Value of Decision Analysis for Climate Adaptation Planning: *Which Adaptation Decisions Can Benefit Most?*

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Climate Adaptation Decisions

Photo Credit: DailyMail

- **Adaptation Planning**
  - Uncertain climate & social conditions
- **Decision Analysis**
  - Uncertainty
  - Multi-stage
- **Cost – Benefit of Analysis**
  - Improved decisions
  - Significant cost

Research Questions

1. Screening – *single* problem

- Is a comprehensive decision analysis needed for every adaptation problem?

2. Prioritization - *multiple* problems

- Which problems are most likely to benefit from such an analysis?

A Five-Step Screening Tool

Goal: identify type of decision analysis that's the best fit for a particular adaptation problem

A Hypothetical Example

- **Alternatives**

electric substation

build floodwall

VS

do nothing

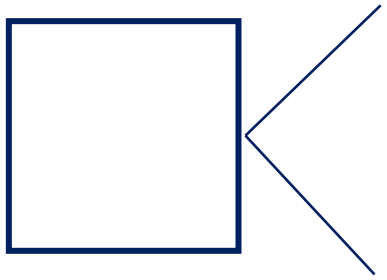
Photo Credit: Haugland Group

- **Objective**
  - minimize construction cost + flood damage
  - over next 30 years

- **Uncertainties**
  - future flood damage

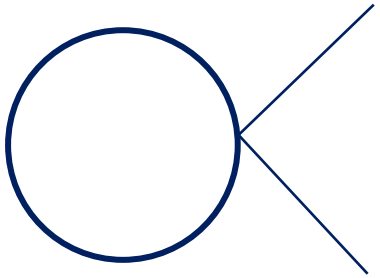
Photo Credit: T&D World

Components of A Decision Tree



Decision Node:
- decision to be made
- calculation: select optimal choice

(*decide whether to build a floodwall*)



Chance Node:
- a random or uncertain event
- calculation: expected value

(*uncertain flood damage*)

Events and decisions happen sequentially from left to right

Solve the tree from right to left

Flood Damage Scenarios

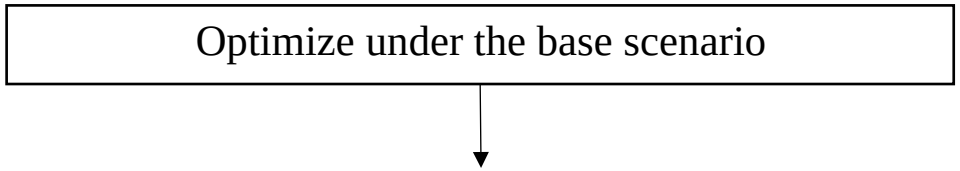
- Flood Damage Scenarios (Near-term & Long-term):
  - Low, moderate, and high

- Deterministic Analysis (No Uncertainty):
  - Base Scenario: Moderate Damage
  - Extreme Scenario: High Damage

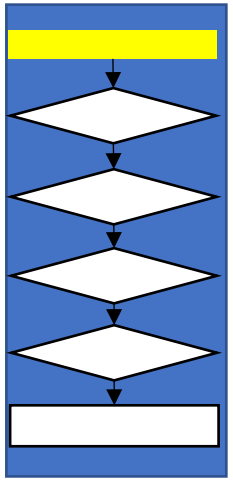
- Stochastic Analysis
  - Widest range: Low and High damage

