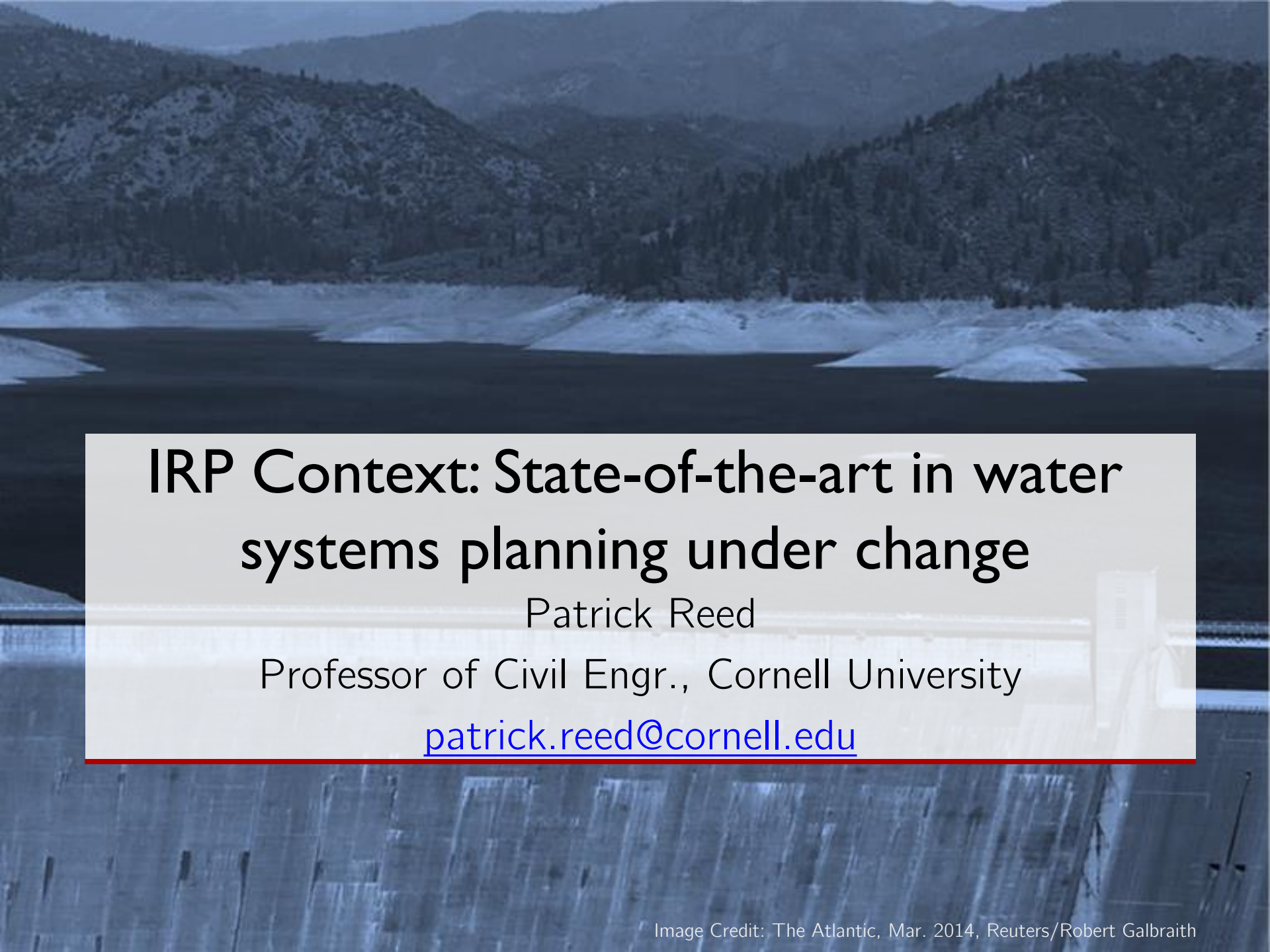


IRP Context: State-of-the-art in water systems planning under change

Patrick Reed

Professor of Civil Engr., Cornell University

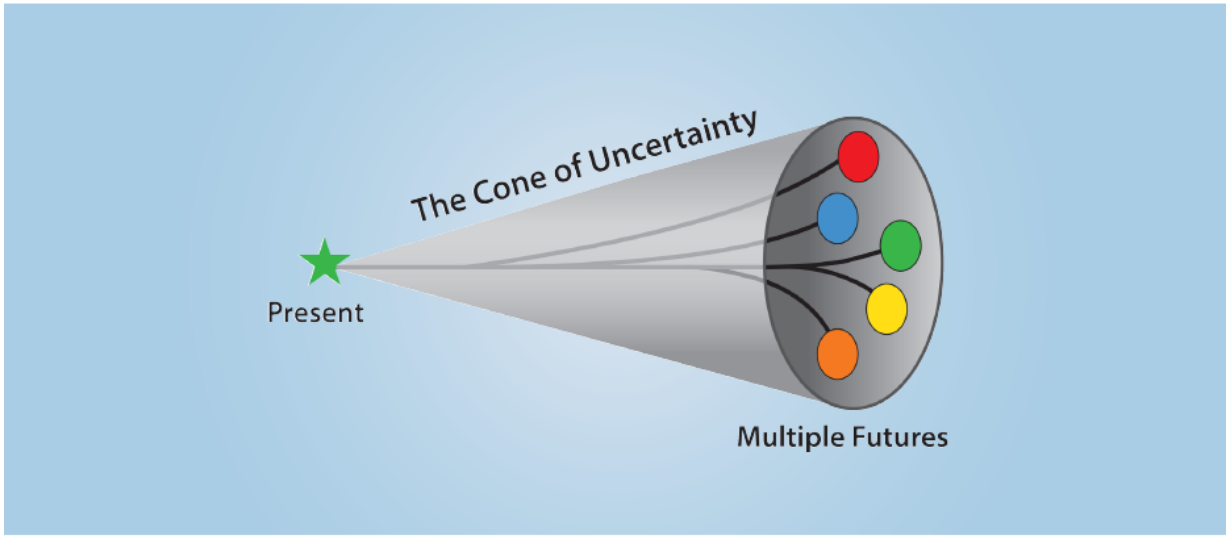
patrick.reed@cornell.edu

Image Credit: The Atlantic, Mar. 2014, Reuters/Robert Galbraith

A qualitative starting point…

EMBRACING UNCERTAINTY

A Case Study Examination of How Climate Change is Shifting Water Utility Planning



