What Strategic Planners Need to Know in the Age of Uncertainty

Yakov Ben-Haim
Technion – Israel Institute of Technology

The claim: 2 types of expertise

First expertise:

Extensive **topical, disciplinary expertise**, and

broad understanding of human affairs.

Based on:

history, economics, political science, anthropology, psychology, engineering etc.

Second expertise:

Methodological **expertise in decisions under uncertainty.**

Based on: decision theory (including **info-gap theory**).

Strategic planners need expertise in both domains.

3 reasons for double expertise

Uncertainty and indeterminism in human affairs.

Ignorance and surprise are common and must be managed.

Uniqueness of each historical situation.

The past is only partial indication of the future.

Theory only partially explains reality.

Pluralism of assessment is essential.

Don't seek the single best model.

Seek diverse perspectives.

Use decision theory to manage disputed understanding.

~~~

Decision theory supports good decision making.
~~~

Attributes of good decision theory

Handles both quantitative and qualitative situations.

Handles uncertainty in facts and functional relations.

Generic:

Applicable to any and all situations and uncertainties

Innovation dilemma: The Idea

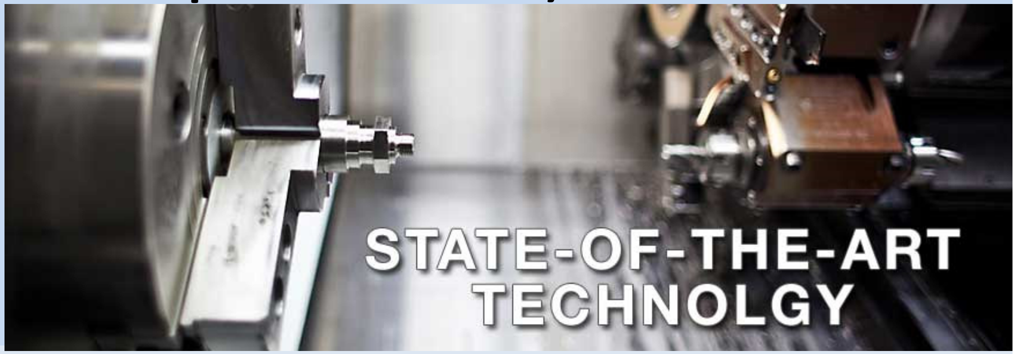
Choose between 2 options:

Option 1: (paradigm: new technology)

- New and innovative.
- Very promising.
- Higher uncertainty.

Option 2: (paradigm: standard procedure).

- State of the art.
- Less promising.
- Lower uncertainty.



Dilemma due to uncertainty.

Innovation dilemma: Examples

Automobile steering and collision control:

- Autonomous sensor-based computer control (innov).
- Human steering and foot-break system (SotA).

Monetary policy:

- New tools for new situations (innov).
- "A little stodginess at the CB" (Blinder) (SotA).

Peace or War:

- Bold diplomatic initiative (Sadat to Jerusalem, '77) (innov).
- Conventional diplomatic-military cycle (SotA).

Risk taking or avoiding:

- Nothing ventured, nothing gained (innov).
- Nothing ventured, nothing lost (SotA).

Probabilistic risk

or

Knightian “true uncertainty”

Probabilistic Risk

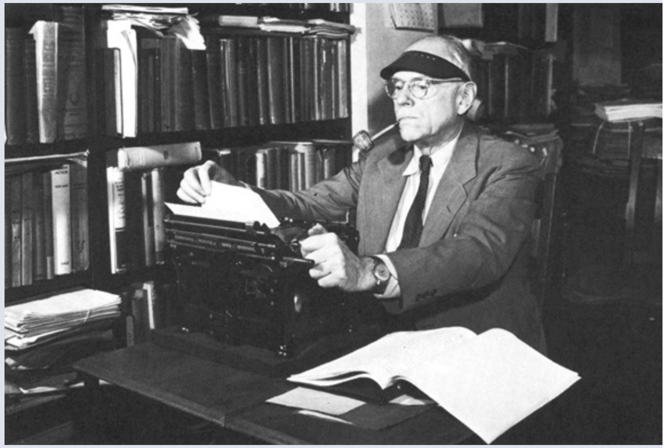
Consequence	Probability
Drought	Stochastic process
Industrial accident	Actuarial tables
Tsunami	Historical data
Faulty air filters	Quality control data
Deception, scam	Sociological data

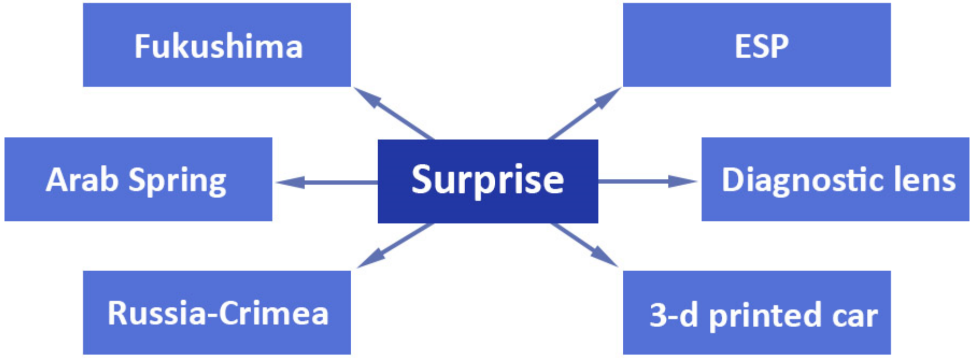
Risk is:

- Structured: known event space
- Modeled with probability
- Manageable (but still risky)

Frank Knight's "true uncertainty"

"The uncertainties which persist … are **uninsurable** because there is **no objective measure of the probability**".