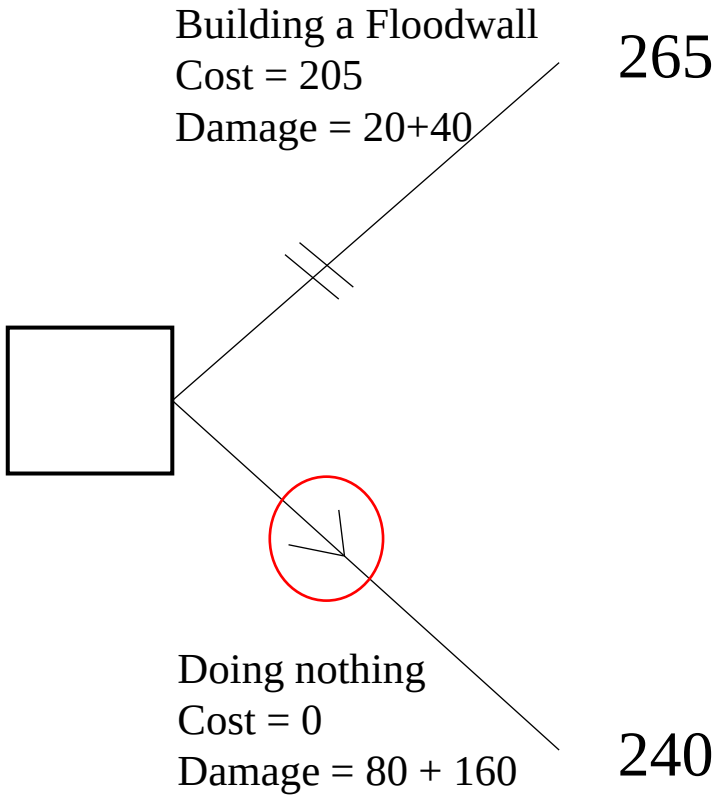
A Five-Step Screening Tool

Step 1 Deterministic Base Case



Steps 1 Deterministic Base Case

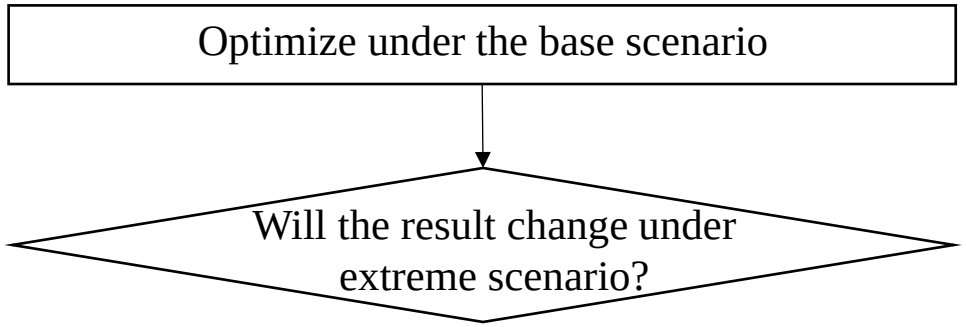




Step 1: Deterministic Base Climate

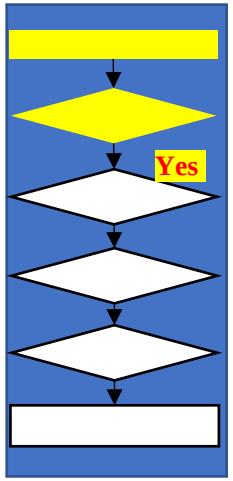
A Five-Step Screening Tool

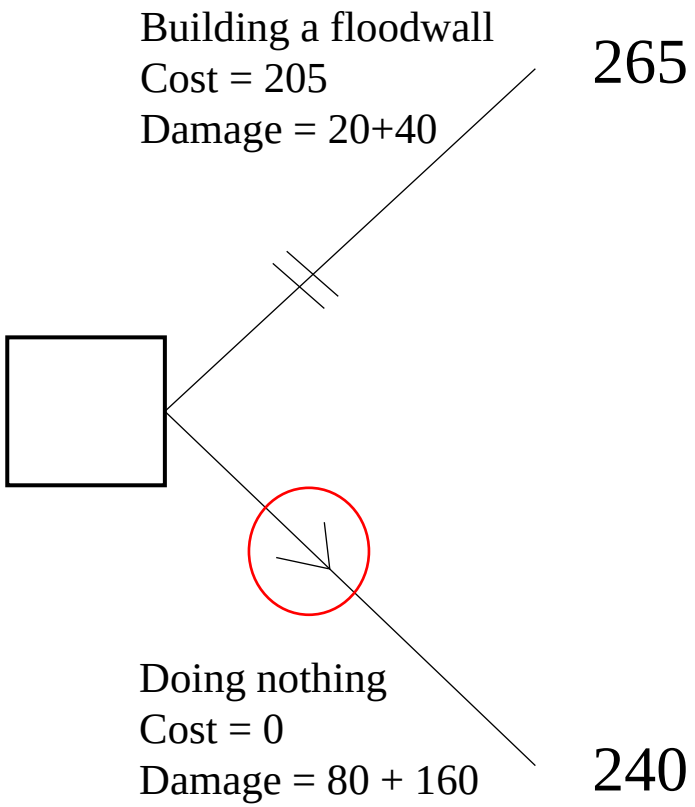
Step 1 Deterministic Base Case



Step 2 Deterministic Extreme Case

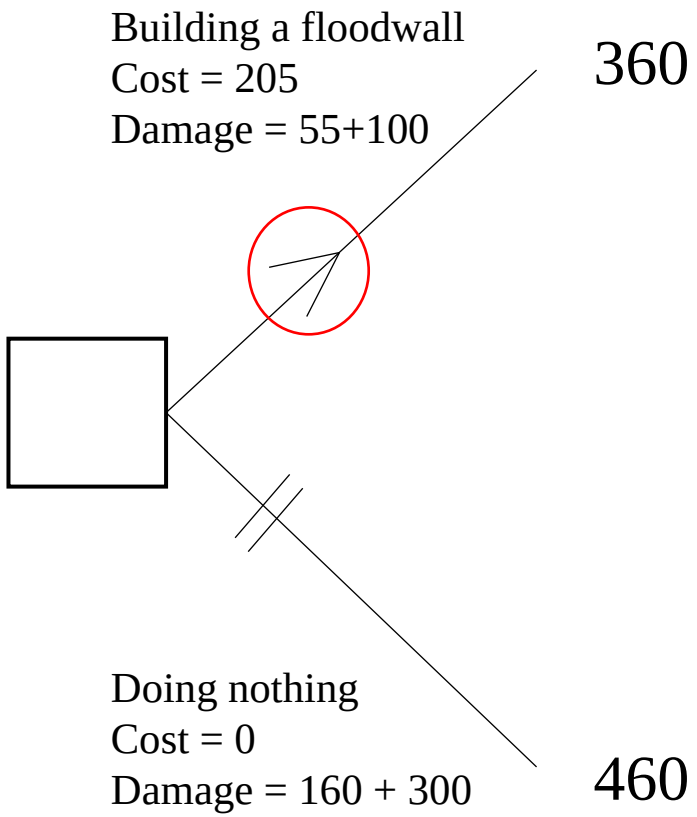