Prepared for:

Water Utility Climate Alliance (WUCA)
American Water Works Association (AWWA)
Water Research Foundation (WRF)
Association of Metropolitan Water Agencies (AMWA)

Project Manager: Laurna Kaatz, Denver Water

13 Case Studies

-UK & Australia
-Denver Water
-Bureau of Rec.
-CA DWR
-MWD
-many more

Seeking robustness across possible futures

"Bottom-up" decision frameworks

(Decision Scaling, Info-Gap, RDM, MORDM, Dynamic Adaptive Policy Pathways …)

> Shift from asking the *prediction question* –
> 'how likely is this scenario?'
> to asking the *decision impact question* –
> 'how likely would this scenario need to be to affect one's choice of strategy?'

— Bryant and Lempert (2010)

Planning under uncertainty: Some context

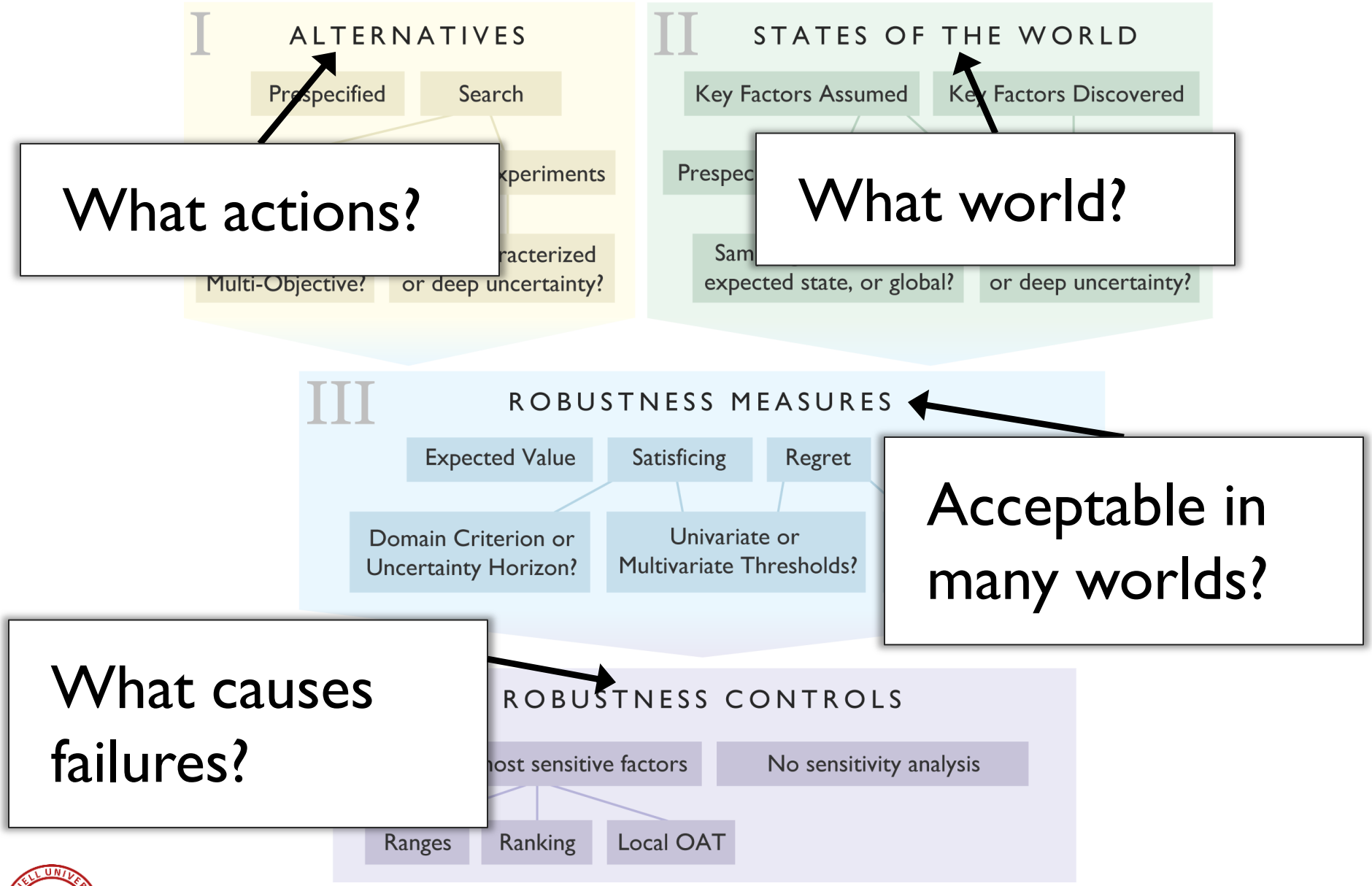
1. What do robustness-based decision frameworks have in common?
2. How do methodological choices impact decision recommendations?
3. How does the MWD IRP link to the state-of-the-art?

What do robustness analyses have in common?

Evaluate alternatives in multiple states of the world…

Quantify robustness measures and determine sensitive uncertainties

Taxonomy of Robustness Frameworks



What actions?

What world?

Acceptable in many worlds?

What causes failures?

