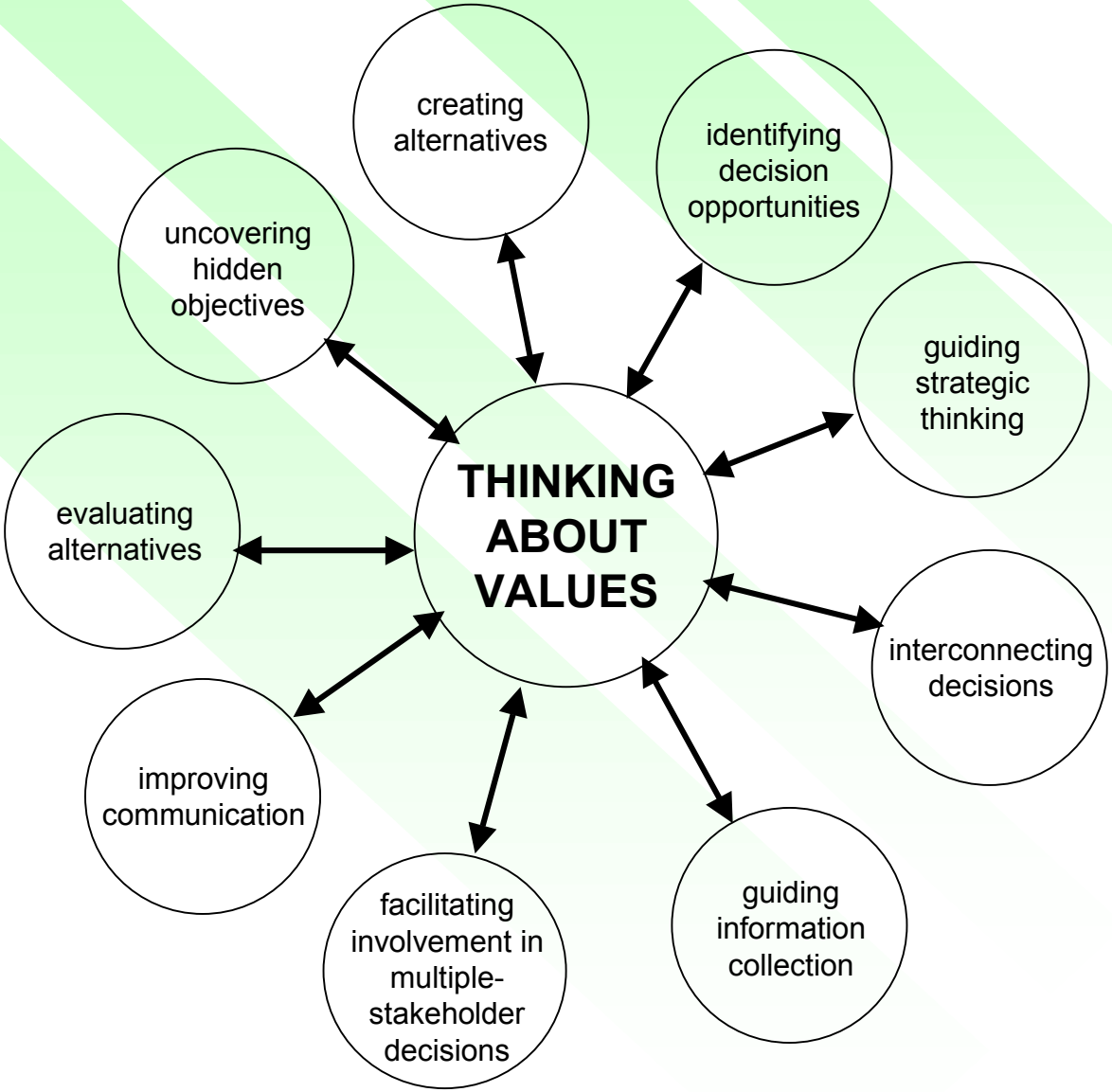
Triggers: Information Systems

- **MIS / EIS / Accounting / Inventory management**
- **Watch**
- **Prospective**
- **Information**
  - ⇨ **of *adequate* nature**
  - ⇨ **in a *timely* manner**

Values - Objectives

- "Decision-Making is what you do to satisfy objectives" (R.L. Keeney)
- Objectives
  - ⇨ guide the collection of information
  - ⇨ facilitate communication
  - ⇨ allow audits and evaluation
  - ⇨ avoid endless debates
- Examples
  - ⇨ Should we legalize Cannabis ?
  - ⇨ What should be the speed limit on highways ?
  - ⇨ Should I take this job?





Adapted from Keeney, 1992

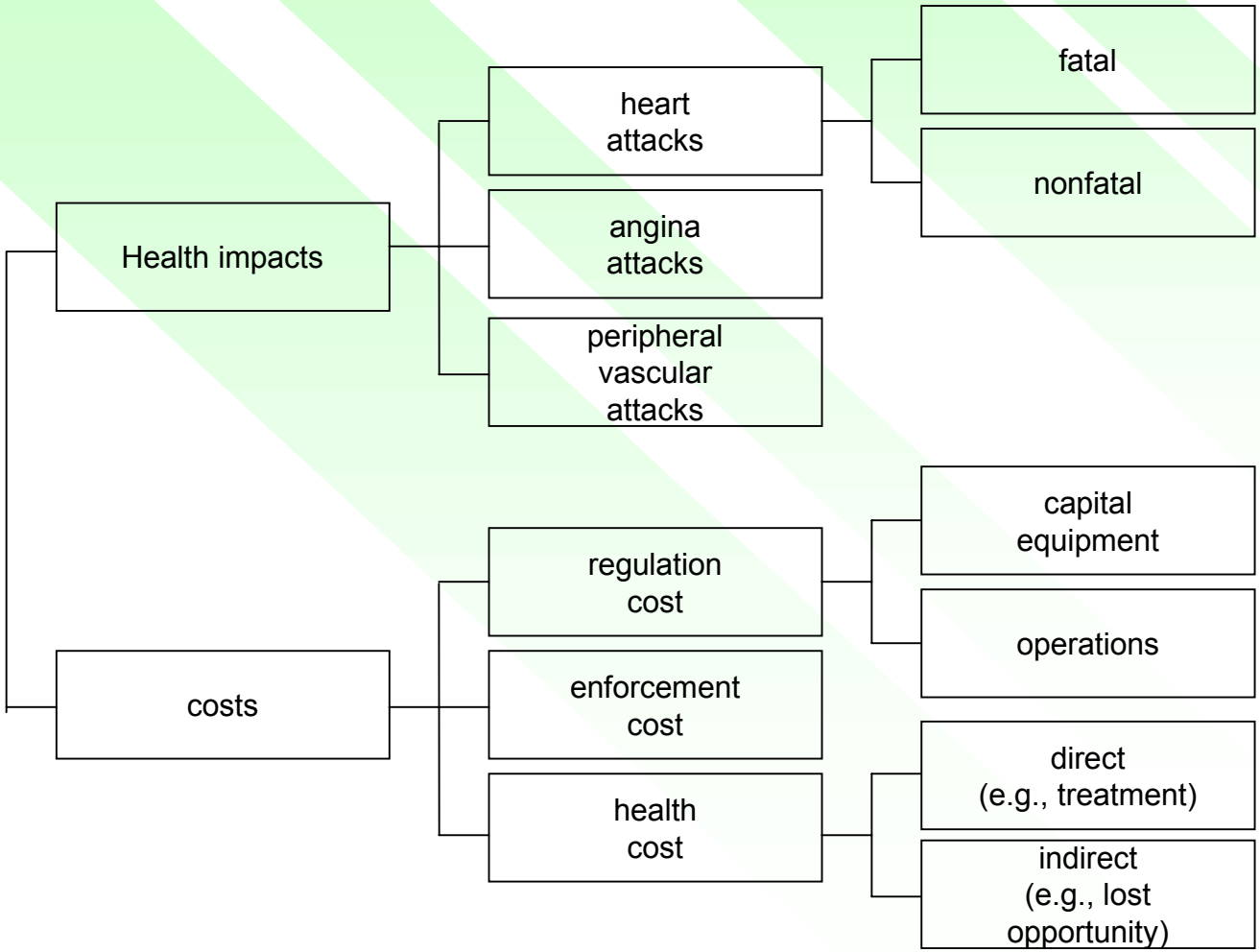
Values - Objectives

- **Ends objectives**
  - **Why is this important to me ?**
  - **Evaluation**
- **Means objectives**
  - **How ?**
  - **Alternatives**
- ***Means Objective*: an objective whose importance stems from its contributions to achieving another objective**
- ***Ends Objective*: objective that defines a basic reason for caring about a decision**
  - **Means Objective - arrive home from work early**
  - **Ends Objective - make my spouse happy**