Wheeler's Island

"We live on an island of knowledge
surrounded by a sea of ignorance.
As our island of knowledge grows,
so does the shore of our ignorance."

John A. Wheeler

Non-probabilistic true uncertainty

D Discovery

- o America
- o Nuclear fission
- o Martians (not yet?)

Non-probabilistic true uncertainty

D Discovery

I Invention/Innovation

- Printing press: material invention.
- Ecological responsibility: conceptual innovation.
- French revolution: social innovation.

Non-probabilistic true uncertainty

D Discovery

I Invention/Innovation

S Surprise (Asymmetric uncertainty)

- Ambush
- Competitor's innovation
- Natural catastrophe

Non-probabilistic true uncertainty

D Discovery

I Invention/Innovation

S Surprise (Asymmetric uncertainty)

What's the next D I or S ???

Knightian uncertainty:

- Unstructured: unknown event space.
- Indeterminate: no laws.
- Barely manageable (huge info-gaps).

What is an info-gap?

Info-gap:

Disparity between what one

does know

and what one

needs to know

in order to make a

responsible decision.

Two elements: **uncertainty** and **consequence**.

Distinct from probability.

Questions

When to use info-gap theory, and when not?

What do you learn from an info-gap analysis?

How to do an info-gap analysis?

When to use info-gap?

Manage uncertainty in
parameters, vectors and especially **functions.**

Probability distributions are uncertain or lacking.

You don't need info-gap if you know pdf's.

Info-gap uncertainty: examples

- Transcendental probability.
- Policy for climate change.
- Profiling criminals.

Carroll's Transcendental Probability

Riddle from *Pillow Problems*:

"A bag contains 2 counters, as to which nothing is known except that each is either black or white. Ascertain their colours without taking them out of the bag."

Answer: "One is black, and the other white."

Charles Dodgson

Alice

Policy for climate change

Sustained rise in green house gases causes:

- Temperature rise.
- Economic loss.

Models:

- Temperature change: $\Delta CO2 \Rightarrow \Delta T$.
- Economic impact: $\Delta T \Rightarrow \Delta GDP$.

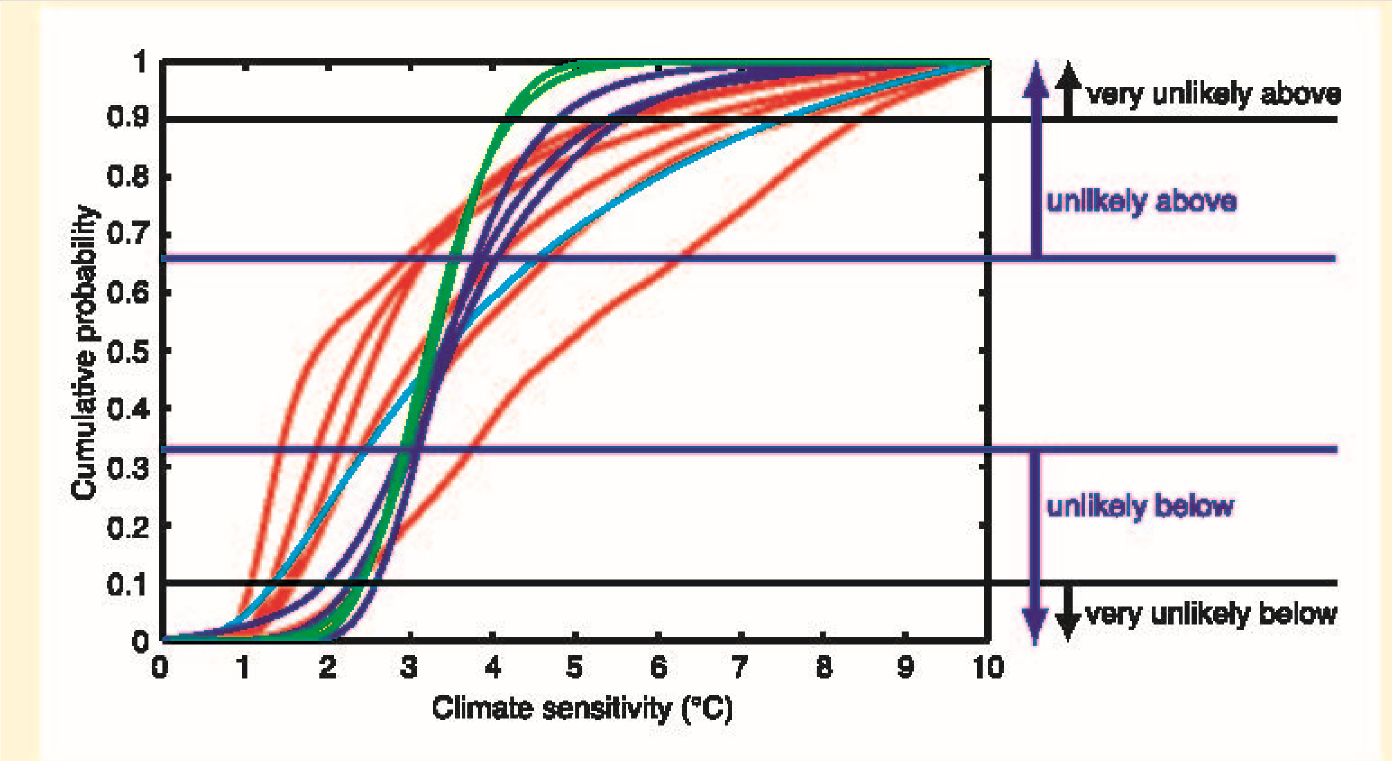
The problems:

- Models highly uncertain.
- Data controversial.