Planning under uncertainty: Some context

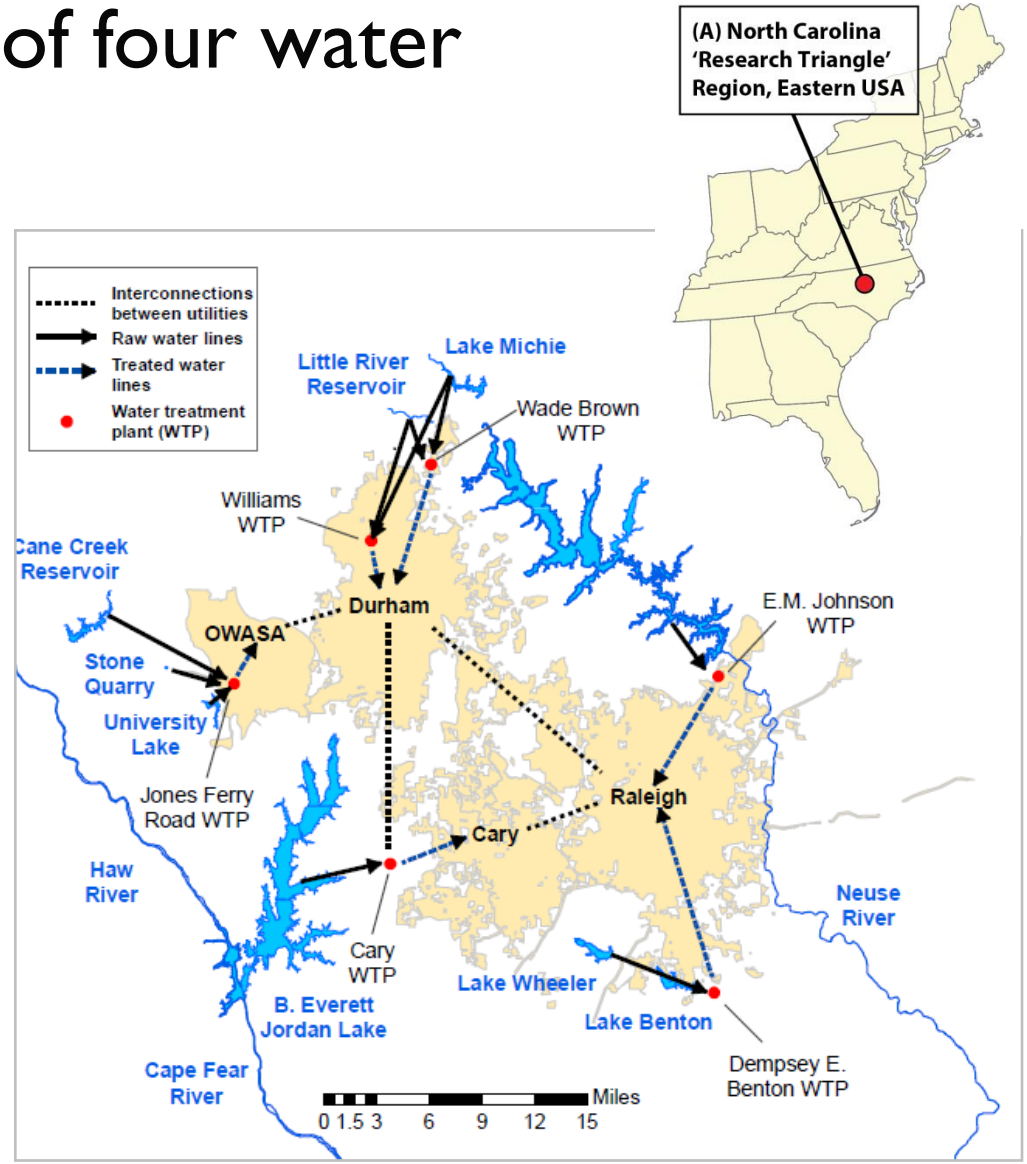
1. What do robustness-based decision frameworks have in common?
2. **How do methodological choices impact decision recommendations?**
3. How does the MWD IRP link to the state-of-the-art?

Eastern U.S. example of four water utilities through 2025

Four regional objectives:

- Volumetric reliability
- Restriction frequency
- Average cost
- Worst-case cost

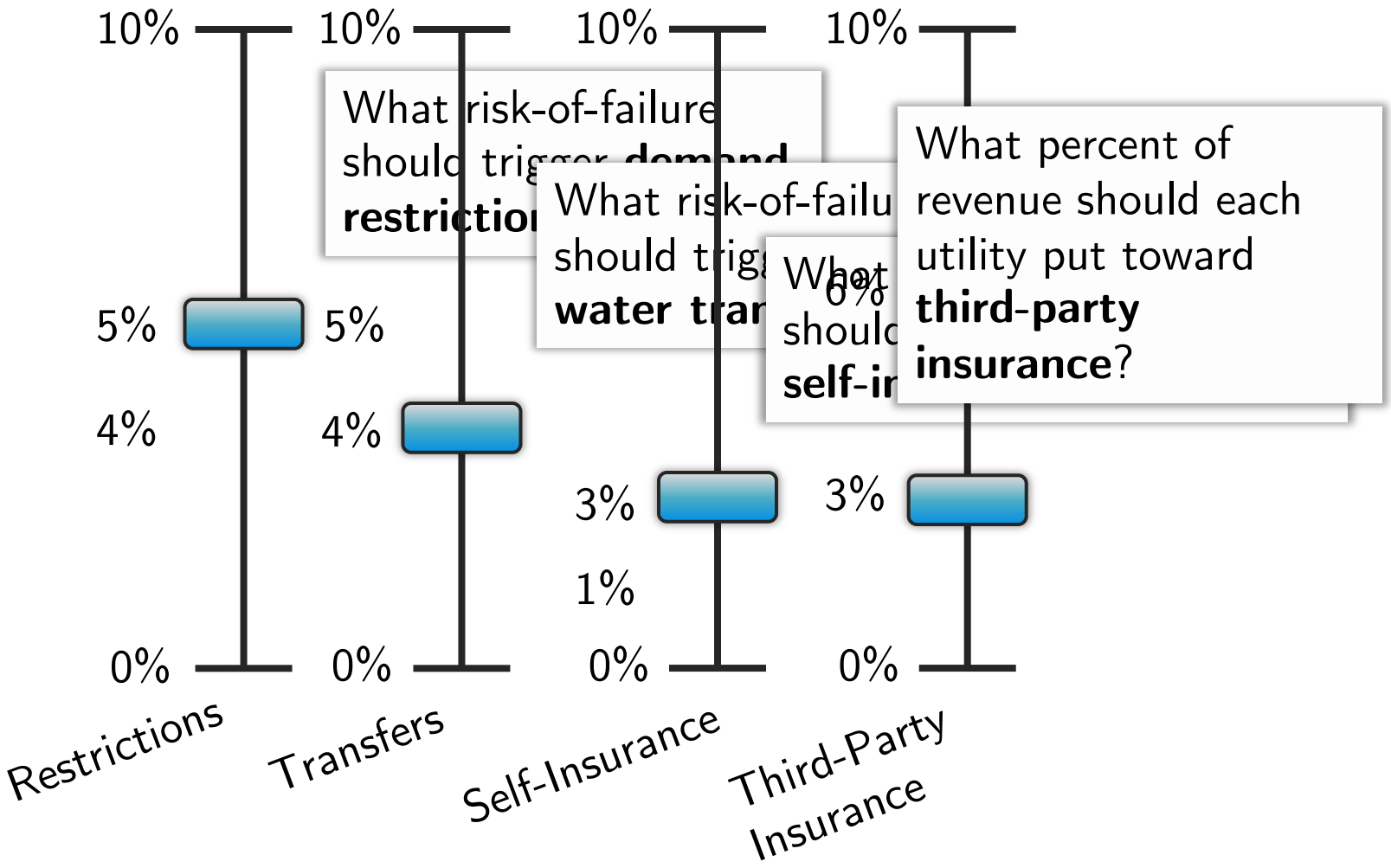
The worst-performing utility is optimized such that others will perform as well or better.



