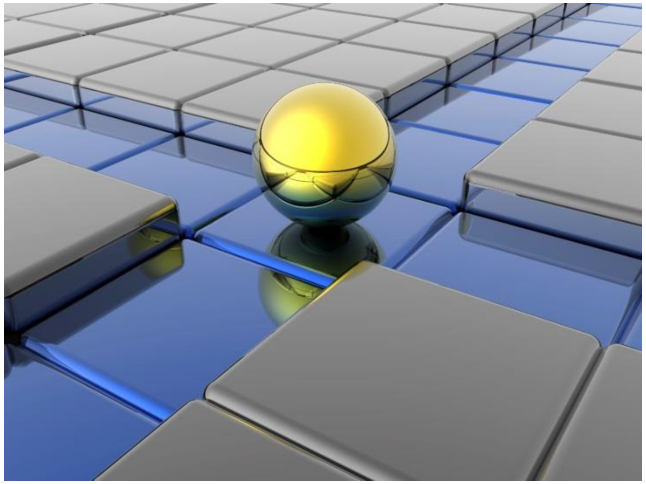
Policy for Environmental Change
Info-Gap Response to Uncertainty

Yakov Ben-Haim
Technion
Israel Institute of Technology



Outline

Risk or Uncertainty?

Probability is powerful, but ignorance is not probabilistic

Uncertainty and the optimization imperative

- Limits of prediction and outcome-optimization
- Robust satisficing

Remediation: What? How? When?

Optimal monitoring and surveillance: A paradox

Risk and Uncertainty

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)

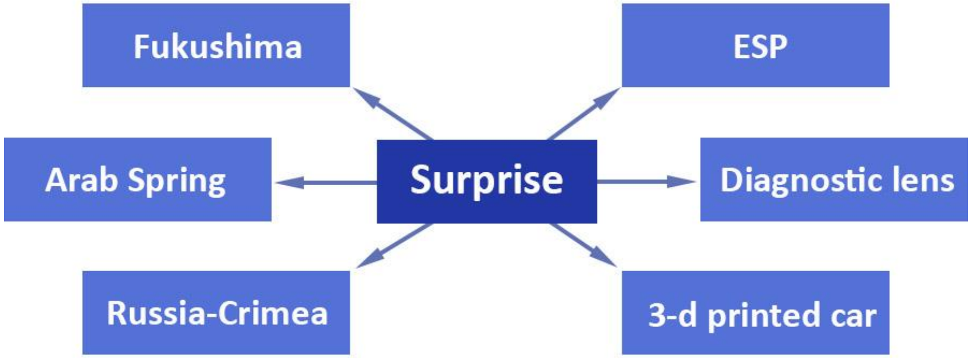
Frank Knight's "true uncertainty"

"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

- America
- Nuclear fission
- 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 ???

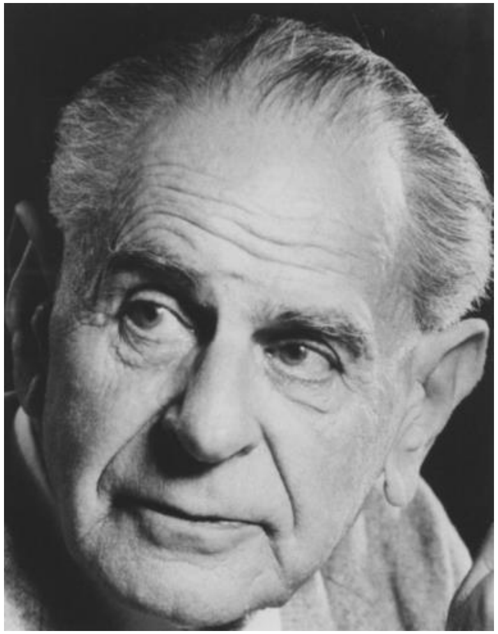
Knightian uncertainty:

- Unstructured: unknown event space.
- Indeterminate: no laws.
- Barely manageable.

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.

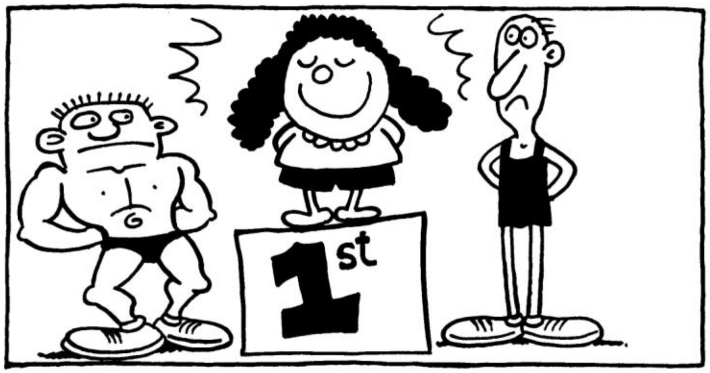
- Info-gaps, indeterminism: **unpredictable.**
- **Ignorance is not probabilistic.**