Policy for climate change

E.g., IPCC model for equilibrium clim. sensitivity, S.

- Likely range: 1.5C to 4.5C.
- Extreme values highly uncertain: **info-gaps.**
- 10 models for *P(S)*:



Profiling Criminals

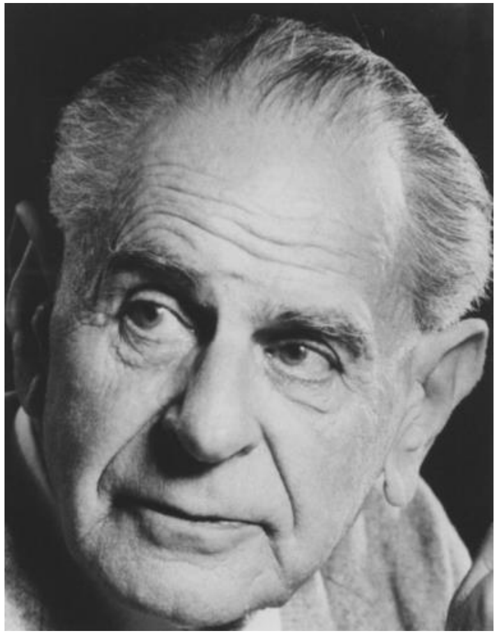
Profiling: focus policing resources.

- **Arrests rise** in profiled group.
- **Crime rises** in other groups.
- **Everybody happy?**

Info-gap: Uncertain response functions.

Shackle-Popper indeterminism

GLS Shackle, 1903-1992



Karl Popper, 1902-1994

Shackle-Popper Indeterminism

Intelligence:

What people **know**, influences how they **behave**.

Discovery:

What will be **discovered tomorrow** can't be **known today**.

Implies

Indeterminism:

Tomorrow's behavior can't be fully modelled today.

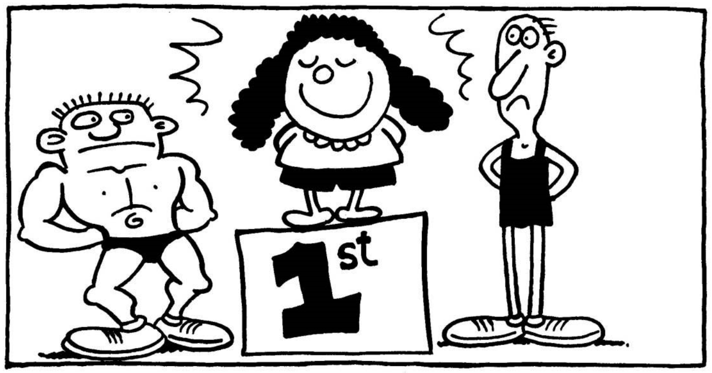
- Info-gaps, indeterminism: **unpredictable.**
- **Ignorance is not probabilistic.**

Uncertainty and the Optimization Imperative

Doing your best:

What does that mean?

- Outcome optimization.
- Procedural optimization.



Implications for decision making:

Robust satisficing.

Doing Your Best

Substantive outcome optimization:

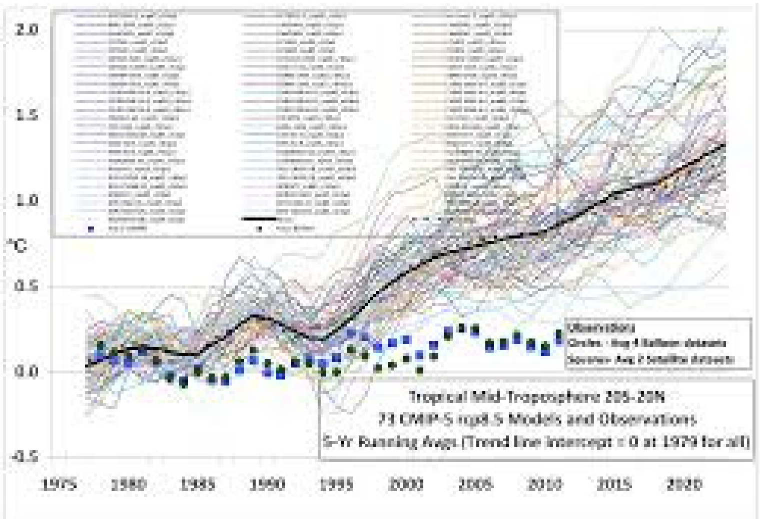
- Predict outcomes of available options.
- Select predicted best option.

Doing Your Best

Substantive outcome optimization.

Useful under risk:

- Structured uncertainty.
- Reliable probabilistic predictions.



Doing Your Best

Substantive outcome optimization:

Useful under risk.

Not useful (irresponsible?) under uncertainty.

- Unstructured uncertainty.
- Unreliable predictions.

Questions

What do we (not) know?

Robustness questions:

- What is an **essential** outcome?
- How to be **robust** to **surprise**?

Opportuneness questions:

- What is a **windfall** outcome?
- How to exploit **opportunities**?

How to prioritize decision options?

What are the trade offs?

Answers: info-gap theory

Robustness answer:

System model
Outcome requirements
Uncertainty model

→ Robustness function → Prioritized options

Opportuneness answer:

System model
Outcome aspirations
Uncertainty model

→ Opportuneness function → Prioritized options

Robust Satisficing

Two questions for decision makers:

1. What are our goals?
2. How much error/surprise can we tolerate?

Robust Satisficing

Two questions for decision makers:

1. What are our goals?
2. How much error/surprise can we tolerate?

1. Satisficing: Achieving critical outcomes.

- Essential goals.
- Worst acceptable outcomes.
- Modest or ambitious.