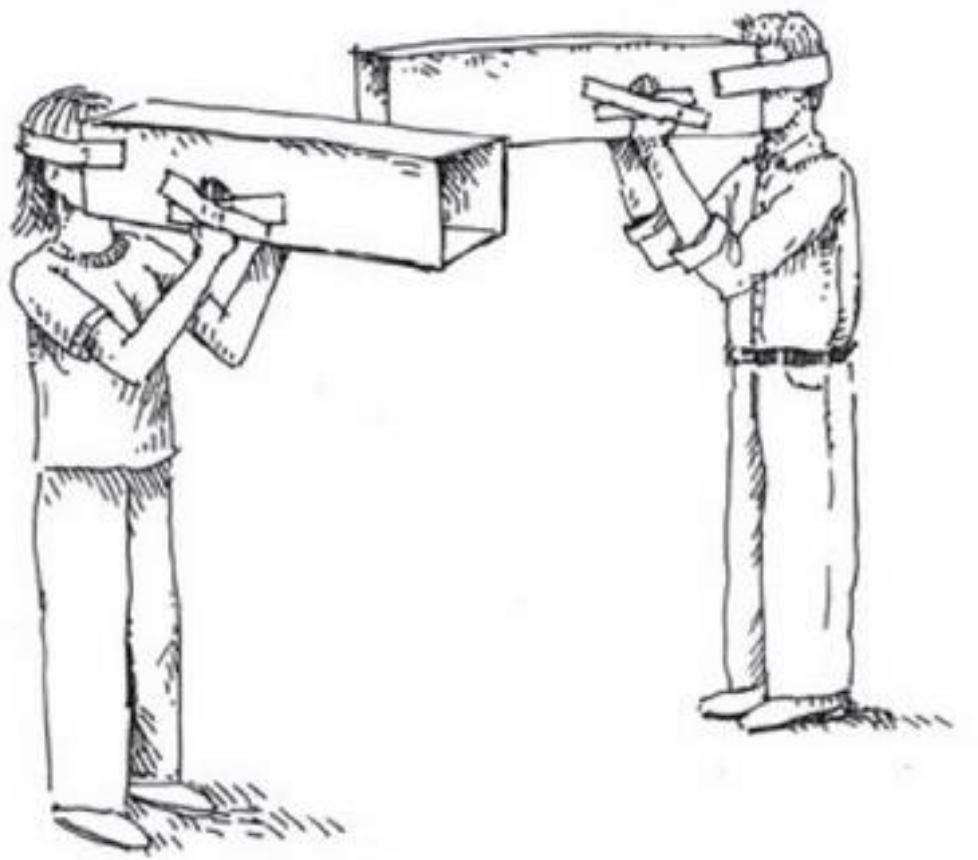
(Zeff et al. 2014)

Risk-based triggers for drought management

(Must be specified for every utility)