Techniques to Identify Objectives

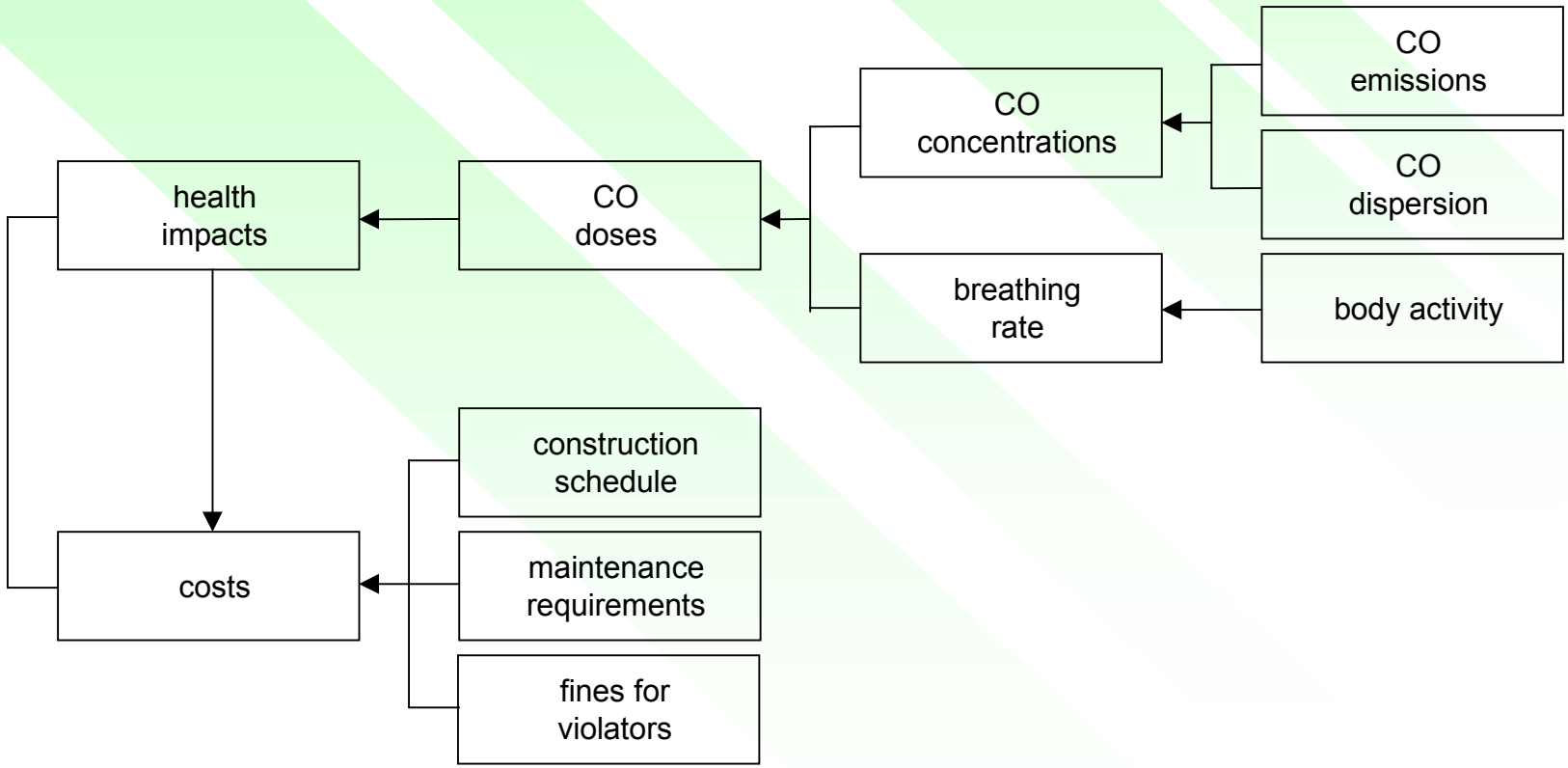
- Use a wish list
- Think about alternatives
- Imagine possible consequences
- Describe problems and shortcomings
- Identify goals, constraints and guidelines
- Use different perspectives
- Think about strategic objectives
- Ask ‘why’ for each objective
- Do individual thinking first

Fundamental Objectives Hierarchy
CO Air Quality Standards



Adapted from Keeney, 1992

Means-Ends Objectives Network
CO Air Quality Standards



Adapted from Keeney, 1992

Summary of How to Construct Objectives Hierarchies and Networks

	Fundamental Objectives	Means Objectives
To Move:	Downward in the Hierarchy:	Away from Fundamental Objectives:
Ask:	"What do you mean by that?"	"How could you achieve this?"
To Move:	Upward in the Hierarchy:	Toward Fundamental Objectives:
Ask:	"Of what more general objective is this an aspect?"	"Why is this important?"

Frontiers

- A model *has to* simplify (Maps / Territory)
- Frontiers
  - Time
  - Space
  - Persons
  - Linked decisions
- Examples
  - Elevators
  - J-I-T

Frontiers

- Key points?
- Neglected points?
- Traps
  - ➪ metaphors, language
  - ➪ firm stereotypes
  - ➪ trigger
  - ➪ obvious constraints

Metaphors

- Sports/war/health, etc.
  - “winning team”
  - “price war”
  - “terminal phase”
  - “strategic movement”
  - “general mobilization”
  - “battle of quality”
  - etc.

Trap # 2

Frame Blindness

- **"Setting out to solve the wrong problem because you have created a mental framework for your decision with little thought that causes you to overlook the best options or lose sight of important objectives"**

Russo & Shoemaker

Trap # 3

Lack of Frame Control

- **"Failing to consciously define the problem in more than one way or being unduly influenced by the frames of others"**

Russo & Shoemaker

Example (Kahneman/Tversky)

- **You have decided to go to see a play and bought a ticket for 30 €**

  As you enter the theater, you discover that you have lost the ticket. The seat was not marked and the ticket cannot be recovered.

  Would you pay 30 € for another ticket to see the play (assuming you have enough cash)

- **38 % do not buy**

Example (Kahneman/Tversky)

- **You have decided to go to see a play where admission is 30 € per ticket, but you have not yet purchased the ticket. As you enter the theater, you discover that you have lost 30 € from your wallet.**

  Would you still pay 30 € for a ticket to see the play (assuming you have enough cash).

- **17 % do not buy (vs. 38%)**

- **Lost cash is out-of-boundary**

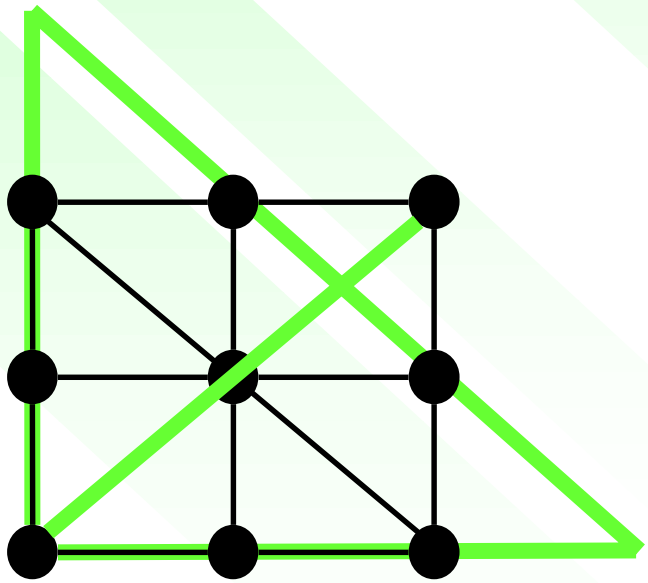
Set of alternatives

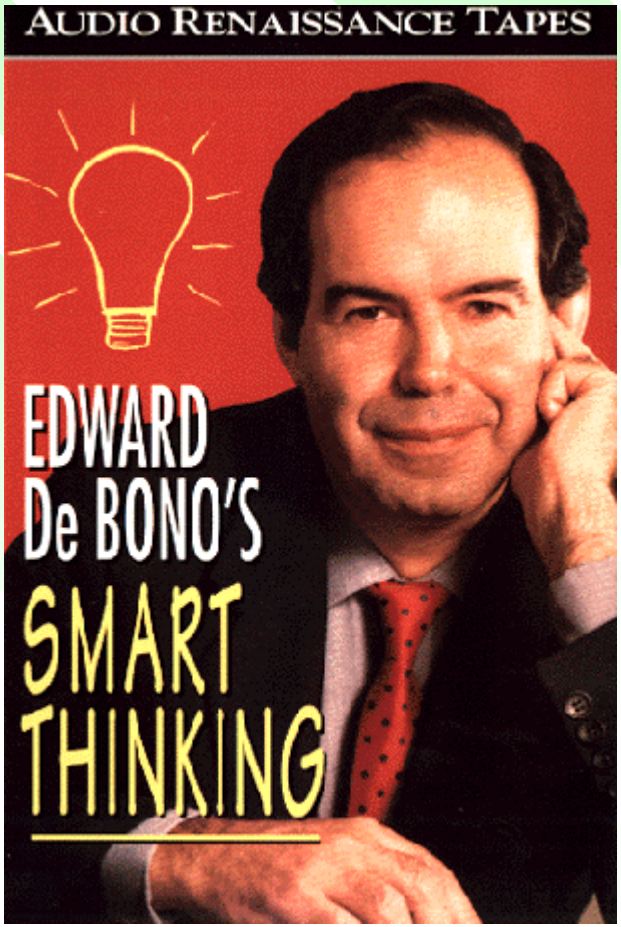
- "Let A be a an exhaustive set of mutually exclusive alternatives"
- Creativity
  - ➪ test: is there at least one satisfactory alternatives?
- R.L. Keeney
  - ➪ "your decision cannot be better than your best alternative"
  - ➪ "you can never choose an alternative you haven't considered"


CREATIVITY
IT JUST WON'T GET OFF THE GROUND
FEAR

Problem

- **Join these 9 points by 4 lines without lifting the pencil from the paper**




AUDIO RENAISSANCE TAPES
EDWARD
De BONO'S
SMART
THINKING

Problem: Complete last line

1

11

21

1211

111221

312211

13112221 ??