Robust Satisficing

Two questions for decision makers:

1. What are our goals?
2. How much error/surprise can we tolerate?

1. Satisficing: Achieving critical outcomes.

2. Robustness:

- Immunity to ignorance.
- Greatest tolerable error or surprise.

Robust Satisficing

Two questions for decision makers:

1. What are our goals?
2. How much error/surprise can we tolerate?

1. Satisficing: Achieving critical outcomes.

2. Robustness: Greatest tolerable error.

Optimize robustness; satisfice goals:

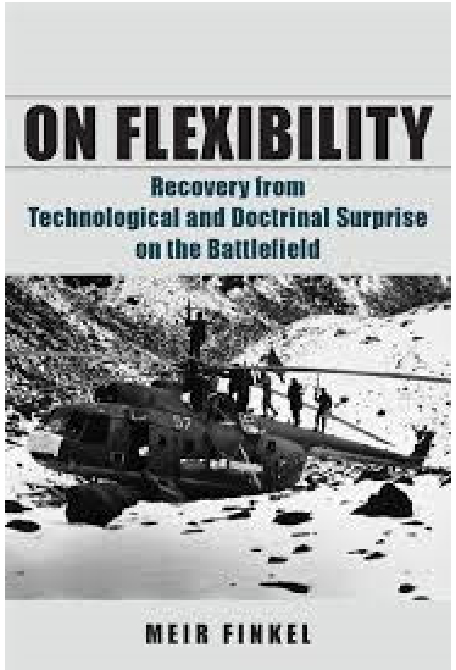
Procedural (not substantive) **optimization.**

Don't try to **optimize the outcome.**

Achieving Robustness

Flexibility (Finkel).

"The solution to technological and doctrinal surprise lies **not in predicting** the nature of the future battlefield **or obtaining information** about the enemy's preparations ..., but in the **ability to recuperate from the initial surprise."**



Achieving Robustness

Flexibility (Finkel).

Indirect approach (Liddell Hart).

- "Line of operation which offers alternative objectives."
- "Plan and dispositions are flexible-adaptable to circumstances."

Achieving Robustness

Flexibility (Finkel).

Indirect approach (Liddell Hart).

Complementary approaches:

- **Finkel:** manage our uncertainty.
- **Liddell Hart:** exploit their uncertainty.

Achieving Robustness

Flexibility (Finkel).

Indirect approach (Liddell Hart).

Complementary approaches: Finkel and Liddell Hart.

Robustness and sub-optimality (Luttwak).

"The scientist's natural pursuit of **elegant solutions** and the engineer's quest for **optimality** …"

Achieving Robustness

Flexibility (Finkel).

Indirect approach (Liddell Hart).

Complementary approaches: Finkel and Liddell Hart.

Robustness and sub-optimality (Luttwak).

"The scientist's natural pursuit of **elegant solutions** and the engineer's quest for **optimality** can often yield failure in the paradoxical realm of strategy."

Achieving Robustness

Flexibility (Finkel).

Indirect approach (Liddell Hart).

Complementary approaches: Finkel and Liddell Hart.

Robustness and sub-optimality (Luttwak).

"The scientist's natural pursuit of **elegant solutions** and the engineer's quest for **optimality** can often yield failure in the paradoxical realm of strategy."

"the virtue of **suboptimal** but … **more resilient** solutions."

Achieving Robustness

Flexibility (Finkel).

Indirect approach (Liddell Hart).

Complementary approaches: Finkel and Liddell Hart.

Robustness and sub-optimality (Luttwak).

Robustness vs **outcome-optimality.**

Achieve **specified goals** with **maximal robustness** to surprise.

Don’t try to **optimize the outcome.**

Innovation dilemma of poverty

Rural poverty:

- Low agricultural productivity.
- High mortality/morbidity.
- Resentment and suspicion of government and NGOs.
- Local barons or warlords.

Innovative hi-tech proposal:

- New strains of plants.
- Better irrigation.
- Better fertilizers.
- Mechanization of field work.

Innovation dilemma of poverty

Potential gains from innovation:

- Higher agricultural productivity.
- Higher standard of living.
- Less arduous field work.

Potential losses from innovation:

- Failure of innovative crops, causing starvation.
- Social reorganization and upheaval.
- Rapid population growth, canceling gains (Malthus).

Dilemma: Innovation could be **much better**, or much worse.

How to choose?

Innovation dilemma of poverty

Basic questions:

- What are the **goals**?
- What is our **knowledge**?
- What are the **uncertainties**?

Robustness of an option:

Maximum tolerable uncertainty.

The knowledge-bifurcation. Is your knowledge:

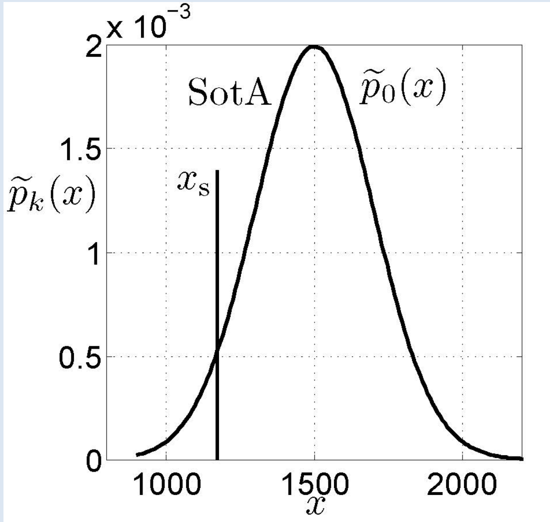
- **Quantitative:** data and equations?
- **Qualitative:** mainly insight and understanding,
  (perhaps with some numbers)?