Avoiding Tunnel Vision:
Scenarios vs. Exploratory Modeling

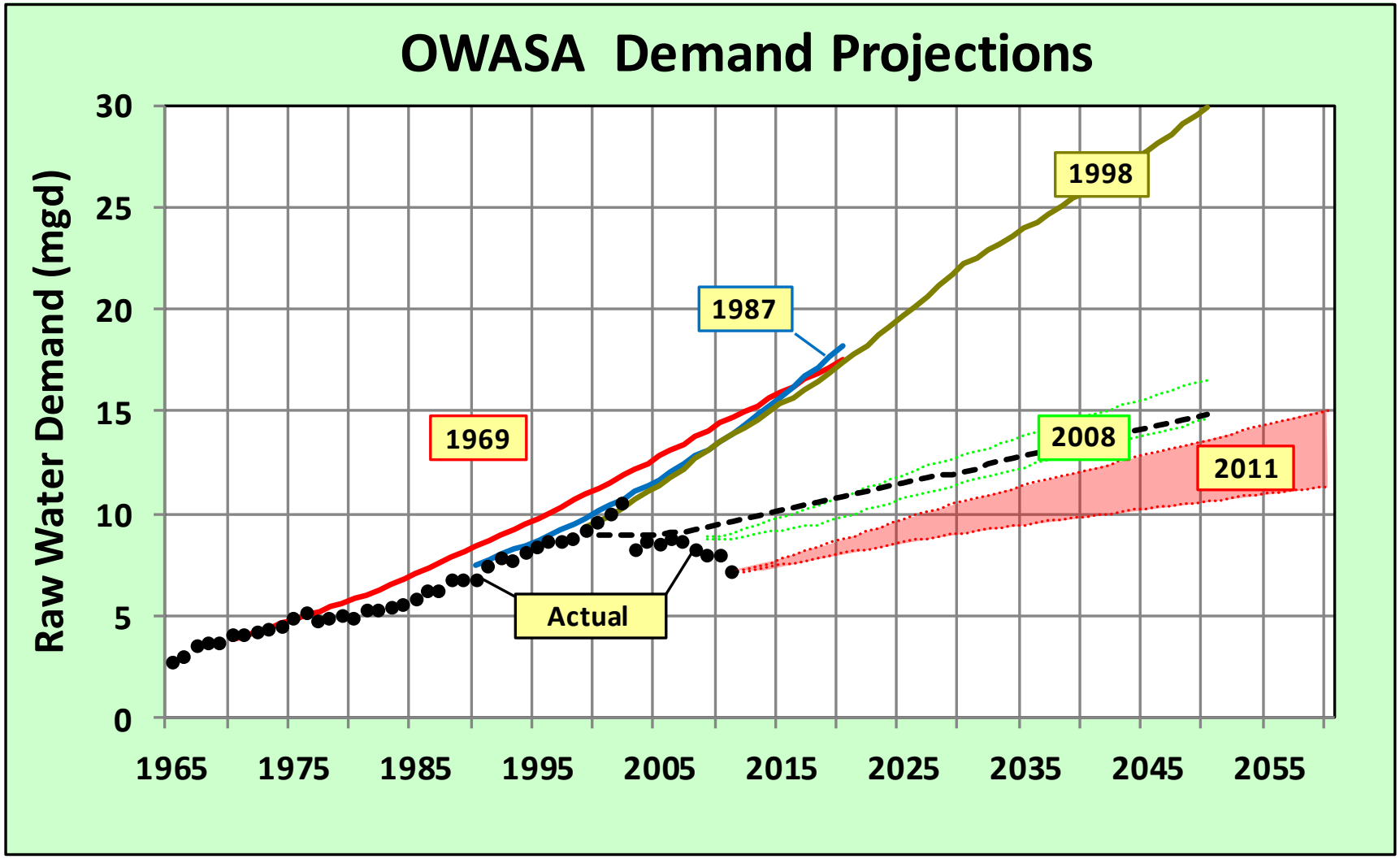


Which solutions are robust? How to decide?

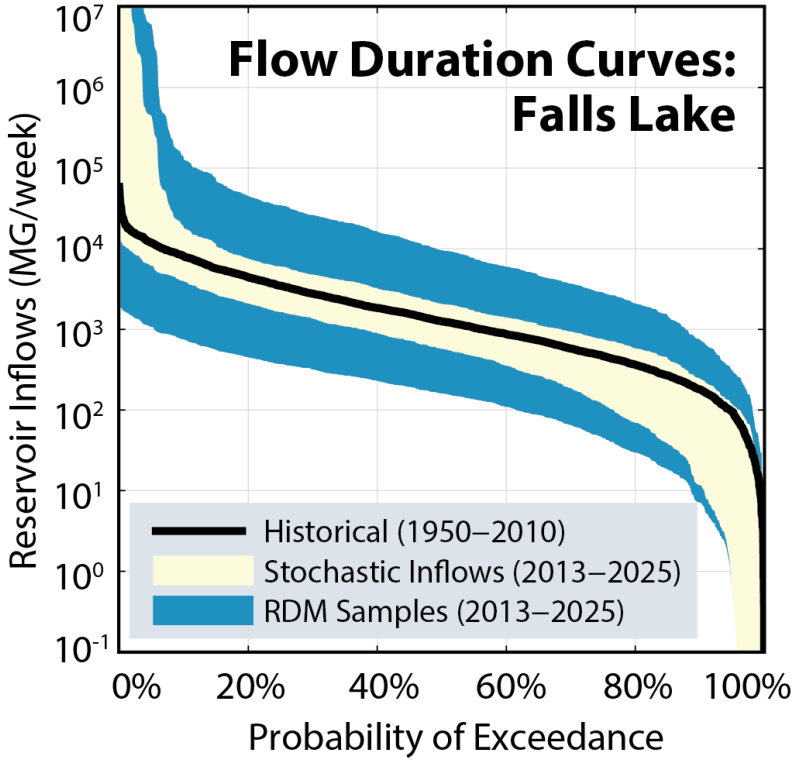
Sample deeply uncertain states of the world (inflows, demand, etc.)