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:

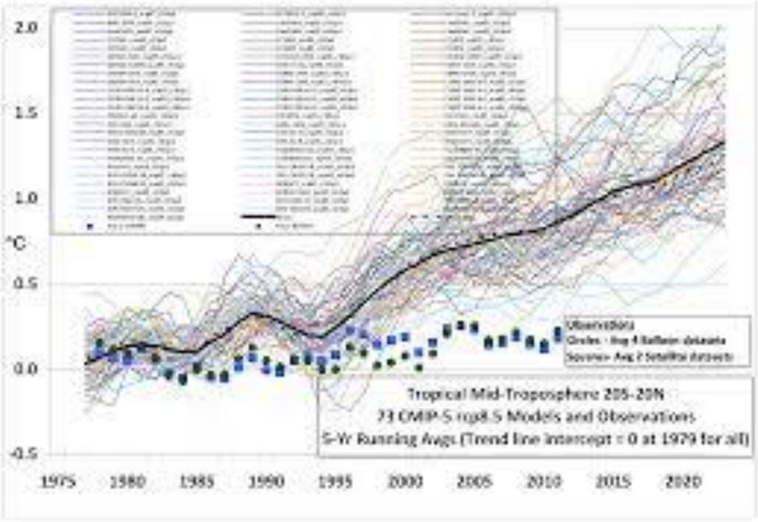
- Predict outcomes of available options.
- Select predicted best option.

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.

Robust Satisficing

Two questions for decision makers:

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

Robust Satisficing

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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.

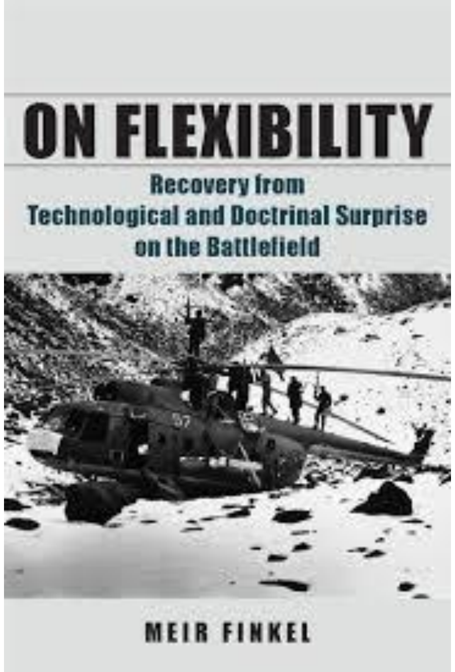
Optimize robustness; satisfice goals:

Procedural (not substantive) **optimization.**

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** …”

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

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Computational robustness.

- Engineering design.
- Operations research.
- Economic analysis.

Achieving Robustness

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Computational robustness.

Robustness vs **substantive-outcome optimality.**

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

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

Remediate: when, how?

Prof. Jim Hall discussed

"Steps towards global flood risk modelling"

"In global risk analysis, **scarcity of information** ...

means that ... risk assessments are

based upon assumptions".

"**Uncertainties** [are] endemic, model-dependent" and "subtle".

"[I]n flood modelling,

a revolution has been taking place. ...

Now all we have to do is fill in the [**info-**]gaps."

Remediate: when, how?

Prof. Myles Allen discussed

“Drivers of peak warming in a

consumption-maximizing world”

“Finally, the existence of at least one technology capable of reducing net CO2 emissions to zero is crucial. This is important, because **we still do not know what this technology is,**
[or] **what it will cost to deploy** at the necessary scale.”

Remediate: when, how?

Goal: Intervene to fix, prevent or reduce damage.

Decisions: Allocate budgets each year for various tasks.

Uncertainties: myriad.

- **Damage** (from intervening or not).
- **Discounting** over time.
- **Prior beliefs** in experts and theories.
- **Critical outcome:** welfare, benefit/cost, GDP, etc.
- More….

Remediate: Example

Policy decision: Budget sequence, $f = (f_1, f_2, \ldots, f_T)$

Uncertainties: loss at each time t: $u_t(f_t)$

We have **estimates** of the loss functions,

But we **don't know how much they err.**

Performance function: total discounted loss (expense):

$$L = \sum_{t=1}^{T} \beta^{t-1} [f_t + u_t(f_t)]$$

Performance requirement: Loss not too large:

$$L \le L_c$$

Satisfice, don't **optimize** the outcome.

Remediate: 1 step

Policy cost, f	Estimated loss, $\widetilde{u}$	Error, s
Do nothing, $f = 0$	1.1	0.2
Intervene, $f = 0.09$	0.55	0.55

Table 1: Estimated data for 1-period management, billions of US$.