We will consider both situations.

Poverty dilemma: quantitative

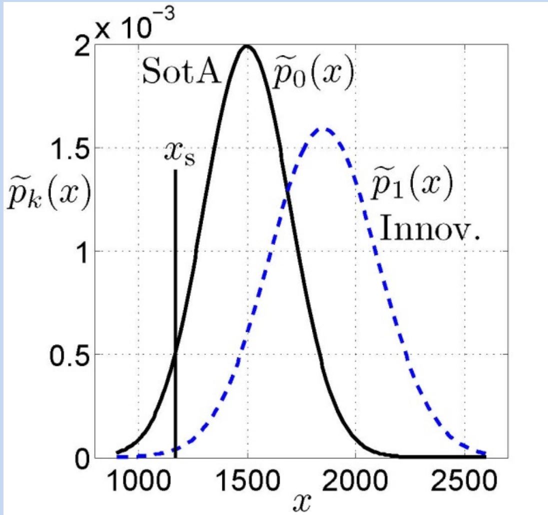
Field study of traditional State of the Art:

- Survival requirement: 1171 kg wheat/ha.
- Probability dist. of productivity **well known**.
- Survival probability: **0.95 (known).**
- Survival catastrophe return-time:
  20 years (known).



Knowledge about innovative option:

- Probability distribution of productivity
  estimated, uncertain.
- Survival probability: **0.9967 (estimate).**
- Survival catastrophe return-time:
  303 years (estimate).

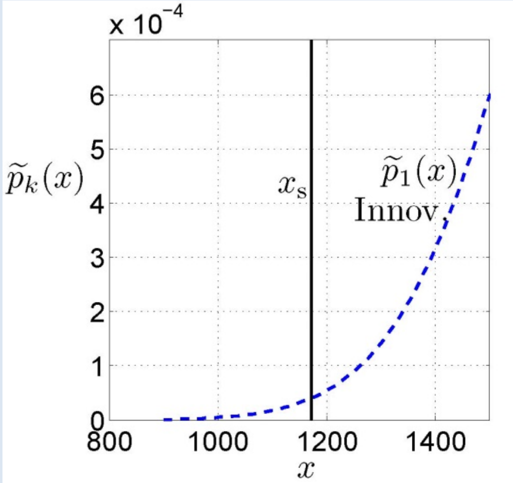


The choice is clear?

Poverty dilemma: quantitative

Info-gaps of innovative option:

- Prob. distribution of productivity: estimated.
- True tail (rare but bad): highly uncertain.
- Survival probability & catastrophe return-time may be **much worse than for SotA**.



How to model uncertainty in innovative pdf, *p1(x)*?

We will consider:

- Parameter uncertainty (very briefly).
- Functional uncertainty.

Parameter uncertainty

We know that *p1(x)* is normal: $p_1(x) \sim \mathcal{N}(\mu, \sigma^2)$

Estimated moments are uncertain:

$\mu = \tilde{\mu} \pm w_\mu$ or more, $\sigma = \tilde{\sigma} \pm w_\sigma$ or more

Unknown fractional errors:

$$\left|\frac{\mu - \tilde{\mu}}{w_\mu}\right| \leq h, \quad \left|\frac{\sigma - \tilde{\sigma}}{w_\sigma}\right| \leq h, \quad h \geq 0$$

Info-gap model of uncertainty:

$$\mathcal{U}(h) = \left\{\mu, \sigma : \ \left|\frac{\mu - \tilde{\mu}}{w_\mu}\right| \leq h, \ \ \sigma > 0, \ \left|\frac{\sigma - \tilde{\sigma}}{w_\sigma}\right| \leq h\right\}, \quad h \geq 0$$

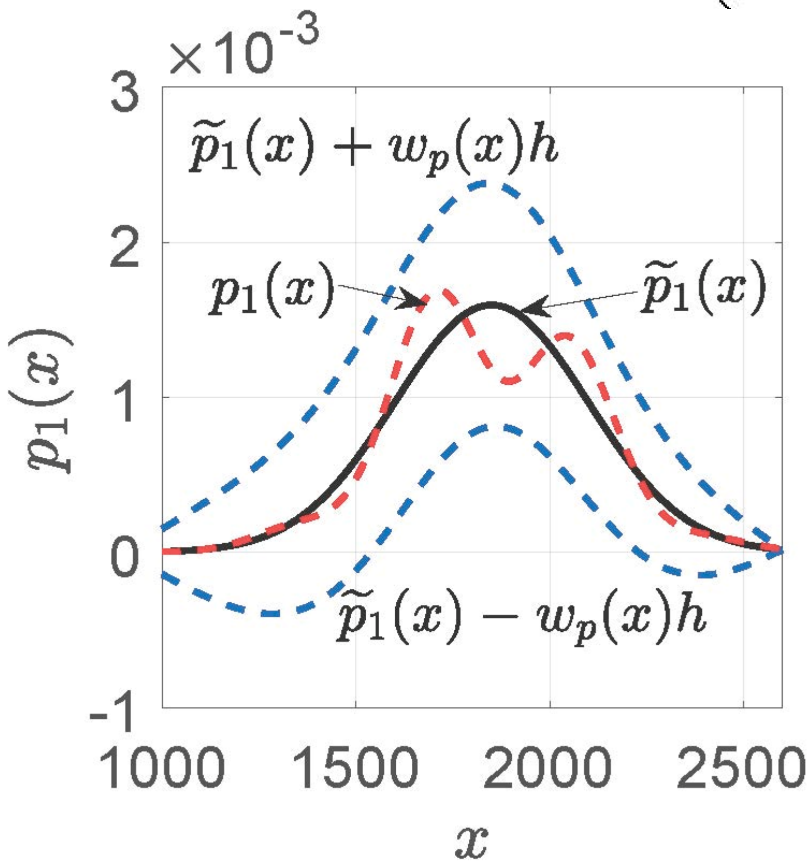
Functional uncertainty

Shape of *p1(x)* is uncertain.