http://www.hockscqc.com/articles/tunnelvision/tunnel-vision.jpg

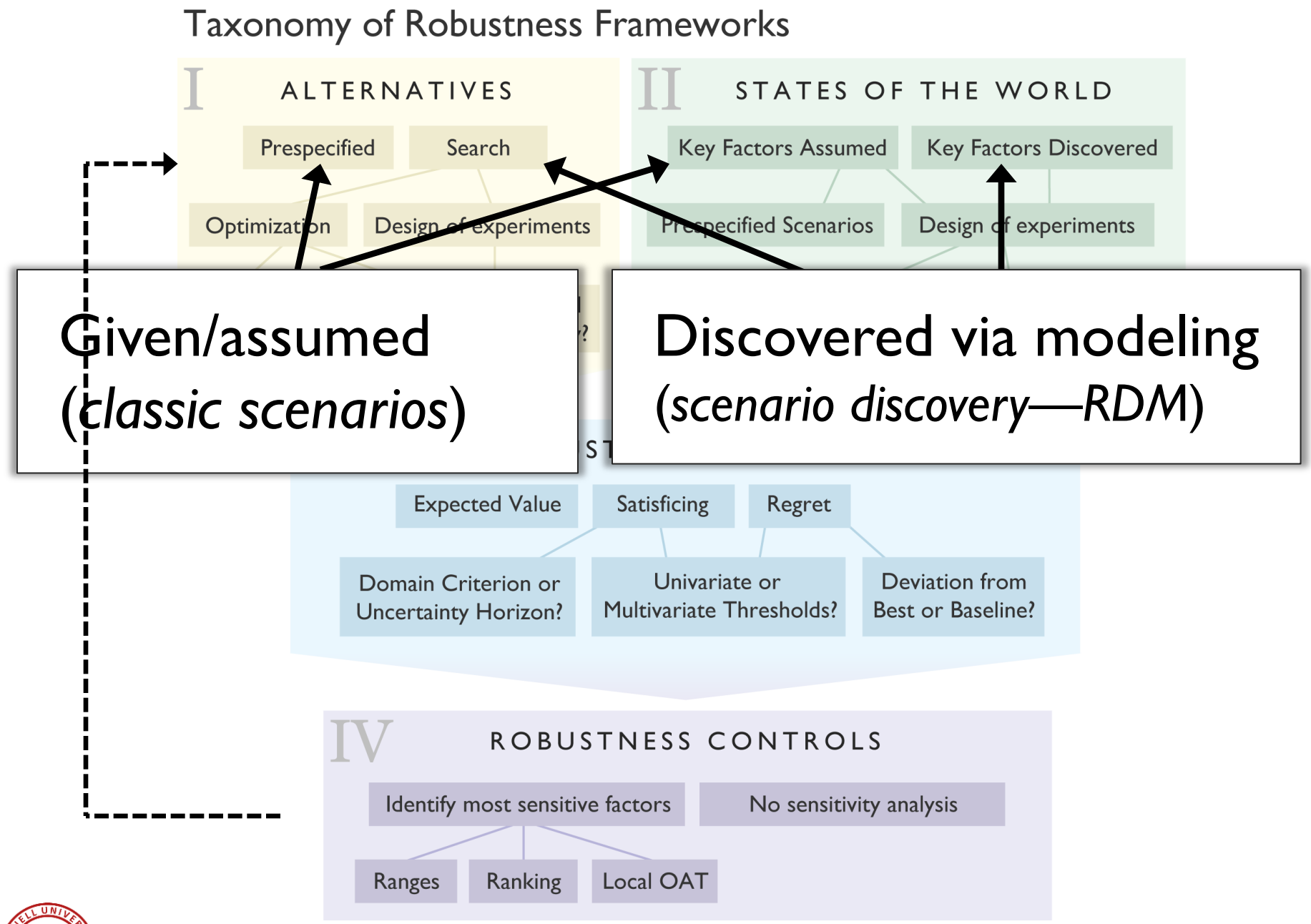
It is very common to make poor predictions



Construct alternative states of the world for different combinations of uncertainties

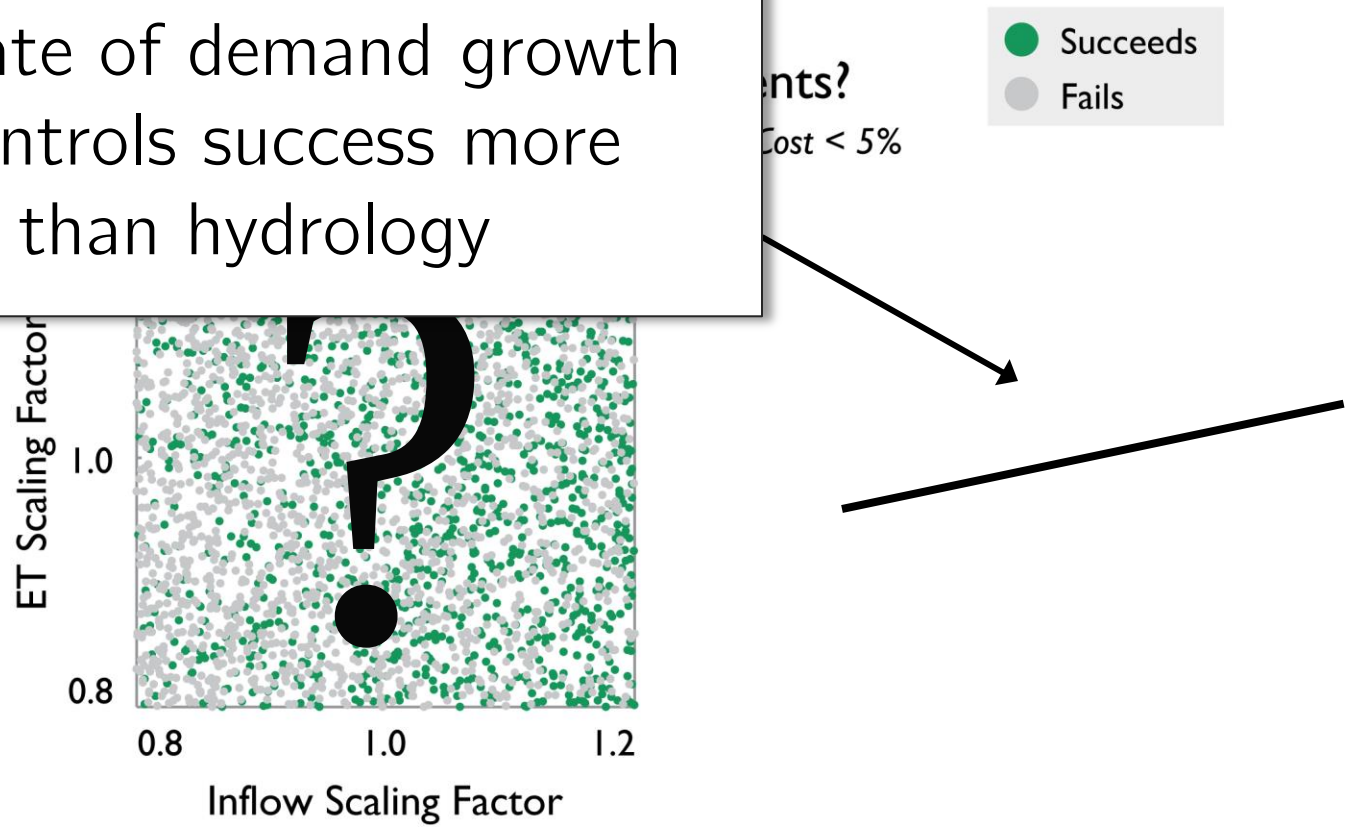


2 of 13 uncertainties including demand seasonality, reservoir evaporation, transfer prices, etc.