“Killers”

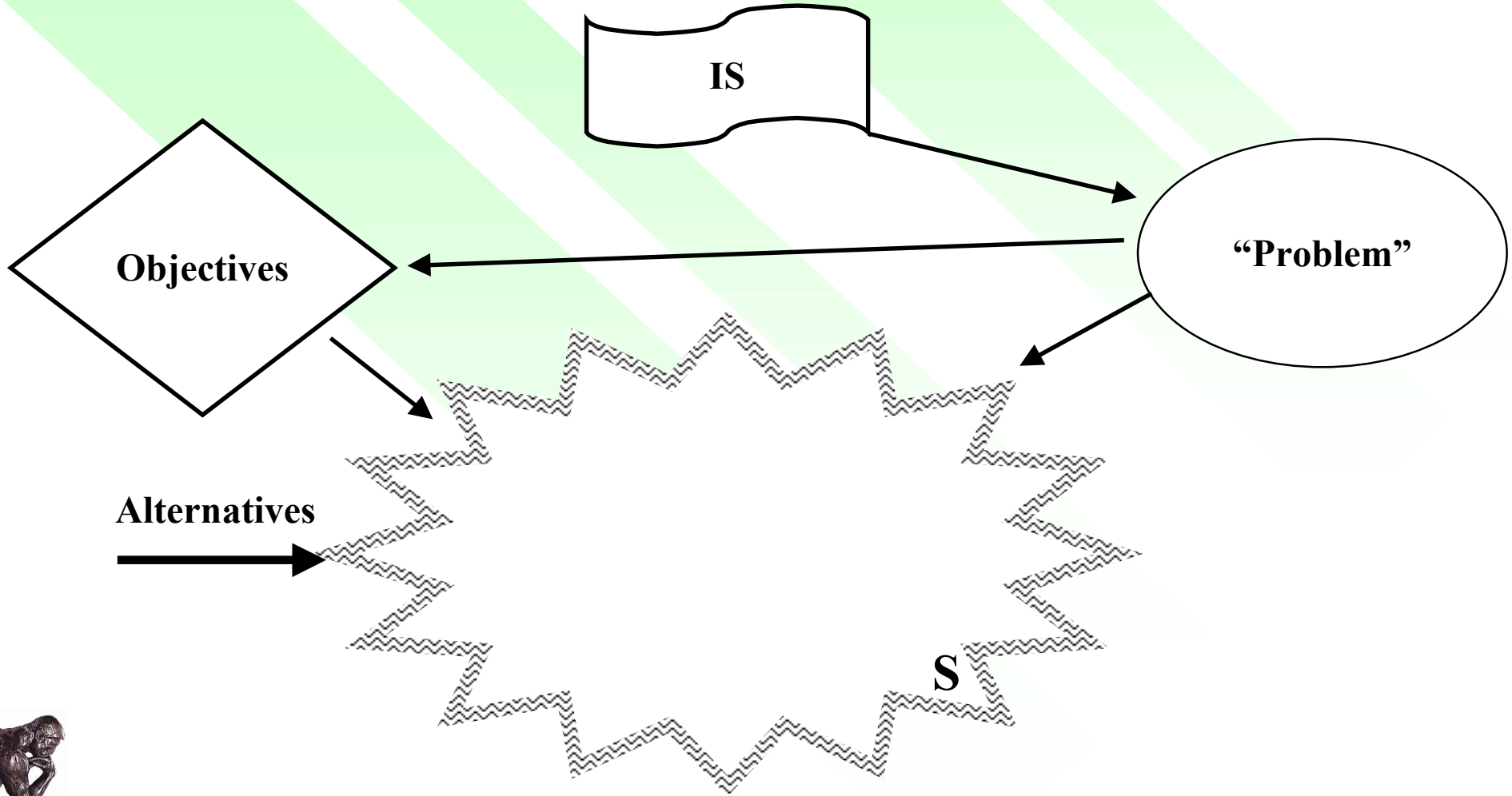
- “Business as usual”: budgets
- Status-quo bias
- No action: letting time/others decide for me
- Fear of being ridiculous
  - ⇨ “brainstorming sessions”
  - ⇨ US army

Remedies

- Use your objectives and ask: How?
- Increase aspiration levels
- Beware of constraints
- Sleep on it
- Modify / improve what is “given”

- Test: Is there anything really satisfactory?

Intelligence Phase



Design

- Describe / forecast the “state of the system” if you apply some alternative
- Examples: most management techniques
  - sales forecasts, financial plans, accounting
- Job
  - salary
  - transportation time
  - social security
  - nights out
  - interest
  - chances of keeping the job

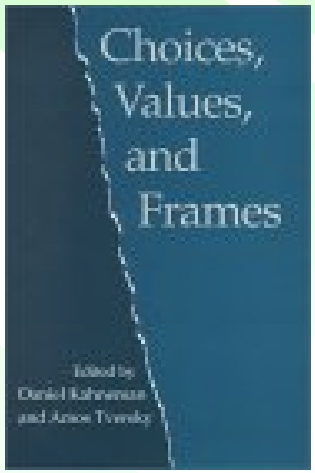
Traps

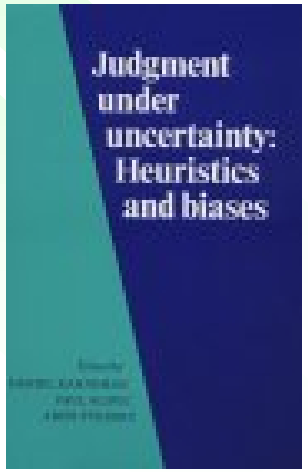
- Not using your objectives
- Not having objectives
- Fetish “hard data”
- Not taking uncertainty into account
- Mixing up “knowledge” of experts with their “values”
  - ⇨doctors

Design: crucial points

- What do I know?
- What should I know?

- Reference points
- Units
  - nature of the measure
  - absolute/relative






GOLD HILL
EST. — 1859
ELEV. — 8463
POP. — 118
TOTAL 10440

Example (Kahneman/Tversky)

- Experiment with 167 doctors
- Choice of a treatment for (own) lung cancer
  - ⇨ Surgery
  - ⇨ Radiotherapy
- Information on survival “chances”
  - ⇨ 2 groups

100 patients Surgery	10 die during operation
	32 are dead after 1 year
	66 are dead after 5 years
100 patients radioth.	0 die during operation
	23 are dead after 1 year
	78 are dead after 5 years

50 % in Group 1 prefer Surgery

100 patients Surgery	90 survive to operation
	68 survive after 1 year
	34 survive after 5 years
100 patients radioth.	100 survive to operation
	77 survive after 1 year
	22 survive after 5 years

84 % in Group 2 prefer Surgery

100 patients Surgery	10 die during operation
	32 are dead after 1 year
	66 are dead after 5 years
100 patients radioth.	0 die during operation
	23 are dead after 1 year
	78 are dead after 5 years

100 patients Surgery	90 survive to operation
	68 survive after 1 year
	34 survive after 5 years
100 patients radioth.	100 survive to operation
	77 survive after 1 year
	22 survive after 5 years

Measurement units

- **Public Health decisions**
  - ⇨ **Number of fatalities**
  - ⇨ **Number of years of life lost**
  - ⇨ **Number of years of “good quality” life lost**
    - **QUALY, HYE**

Absolute/Relative measurement

- **Situation A**

  Watch = 70 €

  You are told by a friend that, five blocks away, you can buy the same watch (same service and guarantee) at 30 €

  Question: Are you going to buy the watch in the distant shop? (90% Yes)

- **Situation B**

  Video camera = 800 €

  Five blocks away, you can buy the same video (same service and guarantee) at 770 €

- **Question: Are you going to buy the video in the distant shop? (50% Yes)**

Absolute/Relative measurement

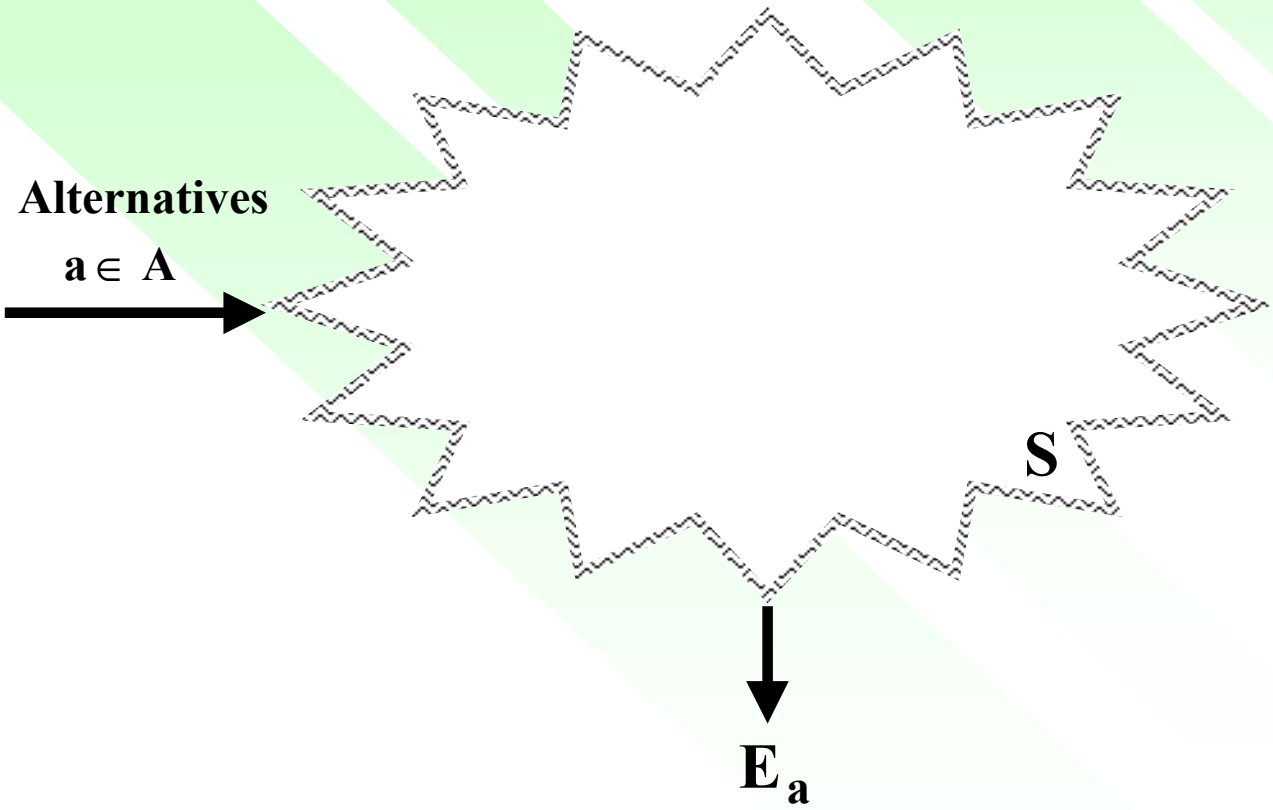
- **Budget: 100 000 €**
- **Expenditures : 90 000 €**
  - ⇨ **“I saved 10 000 € to the firm”**
- **Expenditures : 110 000 €**
  - ⇨ **“I stayed with 10% of the budget”**