Steps 2: Deterministic Extreme Case





Step 1: Deterministic Base Climate

the optimal decision changes



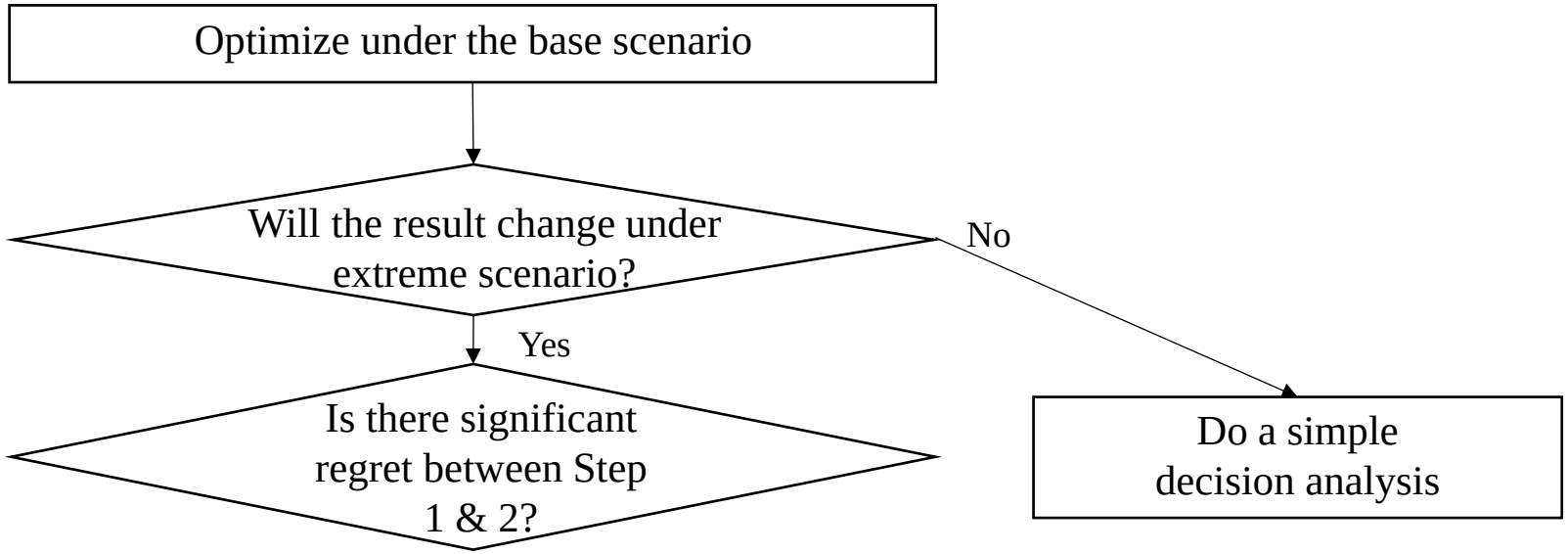
Step 2: Deterministic Extreme Case

A Five-Step Screening Tool

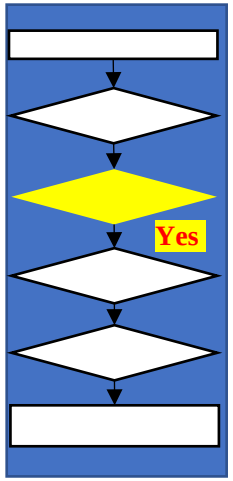
Step 1 Deterministic Base Case

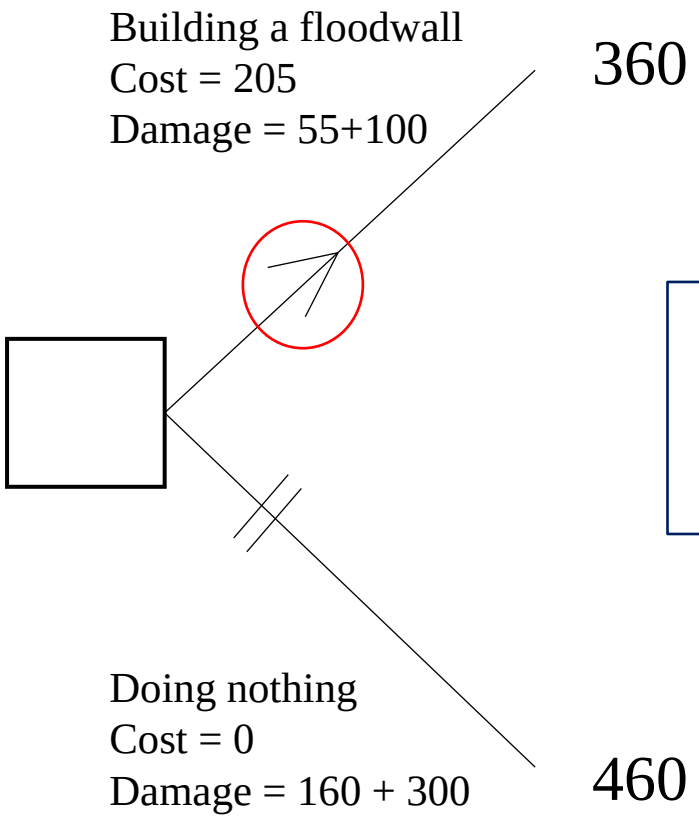
Step 2 Deterministic Extreme Case

Step 3 Regret Significance Check