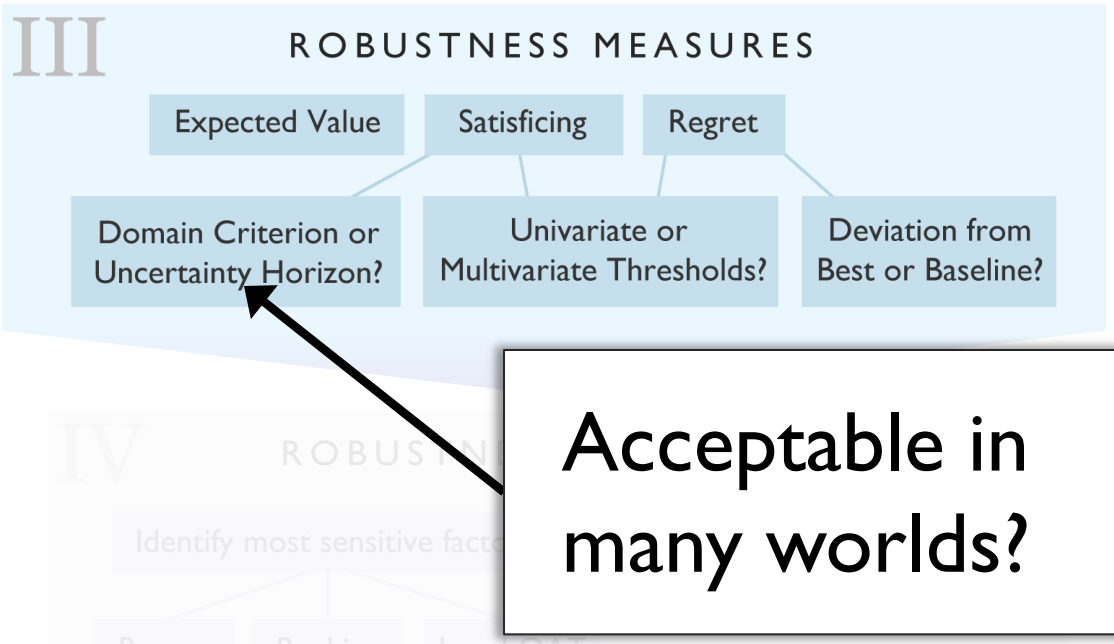

Taxonomy of Robustness Frameworks
I ALTERNATIVES
Prespecified
Search
Optimization
Design of experiments
II STATES OF THE WORLD
Key Factors Assumed
Key Factors Discovered
Prespecified Scenarios
Design of experiments
Given/assumed
(classic scenarios)
Discovered via modeling
(scenario discovery—RDM)
Expected Value
Satisficing
Regret
Domain Criterion or Uncertainty Horizon?
Univariate or Multivariate Thresholds?
Deviation from Best or Baseline?
IV ROBUSTNESS CONTROLS
Identify most sensitive factors
No sensitivity analysis
Ranges
Ranking
Local OAT

An *assumed* focus on climate/hydrologic factors may fail to capture system vulnerabilities

Rate of demand growth controls success more so than hydrology



Taxonomy of Robustness Frameworks

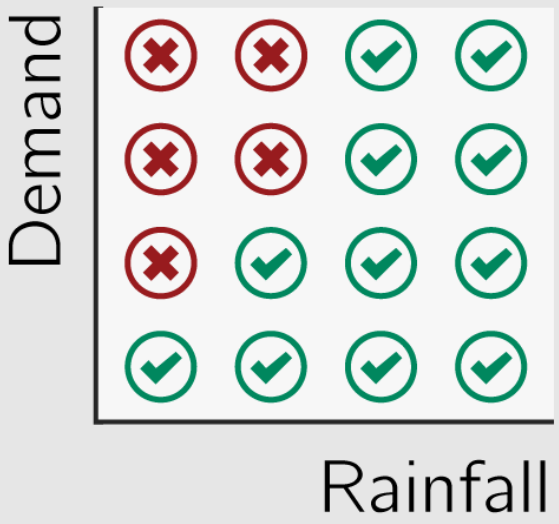


Acceptable in many worlds?

Domain Criterion

$$= \frac{n_1}{n_1 + n_2}$$

Number of failures



References: Schneller and Sphicas (1983)

Taxonomy of Robustness Frameworks

I ALTERNATIVES

Prespecified | Search

Optimization | Design of experiments

Single or Multi-Objective? | Well-characterized or deep uncertainty?

II STATES OF THE WORLD

Key Factors Assumed | Key Factors Discovered

Prespecified Scenarios | Design of experiments

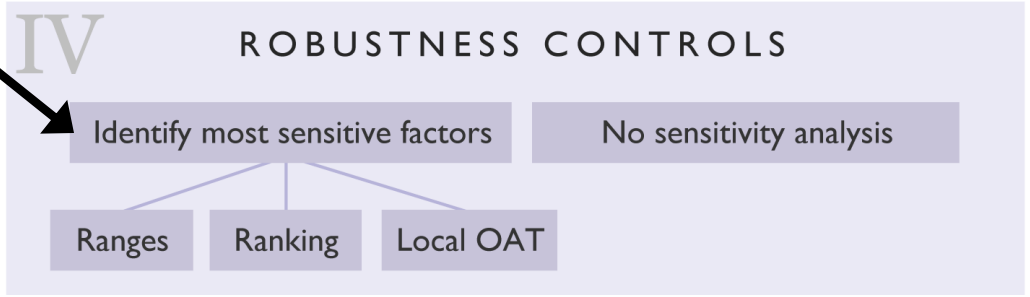
Sampling outward from expected state, or global? | Well-characterized or deep uncertainty?

ROBUSTNESS MEASURES

d Value | Satisficing | Regret

rion or orizon? | Univariate or Multivariate Thresholds? | Deviation from Best or Baseline?

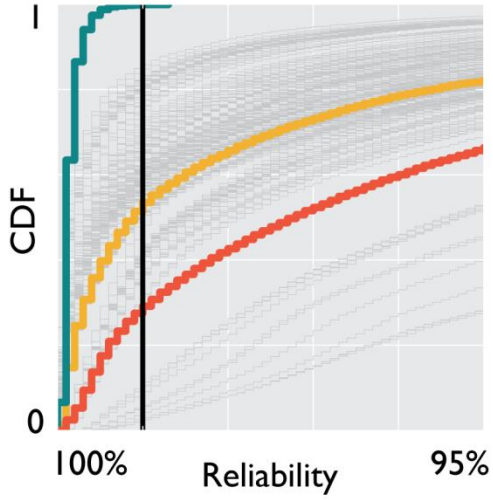
What causes failures?