Example: locating an airport

- Model impacts on riparians
- 2002 = date of study, 2010 = functioning date

- 2002: one possible site = one spot on a map
  - ⇨ Data: counting neighbor population
  - ⇨ Problems
    - Orientation of runaways
    - Imprecise data
    - Categories of population (schools, second homes)
    - Uncertainty on population variation
    - Proximity to the site
    - Nuisance during construction

Design Phase



Description of the system if you apply a ∈ A

Choice Phase

- **Choose alternative giving to system the "most desirable" state**
- **Complexity depends on:**
  - **A (set of alternatives)**
  - **S (system)**
  - **E_x (description of system) / Objectives**
    - **precision/imprecision**
    - **certainty/uncertainty**
    - **Time horizon**
    - **1 opinion / multiple opinions**
    - **1 criterion / several criteria**

$$a \in A \rightarrow E_a$$
$$b \in A \rightarrow E_b$$
$$c \in A \rightarrow E_c$$

Example:
Choice between investments projects

- **Intelligence: what are the possible investments?**
- **Design: Cash flows**
- **Choice: NPV or IRR**

$$\mathbf{v(a) = (v_0(a), v_1(a), \ldots, v_T(a))}$$

$$\mathbf{VNP(a) = \sum_{t=0}^{T} \frac{v_t(a)}{(1+r)^t}}$$

Meta Decision

- **How much time to allocate to each phase?**
- **Design: 80% of time (crunching numbers not to think hard)**

	real	wished
Intelligence	5%	20%
Design	45%	35%

Russo & Shoemaker

Trap # 9

- **Not keeping track**
- **“Assuming that experience will make its lessons automatically, and therefore failing to keep systematic records to track the results of your decisions and failing to analyze these results in ways that reveal their key lessons”**

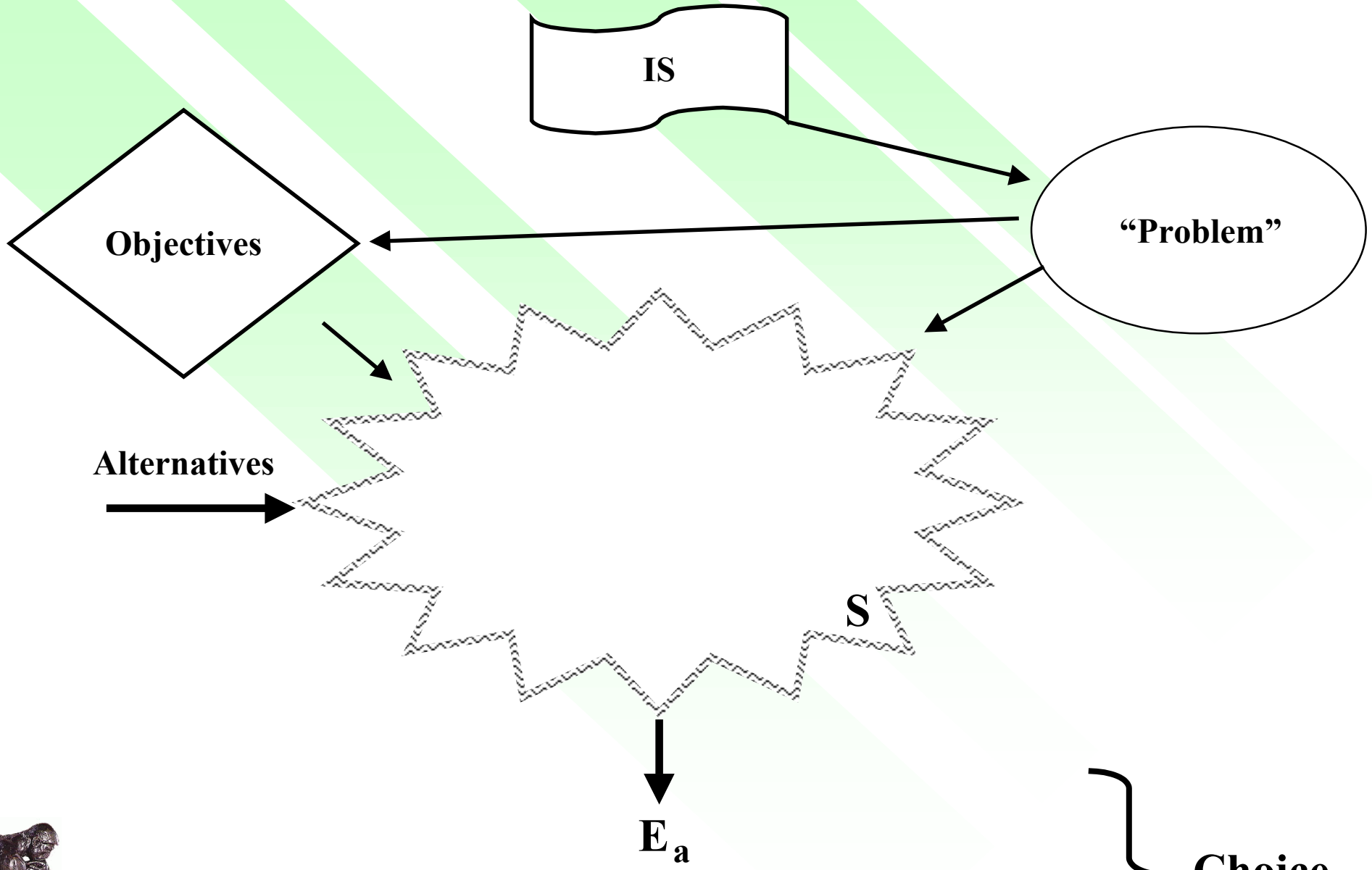
Russo & Shoemaker

Difficulties: Choice

- Very high number of alternatives
- Interdependent decision
  - resources
  - time
- Uncertainty
- Time Horizon
- Multiple Criteria
- System with retro-action
- Group Decision

In Practice

- All difficulties are more or less present
- Design phase will put more emphasis on one or two depending on context
- Sometimes “Intelligence + Design” are enough to give sufficient insights into the situation


IS
Objectives
"Problem"
Alternatives
S
E_a
Description of system if a ∈ A is implemented
Choice

Classical techniques for Generic problems

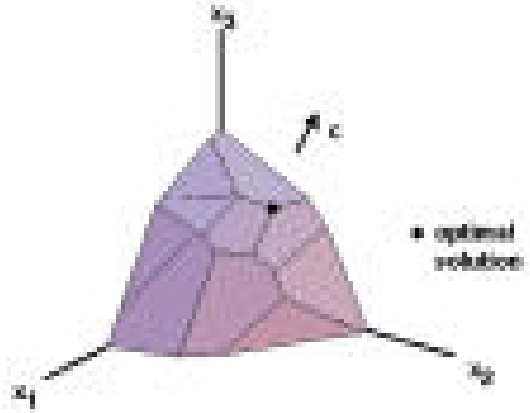
- **Very high number of alternatives**
- **Interdependent decision**