Innovation dilemma. Intervention:

- **Seems better** (lower estimated loss).
- More uncertain (higher estimated error).

Intervene or **Do nothing?**

How to choose?

Remediate: 1 step

Policy cost, f	Estimated loss, $\widetilde{u}$	Error, s
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Table 1: Estimated data for 1-period management, billions of US$.

Intervene or **Do nothing?**

How to choose?

Robustness question: How much error can we tolerate?

Answer: Robustness function.

Max uncertainty at which $L \le L_c$ is still guaranteed.

Decision: Choose by robustly satisfying the requirement.

Remediate: 1 step

Policy cost, f	Estimated loss, $\widetilde{u}$	Error, s
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Table 1: Estimated data for 1-period management, billions of US$.

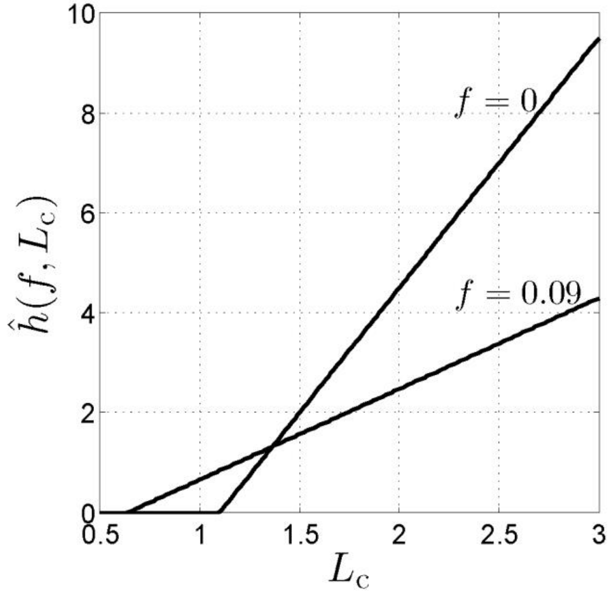
Pessimist's thm. Trade off:

less loss L_c ⟺ less robustness $\hat{h}$

Zeroing: No robustness at est. loss.

Optimizer's fallacy:

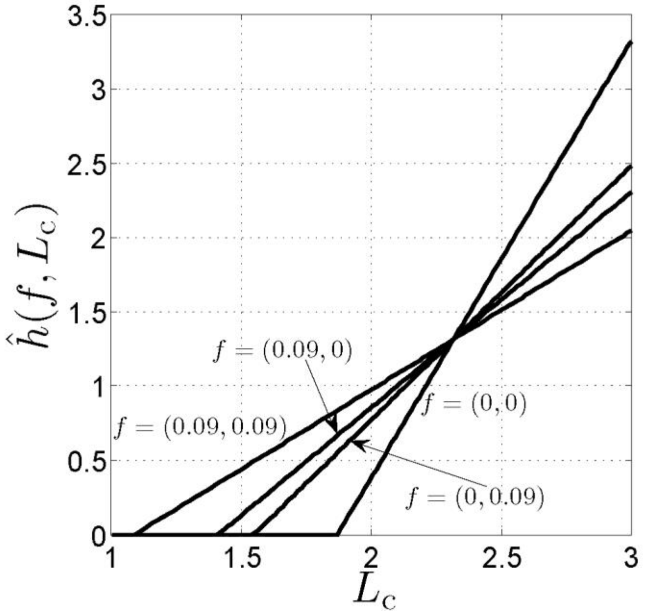
Prioritize by estimated loss.



Robust prioritization: robustly satisfy the requirement.

Preference reversal.

Remediate: 2 steps

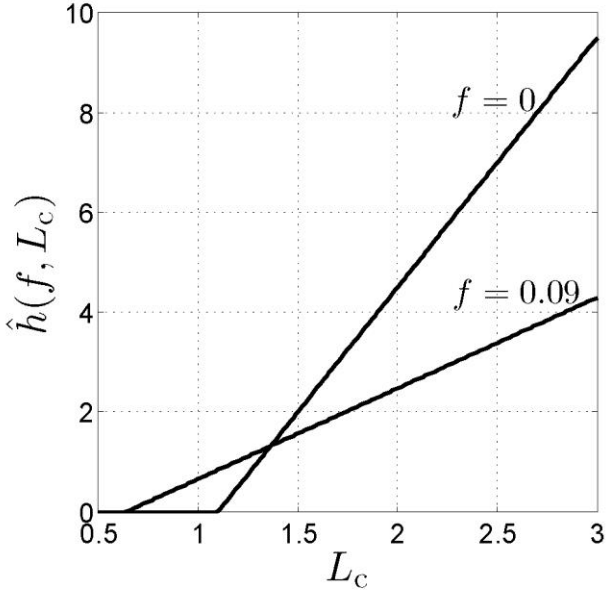


Trade off: robustness vs loss.