Envelope-bound IGM:

$$\mathcal{U}(h) = \left\{ p_1(x) : \quad p_1(x) \geq 0, \quad \int p_1(x)\,\mathrm{d}x = 1 \right.$$

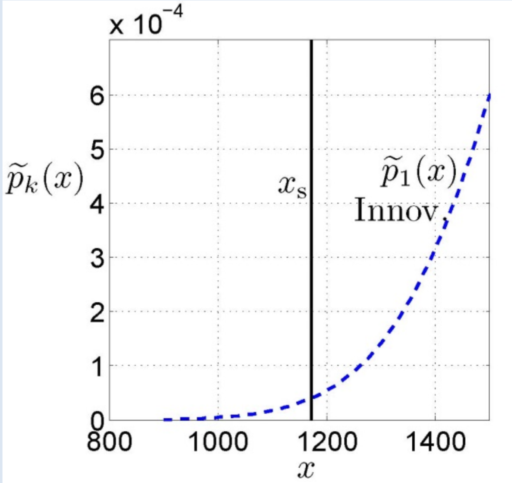
$$\left. \left| \frac{p_1(x) - \widetilde{p}_1(x)}{w_p(x)} \right| \leq h \right\}, \quad h \geq 0$$



Poverty dilemma: quantitative

Info-gap of innovative option:

- Prob. distribution of productivity: estimated.
- True tail (rare but bad): highly uncertain.
- Survival probability & catastrophe return-time may be **much worse than for SotA**.



Robustness of an option: How much error can we tolerate?

Greatest **uncertainty** at which current **knowledge** satisfies the survival **requirement**.

We **don't know** the error in the tail.

We **do know** (can evaluate) the robustness.

Use robustness to choose between the options.

Poverty dilemma: quantitative

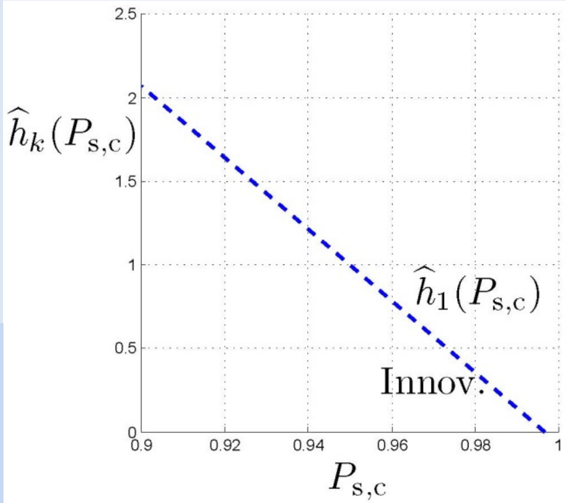
Robust prioritization: Innovation or SotA?

- Maximize robustness, satisfice outcome.
- Don’t try to optimize the outcome.

Poverty dilemma: quantitative

Robustness of innovative option:

Zeroing: No robustness at estimated survival probability.

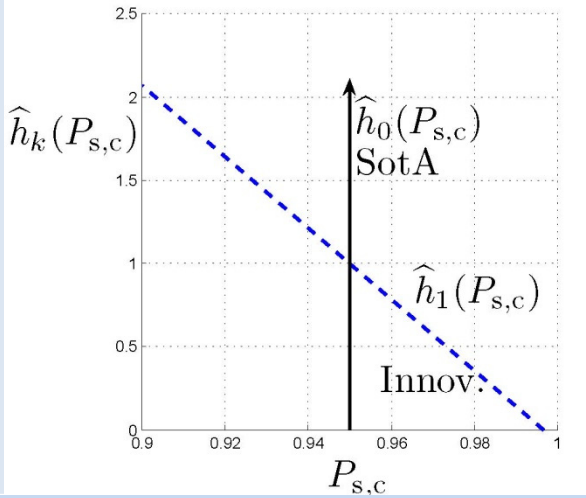


Pessimist's thm. Trade off:

Higher survival prob ⟺ lower robustness

Robustness of SotA:

- **Unbounded** for survival probability up to 0.95.
- **Zero** for survival probability above 0.95.



Decision: Choose by robustly satisfying the requirement.

Poverty dilemma: qualitative

Now for the hard part:

Qualitative analysis of robustness.

Robustness of an option:

- We can't evaluate it quantitatively.
- Assess it qualitatively with **proxies for robustness**:
  - **Resilience**: rapid recovery of critical functions.
  - **Redundancy**: multiple alternative solutions.
  - **Flexibility**: rapid modification of tools and methods.
  - **Adaptiveness**: adjust goals and methods online.
  - **Comprehensiveness**: interdisciplinary system-wide coherence.

Poverty dilemma: qualitative

Basic questions:

- What are the **goals**?
- What is our **knowledge**?
- What are the **uncertainties**?