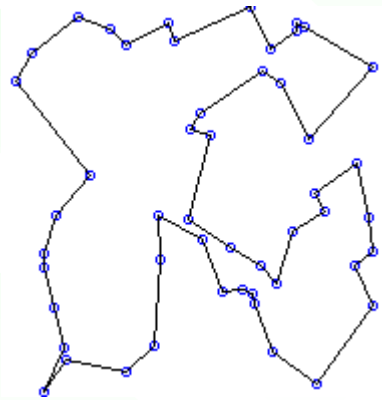
Mathematical Programming

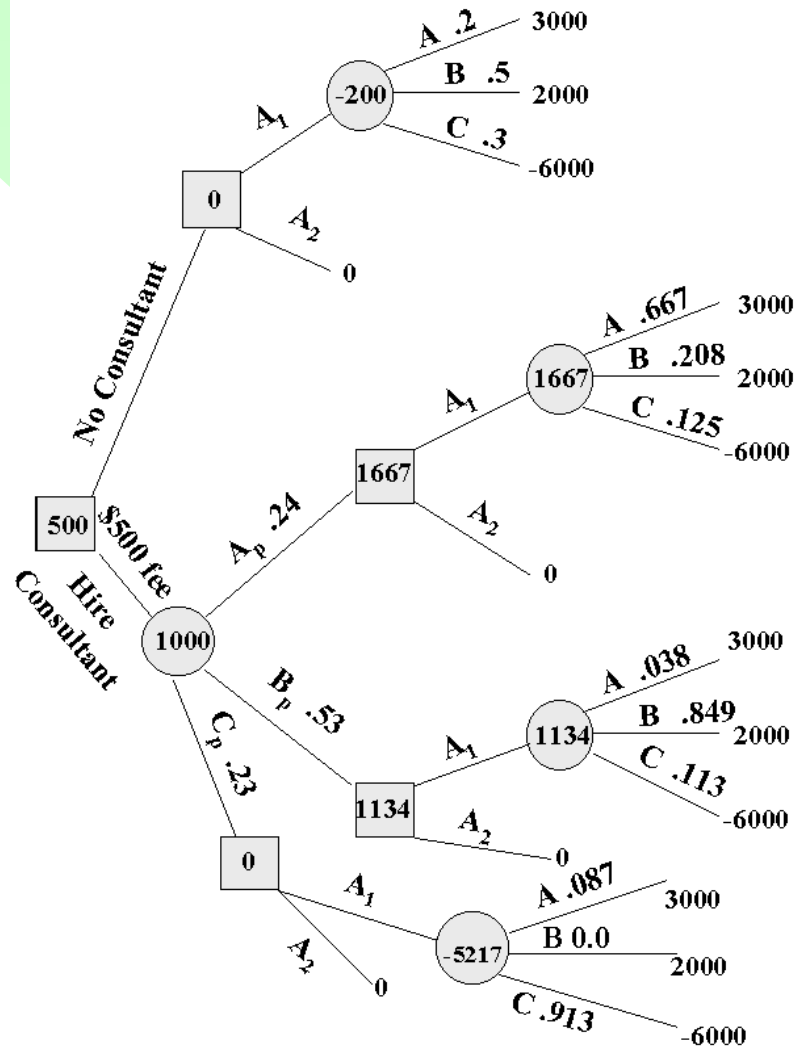
Combinatorial Optimization

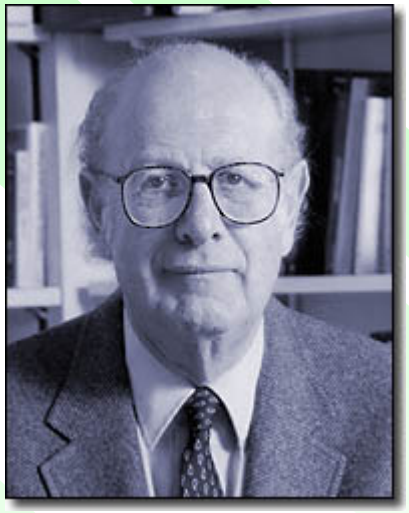
- **Uncertainty**

Bayesian Decision Theory

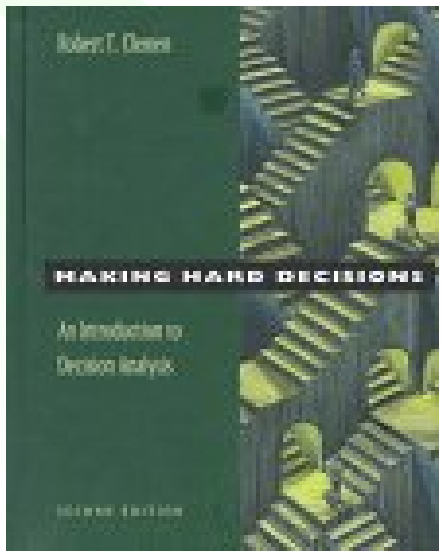

c
optimal solution

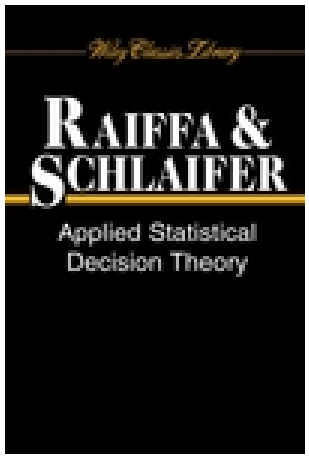



A .2
3000
B .5
2000
C .3
-6000
-200
A1
0
A2
0
No Consultant
A .667
3000
B .208
2000
C .125
-6000
1667
A1
1667
A2
0
500
$500 fee
Hire Consultant
Ap .24
1000
Bp .53
A .038
3000
B .849
2000
C .113
-6000
1134
A1
1134
A2
0
Cp .23
0
A1
A .087
3000
B 0.0
2000
C .913
-6000
-5217
A2
0

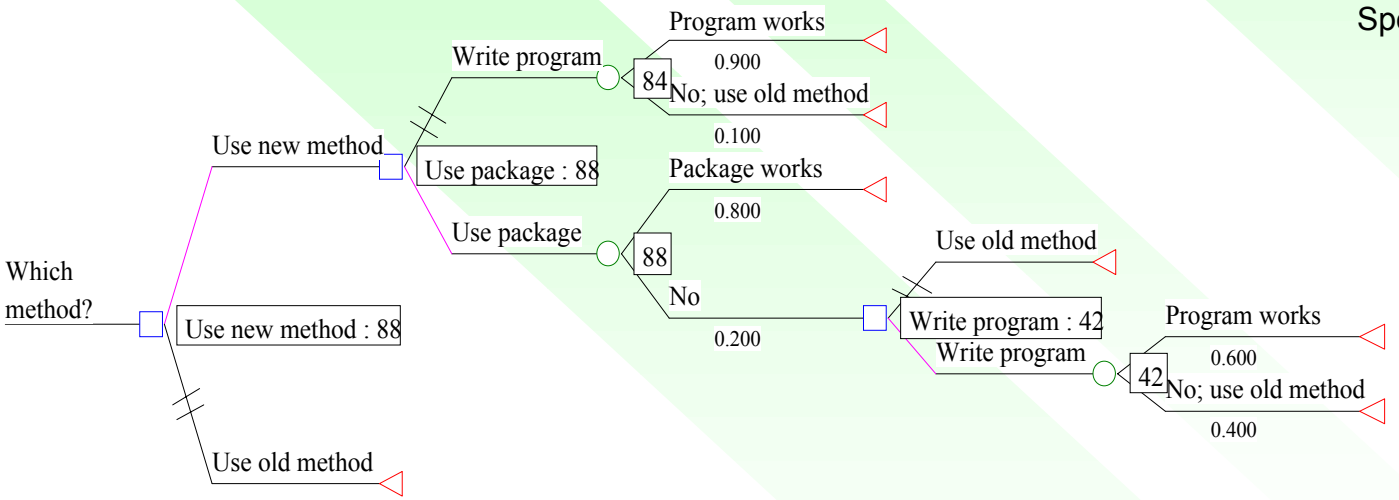



Leonard J. Savage
THE FOUNDATIONS OF
STATISTICS


Robert T. Clemen
MAKING HARD DECISIONS
An Introduction to
Decision Analysis


RAIFFA &
SCHLAIFER
Applied Statistical
Decision Theory

	Jesus' claims false	Jesus' claims true
I accept	some disappointment	infinite reward
I reject	no big deal	consider carefully!!! don't let it happen



Speed	Flexibility	Accuracy	Cost
92	92	92	92
21	21	21	21
100	100	100	100
24	24	24	24
70	70	70	70
0	0	0	0
32	32	32	32

Classical techniques

- **Time**

Dynamic Programming - Optimal Control - Sustainable Development

- **Retroactions**

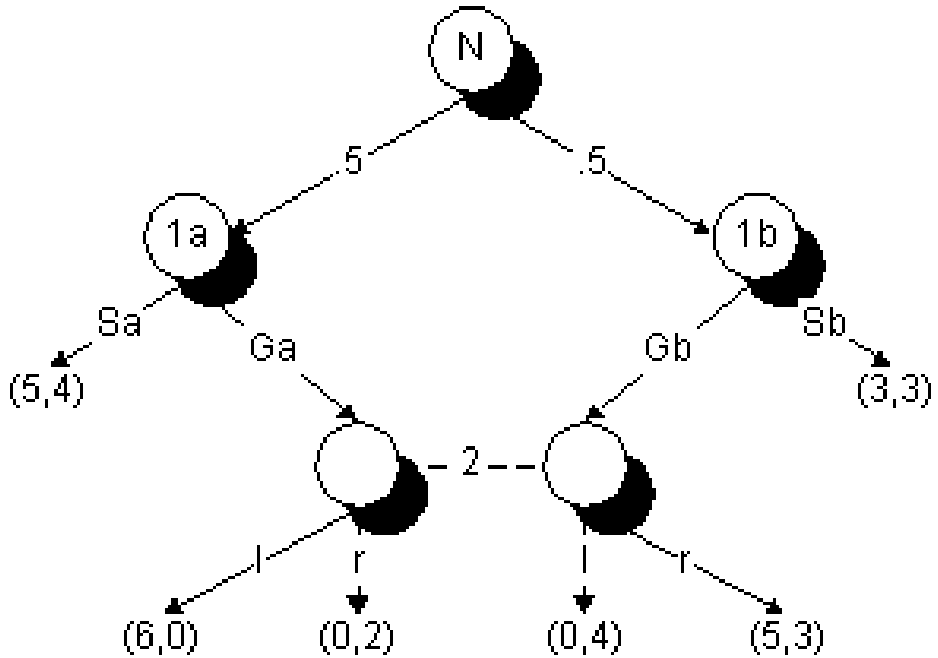
Game Theory

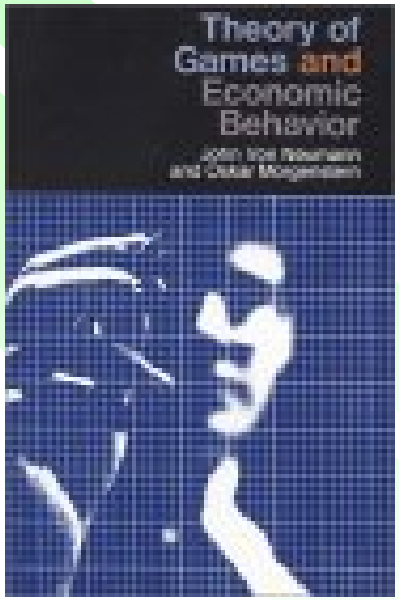
- **Group Decisions**

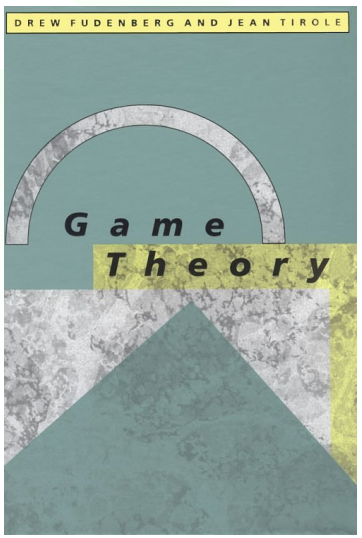
Social Choice Theory - Negotiation

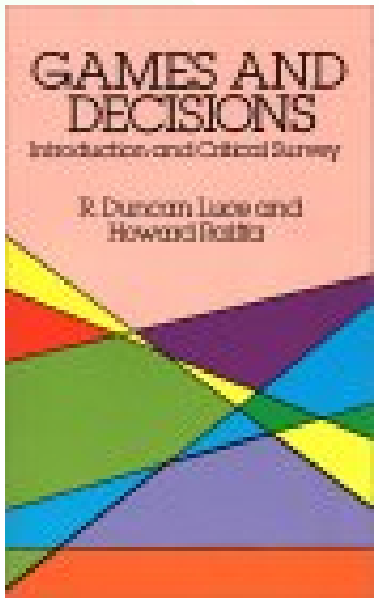
- **Multiple Criteria**

MCDM / MCDA


N
.5
.5
1a
1b
Sa
Ga
Gb
Sb
(5,4)
(3,3)
2
l
r
l
r
(6,0)
(0,2)
(0,4)
(5,3)