Discovering sensitive uncertainties improves robustness of alternatives

Performance CDFs over Uncertain States of the World

Multi-objective performance for Durham



Prespecified Solution

Robust Solution from Search

Robust Solution with Reduced Demand Growth

Pareto-approximate set (Search)

Stakeholder Requirement

Degrading Performance →

Planning under uncertainty: Some context

1. What do robustness-based decision frameworks have in common?
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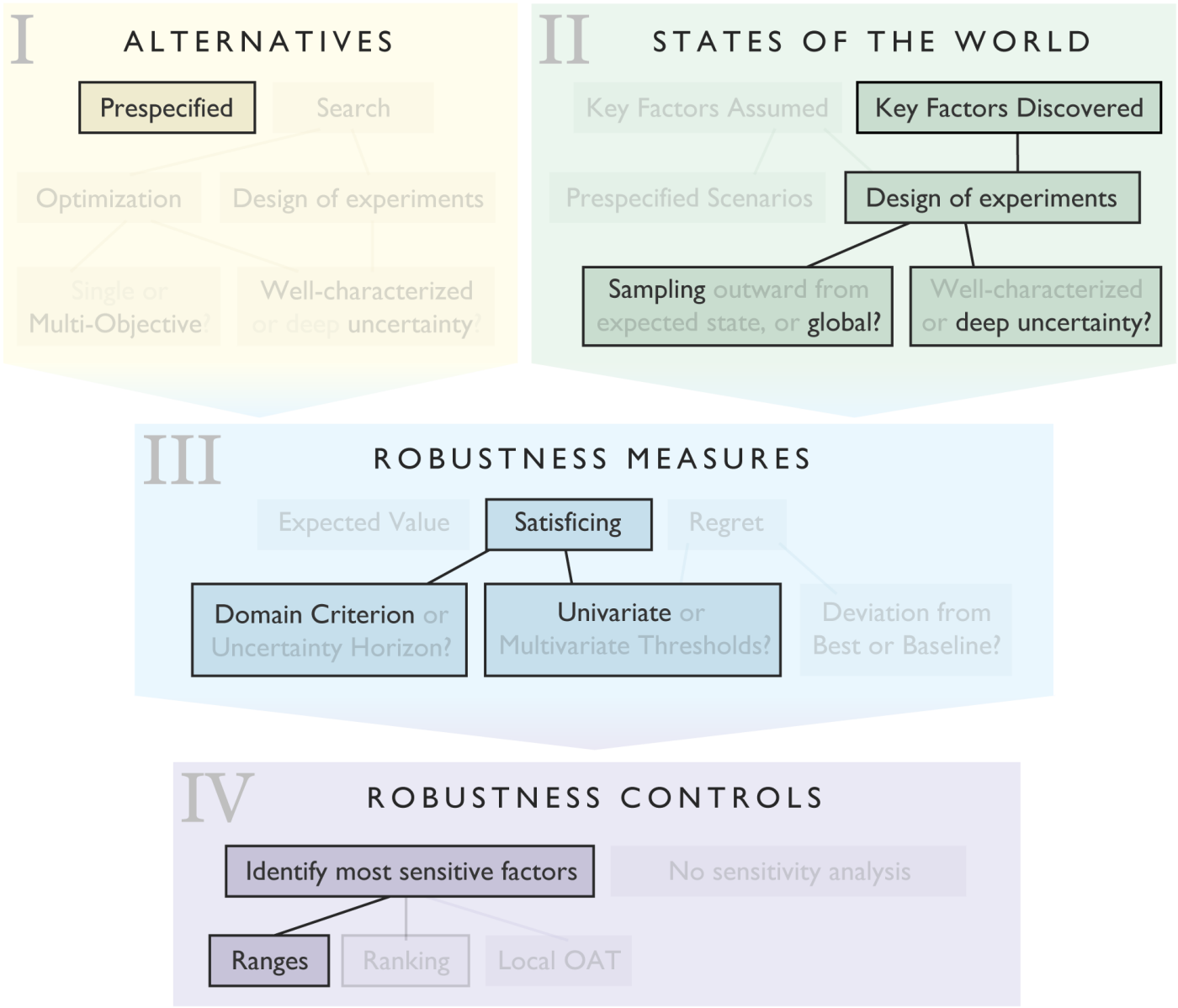
Robust Decision Making



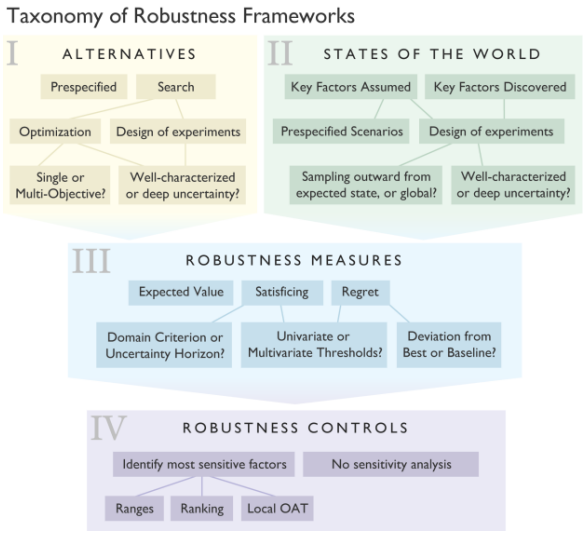
Some summative comments

1. MWD is serving as a national/international leader in planning

2. Climate change is not the only concern, RDM allows the consideration of many uncertainties

3. In the future it would interesting to more fully link the uncertainties in the "scoping" and "implementation/policy" phases of the IRP

Thanks!



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Herman et al. (2014) Beyond Optimality: Multi-stakeholder robustness tradeoffs for regional water portfolio planning under deep uncertainty. *WRR*, 50, 7692-7713.

Zeff et al. (2014) Navigating financial and supply reliability tradeoffs in regional drought portfolios. *WRR*, 50, 4906-4923.

Acknowledgements

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