Bernard Amadei: pumps or water carriers?

- **Goal**: more potable water.
- **Knowledge**: Abundant fuel. Pump tech. Local culture.
- **Uncertainties:**
  - Long-term pump maintenance? Catastrophe if not.
  - Stable fuel supply?
  - Social response: what happens to the girls?

Poverty dilemma: qualitative

Robust solution:

- **Satisfice** the goal. Don’t try to maximize. (Exploit trade off)
- **Co-design**: local involvement in all stages (comprehensive).
- **Train** locals in pump maintenance (resilience, flexibility).
- **Transition period** of dual supply (redundancy).
- **Long-term contact** for emergency support (adaptiveness).
- **Education** for girls (and boys) (comprehensiveness).
- **Quantitative** analysis where possible.

Poverty dilemma: qualitative

Methodological re-cap:

- **Trade off:** higher ambition = lower robustness.

  Ambitions: Yes. Wishful thinking: No.
- **Zeroing:** Best-estimated outcomes have no robustness.
- **Satisfice** your goals. **Optimize** your robustness.

  Don’t try to maximize the outcome.
- **Preference reversal:** sub-optimal may be more robust:

  Wood burning steam pump more robust to uncertainty than solar electric technology.

Iraqi WMD in 2002

Intel in 2002: Iraq holds major WMDs.

Iraqi WMD in 2002

Intel in 2002: Iraq holds major WMDs.

Leads to 2003 Decision:

Launch Operation Iraqi Freedom.

Iraqi WMD in 2002

3 scenarios after review and analysis (Canton):

- **Scenario 1:** Iraq destroyed stockpiles.
- **Scenario 2:** Iraq has stockpiles.

  Limited ability to make more.
- **Scenario 3:** Stockpiles being replenished.

Lead analyst believes:

- **Scenario 1 is most likely.**
- **Scenario 3 cannot be ruled out.**
- **Intel** on Iraqi chemical weapons **limited and weak.**
- Intel volume is growing; quality is doubtful.

Iraqi WMD in 2002

Info-gap robust-satisficing extends Canton's analysis:

Supports policymaker's choice between:

- No Initiation of War (**NIW**).
- Initiation of War (**IW**).

3 steps:

- Evaluate **best-estimated cost** for each option.
- Evaluate **robustness** to info-gaps.
- **Prioritize** policies according to robustness.

Decision criterion: **robustly satisfice specified goal.**

Procedural (not substantive) **optimization.**

Iraqi WMD in 2002

Estimated costs: NIW less than IW. Both costs feasible.

Schematically:

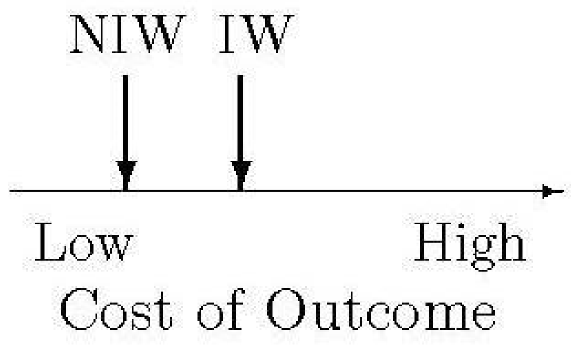


Figure 1: Putative best-estimated outcome costs for two policy options.

Iraqi WMD in 2002

How to evaluate robustness of cost estimates?

Conceptual proxies:

- **Resilience**: rapid recovery of critical functions.
- **Redundancy**: multiple alternative solutions.
- **Preponderance**: margin of safety.
- **Flexibility**: rapid modification of tools and methods.
- **Adaptiveness**: adjust goals and methods online.
- **Comprehensiveness**: interdisciplinary system-wide coherence.

Iraqi WMD in 2002

Robustness of NIW to Iraqi initiative and surprise:

Proxy for robustness	NIW	IW
Resilience	Low	
Redundancy	Med	
Preponderance	Low	
Flexibility	Med	
Adaptiveness	Hi	
Comprehensiveness	Med	

Graphical metaphor

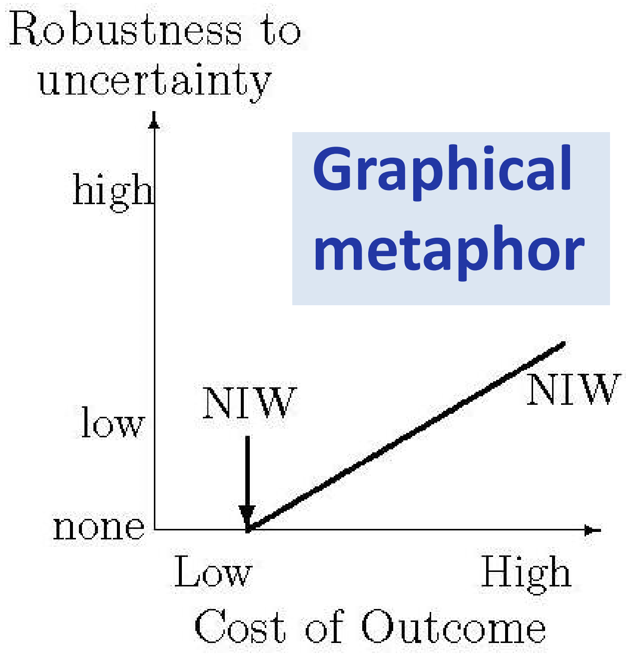


Figure 2: Robustness curve for one policy option.