Theory of Games and Economic Behavior


DREW FUDENBERG AND JEAN TIROLE
Game Theory


GAMES AND DECISIONS
Introduction and Critical Survey
R. Duncan Luce and Howard Raiffa

- **John F. Nash, Nobel Prize in Economics (19)**

  “for his pioneering analysis of equilibria in the theory of non-cooperative games”

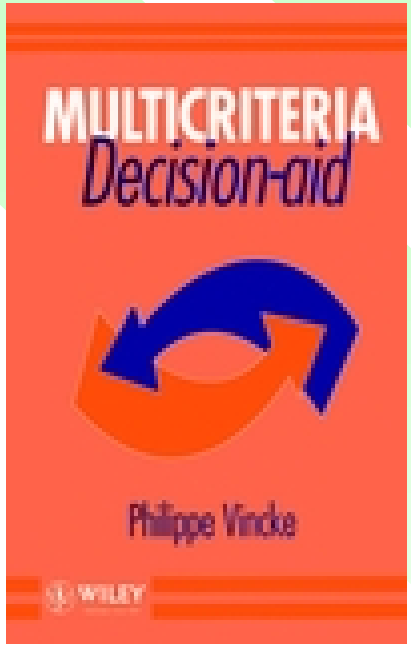
(together with John C. Hasanyi and Reinhard Selten)

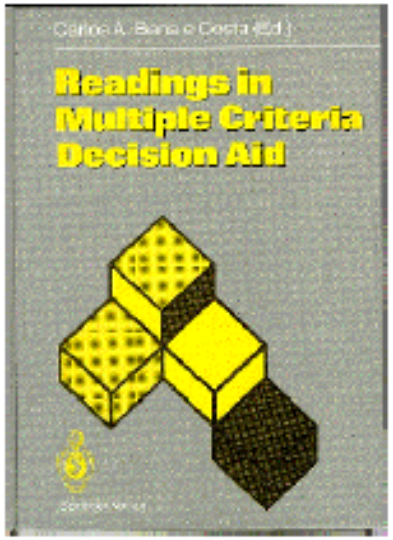
(besides being the subject of a movie)

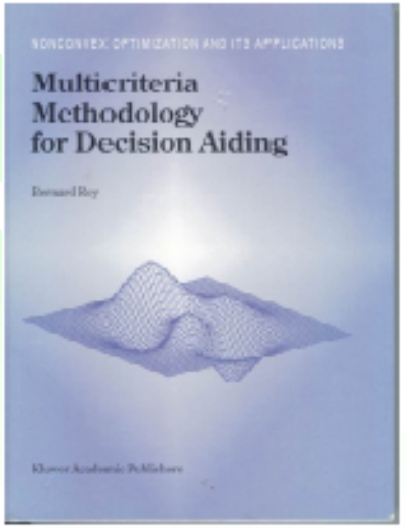
Vilfredo Pareto

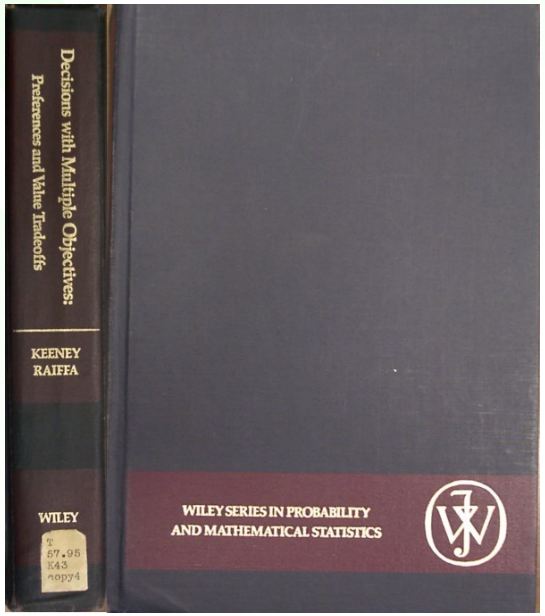
Expansion of the Cellular Phone System

- **Return on Investment**
  - **Implantation Costs**
- **Strategic Issues**
  - **Tourist Poles**
  - **Main Roads**
  - **Company Strategies**
  - **Market Residue**
  - **Geographic Location**
- **Potential Market**
  - **Estimated Demand**
  - **Declared Demand**
  - **Repressed Demand**
  - **Municipality Economy**


MULTICRITERIA
Decision-aid
Philippe Vincke
WILEY


Readings in
Multiple Criteria
Decision Aid


Multicriteria
Methodology
for Decision Aiding


Decisions with Multiple Objectives:
Preferences and Value Tradeoffs
KEENEY
RAIFFA
WILEY
WILEY SERIES IN PROBABILITY
AND MATHEMATICAL STATISTICS

Examples

- Optimization
- Decisions with retroaction of the system

Particular case: Optimization

- **A is stable; alternatives are exclusive**
- **System and objectives allow to summarize E_x by a unique *performance measure***
- **Examples**
  - ➪ **Profit, Sales, Quality, Jobs, Pollution**
- $a \in A \rightarrow E_a \rightarrow f(a)$

E_a preferred to $E_b \Leftrightarrow f(a) > f(b)$

E_a indifferent to $E_b \Leftrightarrow f(a) = f(b)$

Optimization

- **Choose an alternative $a \in A$ making**
  {Maximum *or* Minimum}
  the performance measure $f(a)$

$$\max_{a \in A} f(a) \quad \text{or} \quad \min_{a \in A} f(a)$$

- **Optimize = Maximize or Minimize**
  depending on the nature of $f(a)$

Definition

"Solving" $\boxed{\underset{a \in A}{\text{Max}}\ f(a)}$

means

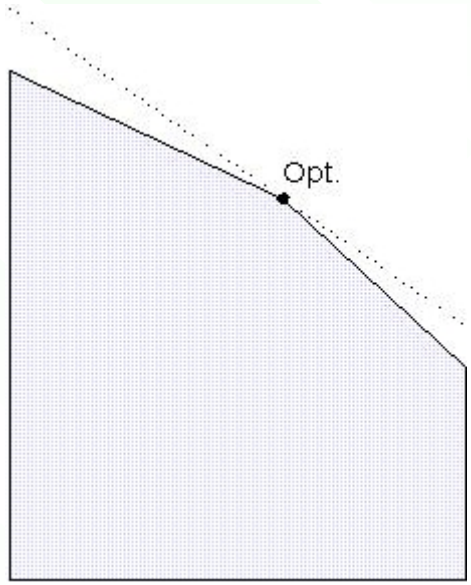
"find, if any, an alternative $a^* \in A$ such that:

$f(a^*) \geq f(a), \forall\ a \in A$"

- **Variants**
  - **find *all* optimal alternatives**
  - **find "good" alternatives**
  - **find "robust" alternatives**

If any?

- **Possible cases**
  - $A = \emptyset$ (no solution, no optimal solution)
  - $A \neq \emptyset$
    - f bounded on A
      - Optimal solution or not
    - f not bounded on A (no optimal solution)



"Optimal decision" contingent to:

- Objectives
- S: System
- A: set of alternatives
- E_a: Description of consequences
- Optimization model is an *aid* to decision
  - ⇨ discuss/modify the optimal solution
  - ⇨ integrate neglected aspects
  - ⇨ Redefine S, A or E_a
- In many cases the very idea of an "optimal solution" is meaningless

Difficulty of Optimization problems

- 2 cases:
  - A finite
  - A infinite
- A finite

$a \in A \rightarrow E_a \rightarrow f(a)$

$b \in A \rightarrow E_b \rightarrow f(b)$

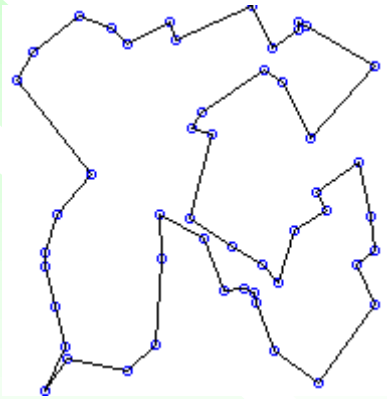
$c \in A \rightarrow E_c \rightarrow f(c)$

Choose the optimal solution by simple inspection?