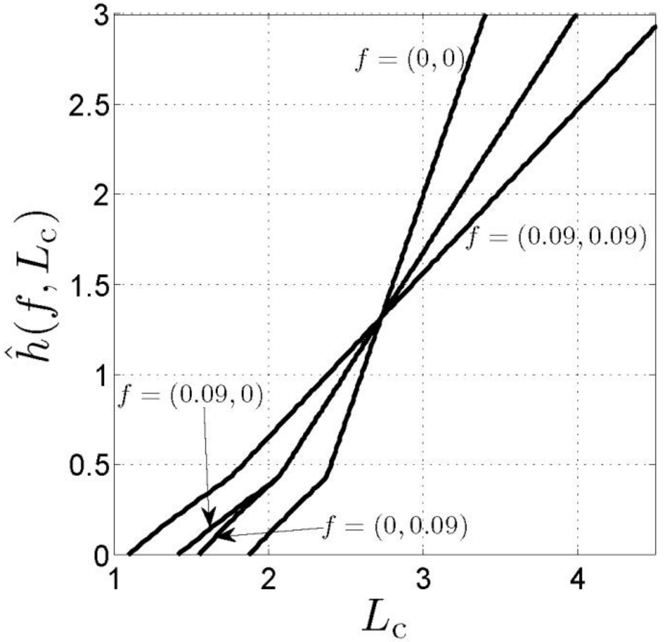
Zeroing: no robustness at est. loss.

Preference reversal.

Time: much less robust than 1 step.



Remediate: uncertain discount



2 time steps.

Uncertainties:

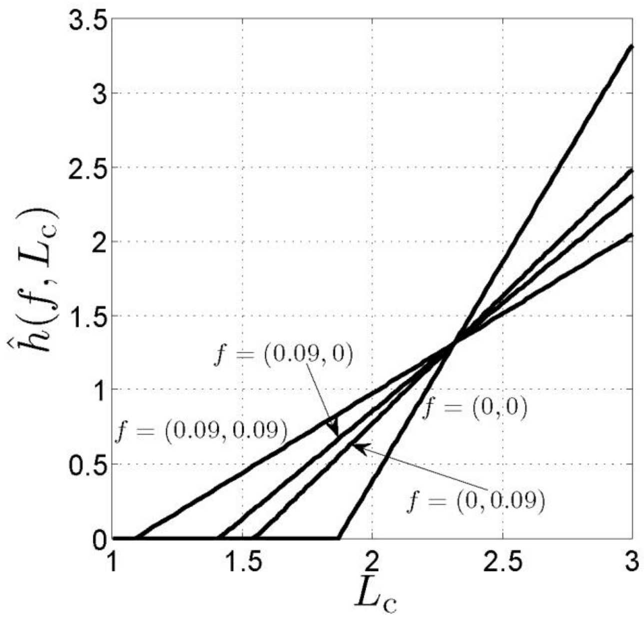
losses and discount rate.

Trade off: robustness vs loss.

Zeroing: no robustness at est. loss.

Preference reversal.

Time: less robust than 2 steps.



Remediate: Summary

Recognize your **info-gaps.**

Specify your goals.

Prioritize your options: robust satisficing:

- **Satisfice** your goals.
- **Optimize your robustness** to surprise.

Don't try to optimize the outcome.

Optimal monitoring and surveillance: A paradox of learning

Learning:

- **Discover new knowledge.**
- **Not:** learn French or Newtonian Physics.

Optimal learning:

Min time, max quantity, min cost, max quality…

Monitoring and surveillance as learning:

- New eco-failure mechanism emerging? Where? What?...
- **Not:** does this firm release that pollutant in this river?

Optimal Learning: A Paradox

- **Discover & prevent new eco-failure** with **max effectivity.**
- **Range of design alternatives with fixed resources:**
  - **Extensive** research: **more** knowledge, but less impact.
  - **Limited** research: less knowledge, but **more** impact.
- **Optimal** research amount depends on failure mechanism.
- Eco-failure mechanism is unknown.

Resolution: Satisfice effectivity. **Maximize robustness**.

Procedural (not substantive) **optimization.**

Alternatives: Optimal **adaptive** or **stochastic** learning?

Same paradox of optimal learning.

Same resolution: **robustly satisfice** the design of the learning.

Summing Up

Risk or Uncertainty:

- **Probabilistic** risk, **Knightian** uncertainty.
- Shackle-Popper indeterminism.

Substantive outcome optimization:

Useful under risk, not under uncertainty.

Robust satisficing:

- Optimize robustness; satisfice goals.
- **Procedural** (not substantive) **optimization.**

Remediation: what, when, how?

Optimal monitoring and surveillance: A paradox

Questions?