Iraqi WMD in 2002

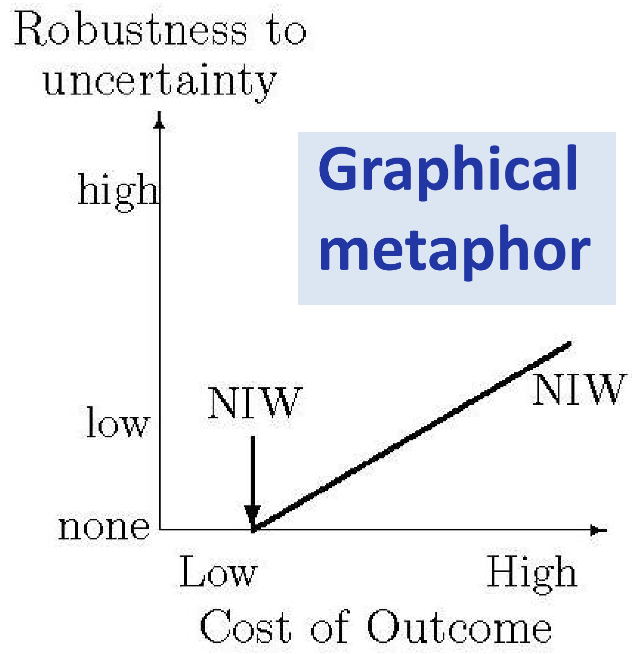
Robustness of NIW to Iraqi initiative and surprise:

Zeroing:

No robustness of predicted outcome.

Trade off: Low cost=low robustness.

- Robustness vs performance. (Pessimist's theorem)
- High cost of robustness.



Graphical metaphor

Figure 2: Robustness curve for one policy option.

Iraqi WMD in 2002

Robustness of IW to surprising Iraqi reaction:

Proxy for robustness	NIW	IW
Resilience	Low	Med
Redundancy	Med	Hi
Preponderance	Low	Hi
Flexibility	Med	Med
Adaptiveness	Hi	Hi
Comprehensiveness	Med	Hi

Graphical metaphor

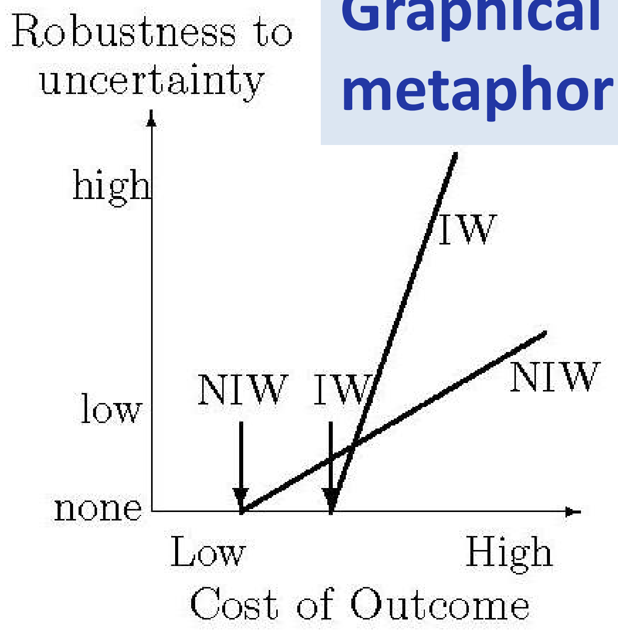


Figure 3: Robustness curves for two policy options.

Zeroing and trade off for both options.

Iraqi WMD in 2002

Robust satisficing decision

Decision dilemma:

- NIW nominally preferred.
- IW less uncertain.

IW more robust for higher costs.

Policy maker decides.

Graphical metaphor

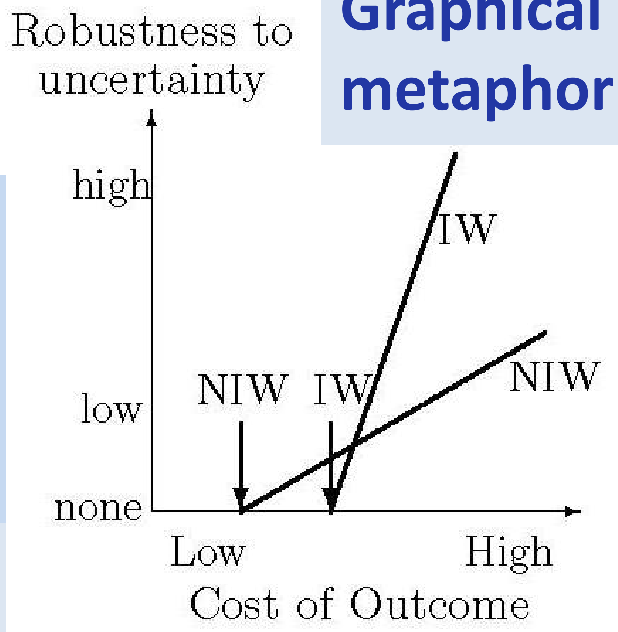


Figure 3: Robustness curves for two policy options.

Speculative methodological expl.

Not historical reconstruction.

Last words

Strategic planners need 2 types of expertise due to uncertainty:

- **Topical, disciplinary:** history, economics, engineering, etc.
- **Methodological, decision theoretic:** info-gap, probability, etc.

Innovation dilemma: New is promising but more uncertain.

Deep uncertainty:

- The idea of an **info-gap**.
- Parameters, vectors, **functions.**

Info-gap robust satisficing:

- Satisfice the goals, optimize the robustness.
- Resolve innovation dilemma.

Examples: (1) Rural poverty. (2) Iraqi WMD.

Questions?

info-gap.com