Traveling Salesman Problem (TSP)

- **Build a "tour": Start from a depot, visit *n* clients and go back to the depot**
- **Constraints**
  - **time windows**
  - **capacity**
  - **roads**
  - **loading / unloading**
- **Examples**
  - **Post (collecting and distributing mail)**
  - **Garbage collection**
  - **Snow**
  - **Milk, etc.**

TSP



- Start, visit n points, return
- A = {set of feasible tours}
- |A| = $n!$ ($n!/2$ if symmetry)
- $69! = 10^{98}$
- Evaluation of 1 tour $\cong$ 100 operations
- 10 000 MIPS $\Rightarrow$ 1 tour each 10^{-8} seconds
- optimal solution after … 10^{90} seconds !!
  (10^{15} seconds since the Big Bang)

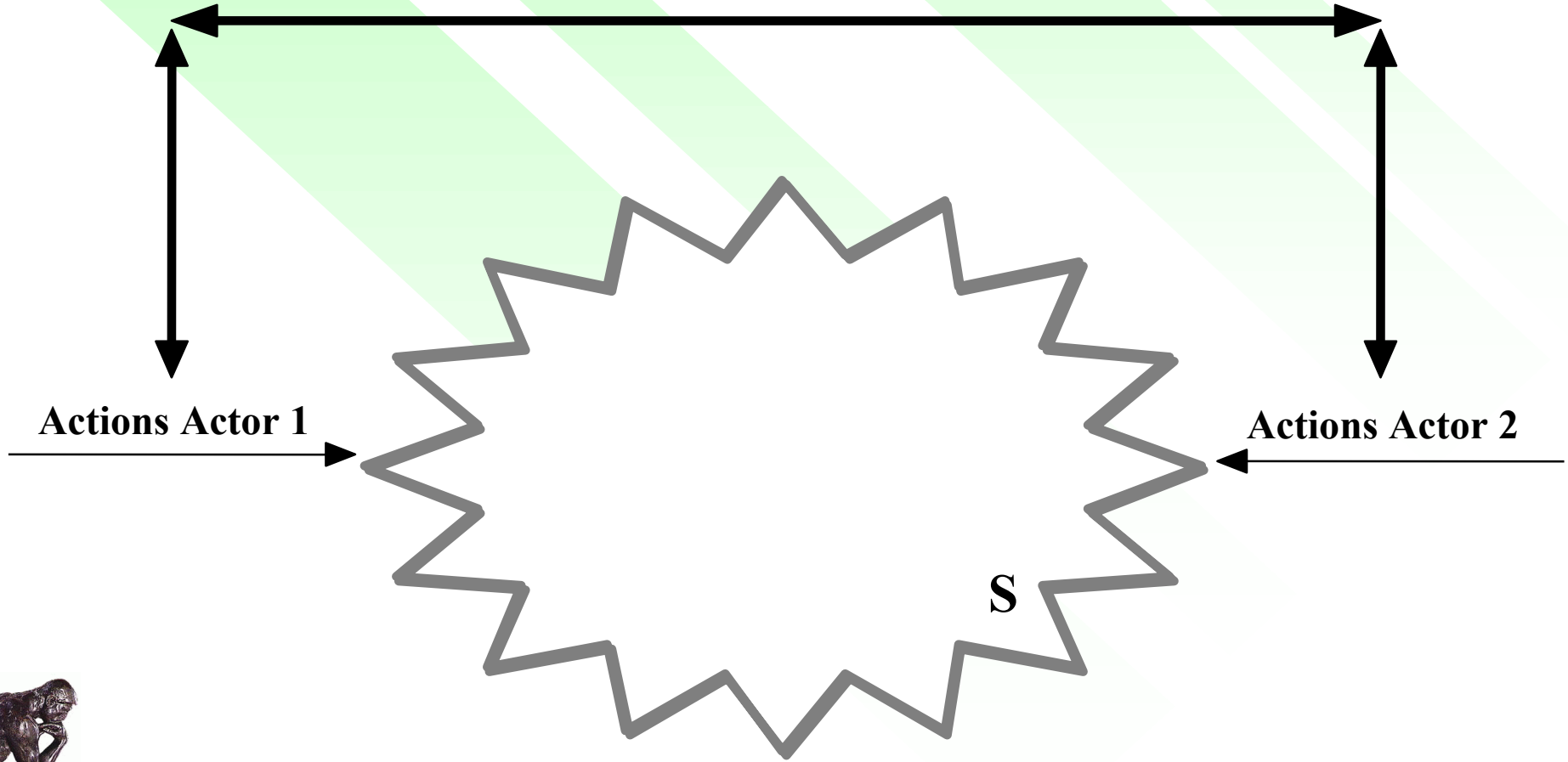
	A	B	C	D	E	*F*
A	0	1	7	3	14	2
B	1	0	6	9	1	24
C	7	6	0	3	7	3
D	3	9	3	0	9	11
E	14	1	7	9	0	4
F	2	24	3	11	4	0

Results

- **Greedy Algorithm**
  - Start from F
  - Go to the nearest unvisited city
  - Continue until each city is visited
  - Go back to F
  - Solution = 25
- **Optimal solution (Little)**
  - Solution = 15
  - difference: 66%

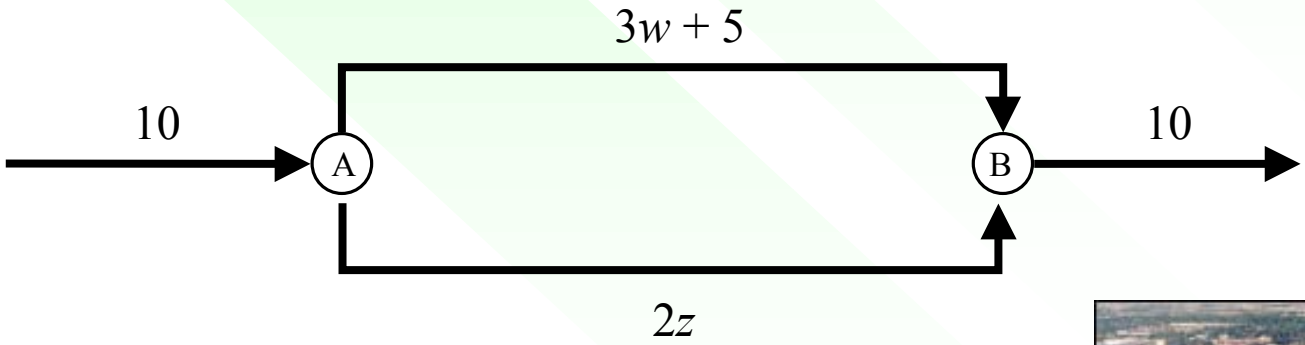
	A	B	C	D	E	*F*
A	0	1	7	3	14	2
B	1	0	6	9	1	24
C	7	6	0	3	7	3
D	3	9	3	0	9	11
E	14	1	7	9	0	4
F	2	24	3	11	4	0

Example: retroaction



“Competition” on a network

- **Road network: point A to point B**
  - **10 Kusers**
  - **2 routes**
  - **travel time (“cost”) = *f*(# of users on route)**



Liberal Regulation

- Informed users choose the route according to travel times
- "Wardrop": equilibrium if
  - cost of two routes is equal
  - $3w + 5 = 2(10 - w) \Rightarrow w = 3$
  - 3 Kusers on upper route (cost = 14)
  - 10 – 3 = 7 Kusers on lower route (cost = 14)
- Each user "pays" 14
- Social "cost" = 140 (time lost in the network)

Bureaucratic Regulation

- A bureaucrat located at A makes the choices for the users. He wishes to minimize social cost

  $CT(w) = w(3w + 5) + 2(10 - w)^2 = 5w^2 - 35w + 200$

- Minimization

  $CT'(w) = 10w - 35 = 0 \Rightarrow w = 3{,}5$

  - 3,5 Kuser on upper route each paying:

    $(3 \times 3{,}5 + 5) = 15{,}5$

  - 6,5 Kusers on lower route each paying:

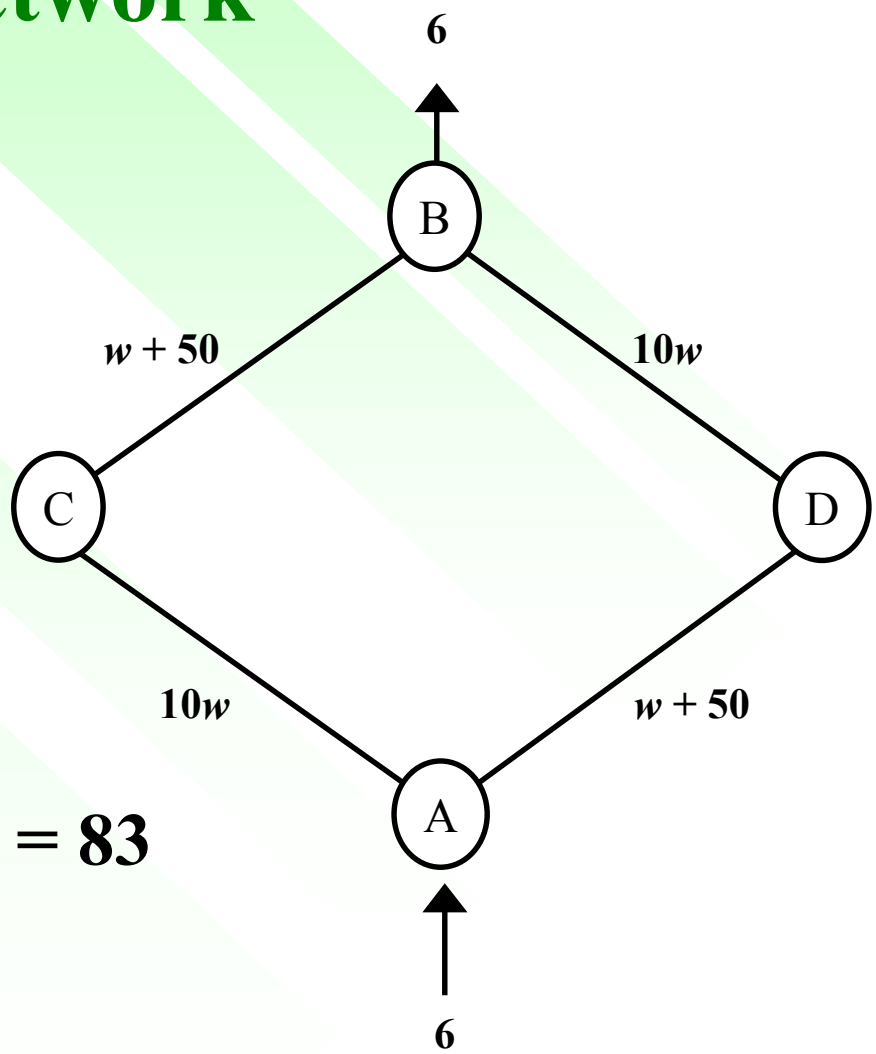
  - $2 \times 6{,}5 = 13$

- Social cost = $3{,}5(3 \times 3{,}5 + 5) + 2(10 - 3{,}5)2 = 138{,}75$

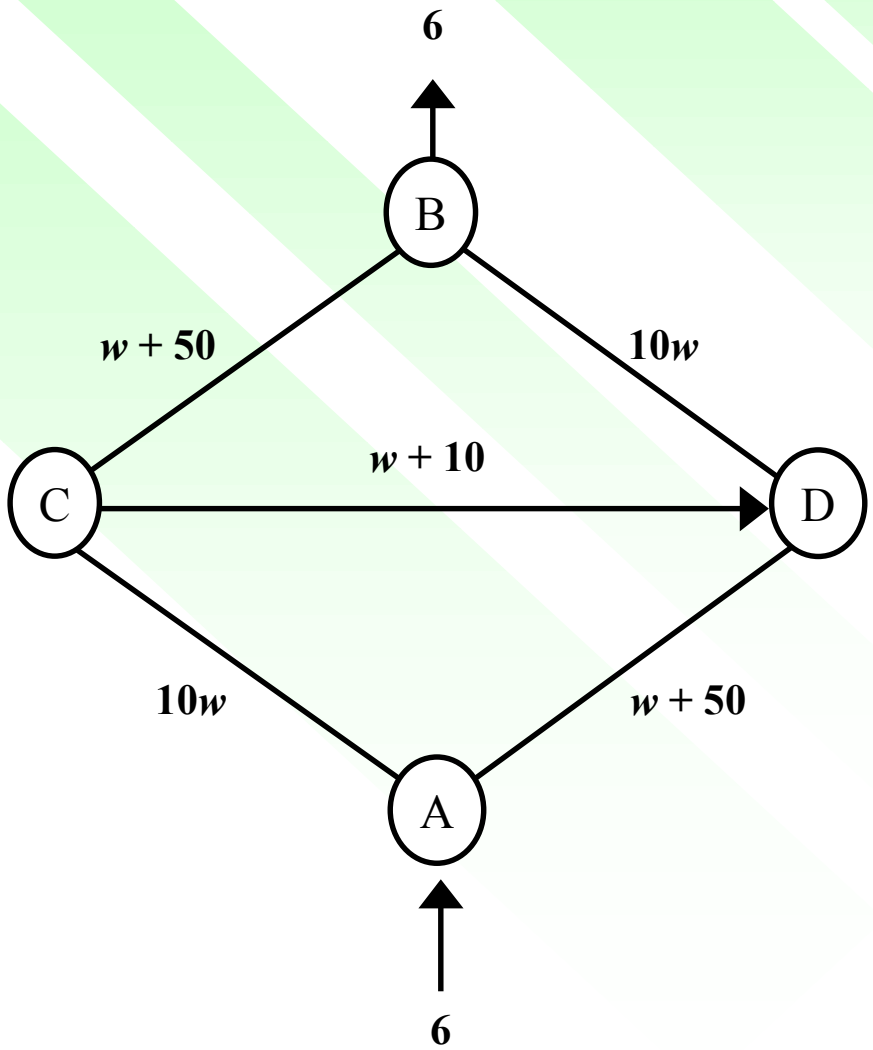
- Efficiency *vs.* Justice ??

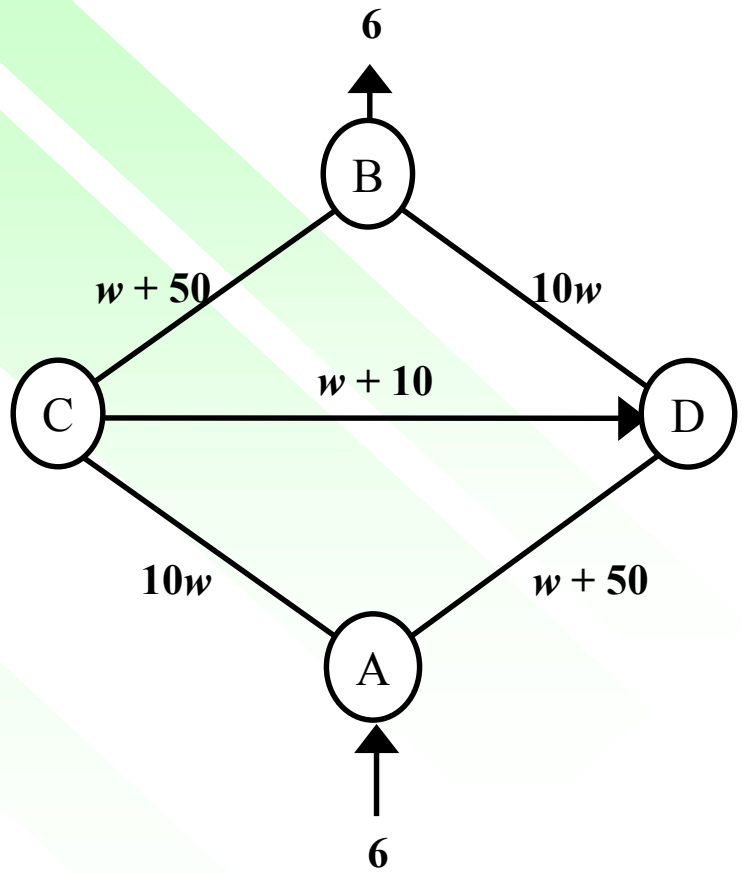
Another Network

- A to B
  - 6 Kusers
  - 2 routes (via C or D)
  - Perfect Information
- Liberal regulation
  - 3 Kuser on ACB
  - 3 Kuser on ADB
- Cost per user = $10 \times 3 + 50 + 3 = 83$
- Social cost = $83 \times 6 = 498$



Improving the network



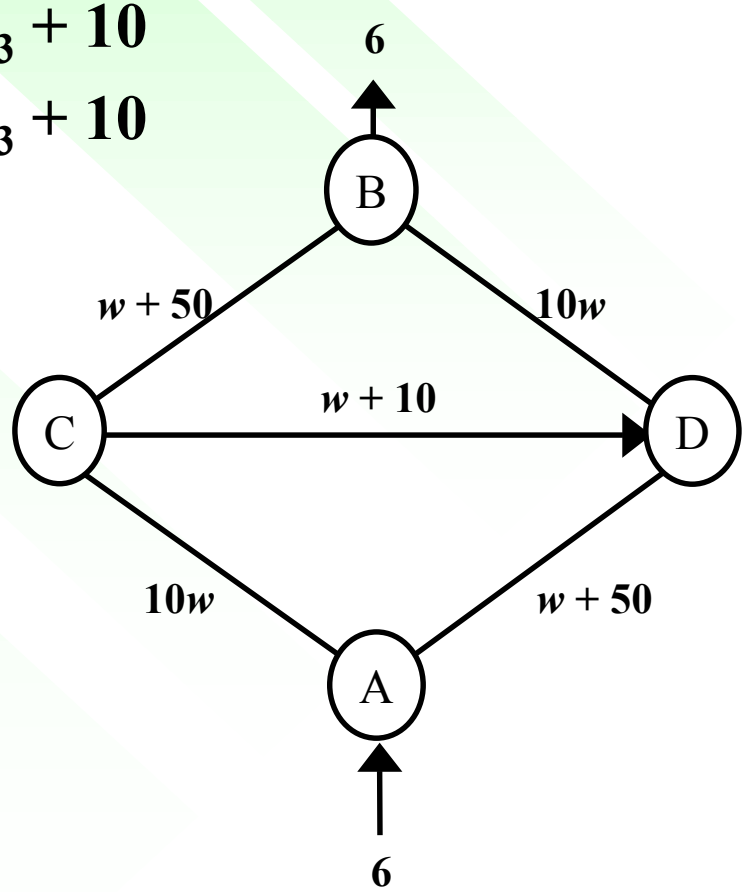


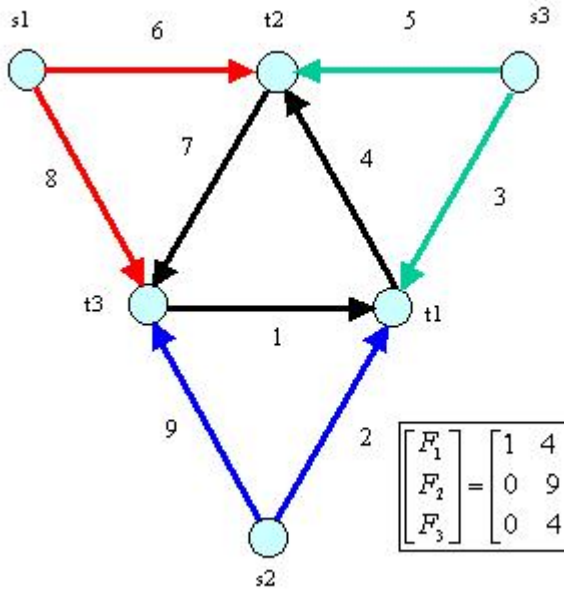
- **3 possible routes from A to B:**
  - A C B (w_1 users)
  - A D B (w_2 users)
  - A C D B (w_3 users)
- **Hypothesis: Perfect Information**
- **Cost per user:**
  - A C B: $c(1) = 10(w_1 + w_3) + (w_1 + 50) = 11w_1 + 10w_3 + 50$
  - A D B: $c(2) = (w_2 + 50) + 10(w_2 + w_3) = 11w_2 + 10w_3 + 50$
  - A C D B: $c(3) = 10(w_1 + w_3) + (10 + w_3) + 10(w_2 + w_3) = 10w_1 + 10w_2 + 21w_3 + 10$

- **Equilibrium:**
  - $11w_1 + 10w_3 + 50 = 10w_1 + 10w_2 + 21w_3 + 10$
  - $11w_2 + 10w_3 + 50 = 10w_1 + 10w_2 + 21w_3 + 10$
  - $w_1 + w_2 + w_3 = 6$

- **Solution:** $w_1 = w_2 = w_3 = 2$
- **Cost per route = 92**

- **Social Cost** $= 6 \times 92 = 552 > 498$ **!**





$$\begin{bmatrix} F_1 \\ F_2 \\ F_3 \end{bmatrix} = \begin{bmatrix} 1 & 4 & 0 \\ 0 & 9 & 0 \\ 0 & 4 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$