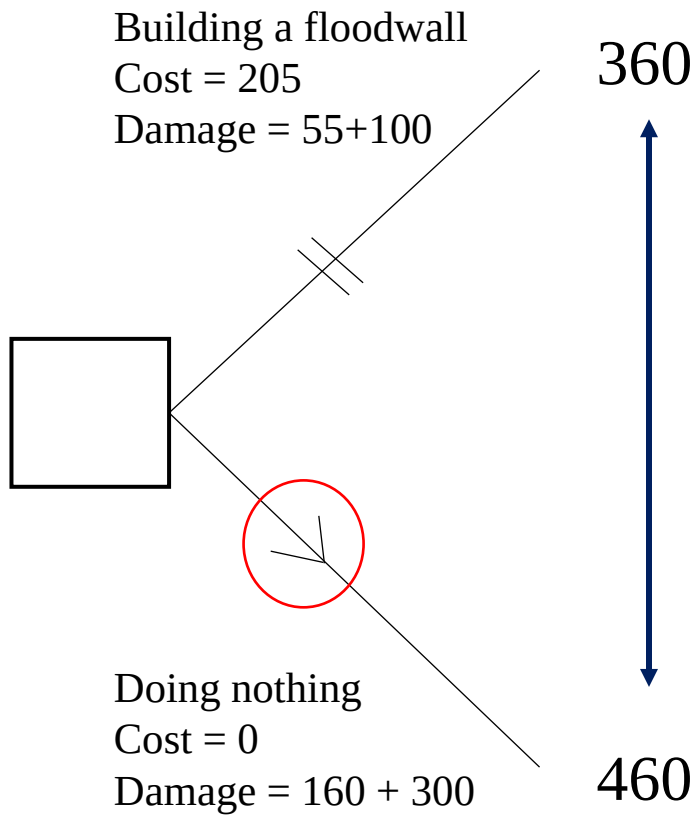
Step 3: Regret significance check





Optimal Decision under Extreme Case

A large difference between two alternatives



Unwise Decision under Extreme Case

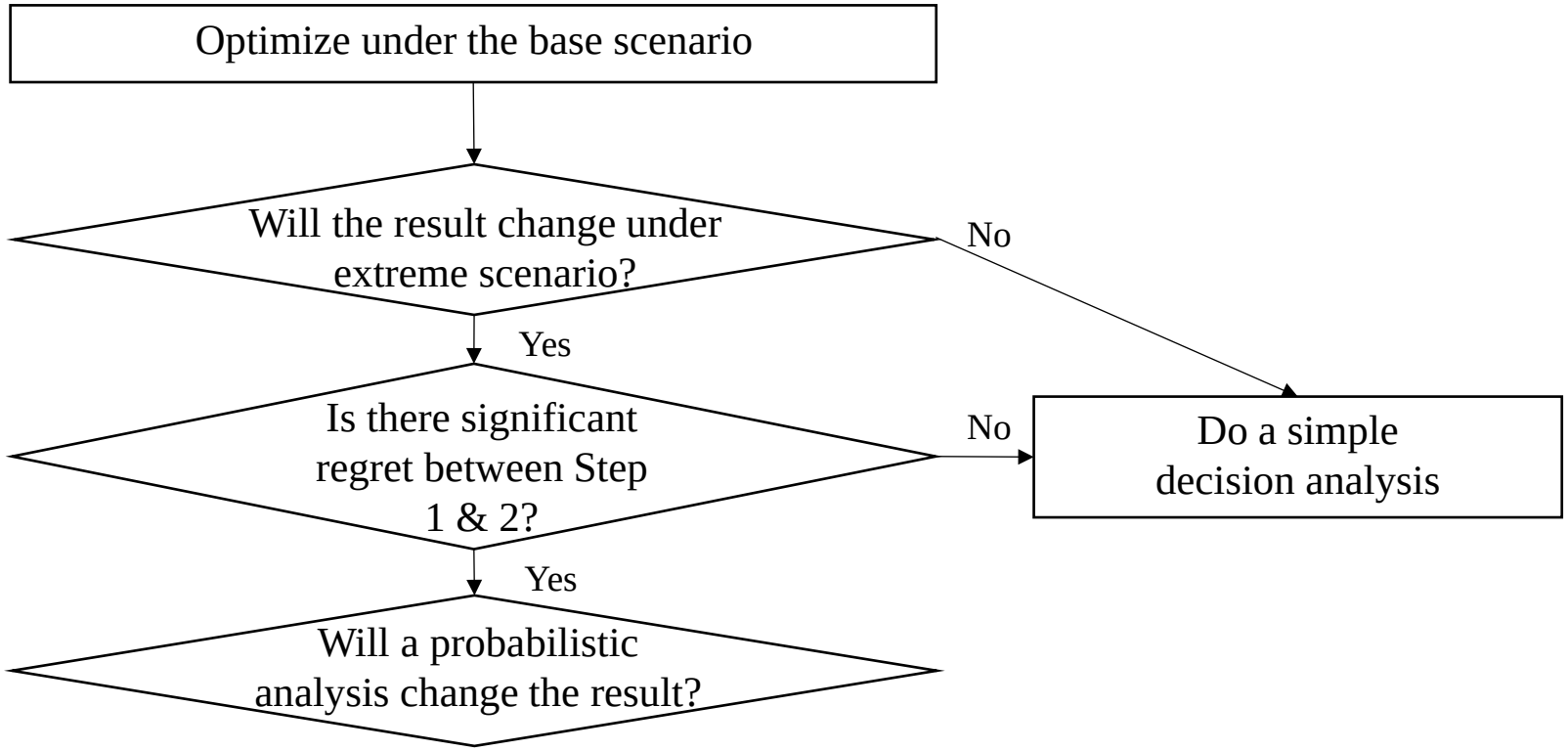
A Five-Step Screening Tool

Step 1 Deterministic Base Case

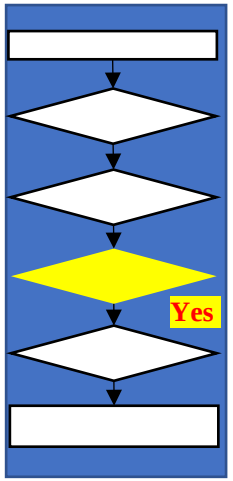
Step 2 Deterministic Extreme Case

Step 3 Regret Significance Check

Step 4 Multi-Scenario Stochastic Analysis



Step 4: Multi-Scenario Stochastic Analysis



Uncertainty Matters!

Building a floodwall
Cost = 205

Do nothing
Cost = 0

different decision than base case

258

262

P(FD_1 = low) = 0.58
Damage1=0

P(FD_1 = high) = 0.42
Damage1= 55

P(FD_1= low) = 0.58
Damage1= 60

P(FD_1 = high) = 0.42
Damage1= 160

221

310

191

360

P(FD_2= low |FD_1= low) = 0.84
Damage2 = 0

P(FD_2= high |FD_1= low) = 0.16
Damage2 = 100

P(FD_2= low |FD_1= high) = 0.50
Damage2 = 0

P(FD_2= high |FD_1= high) = 0.50
Damage2 = 100

P(FD_2= low |FD_1= low) = 0.84
Damage2 = 100

P(FD_2= high |FD_1= low) = 0.16
Damage2 = 300

P(FD_2= low |FD_1= high) = 0.50
Damage2 = 100

P(FD_2= high |FD_1= high) = 0.50
Damage2 = 300

205

305

260

360

160

360

260

460

Year 0 **Year 10** **Year 30**

A Five-Step Screening Tool

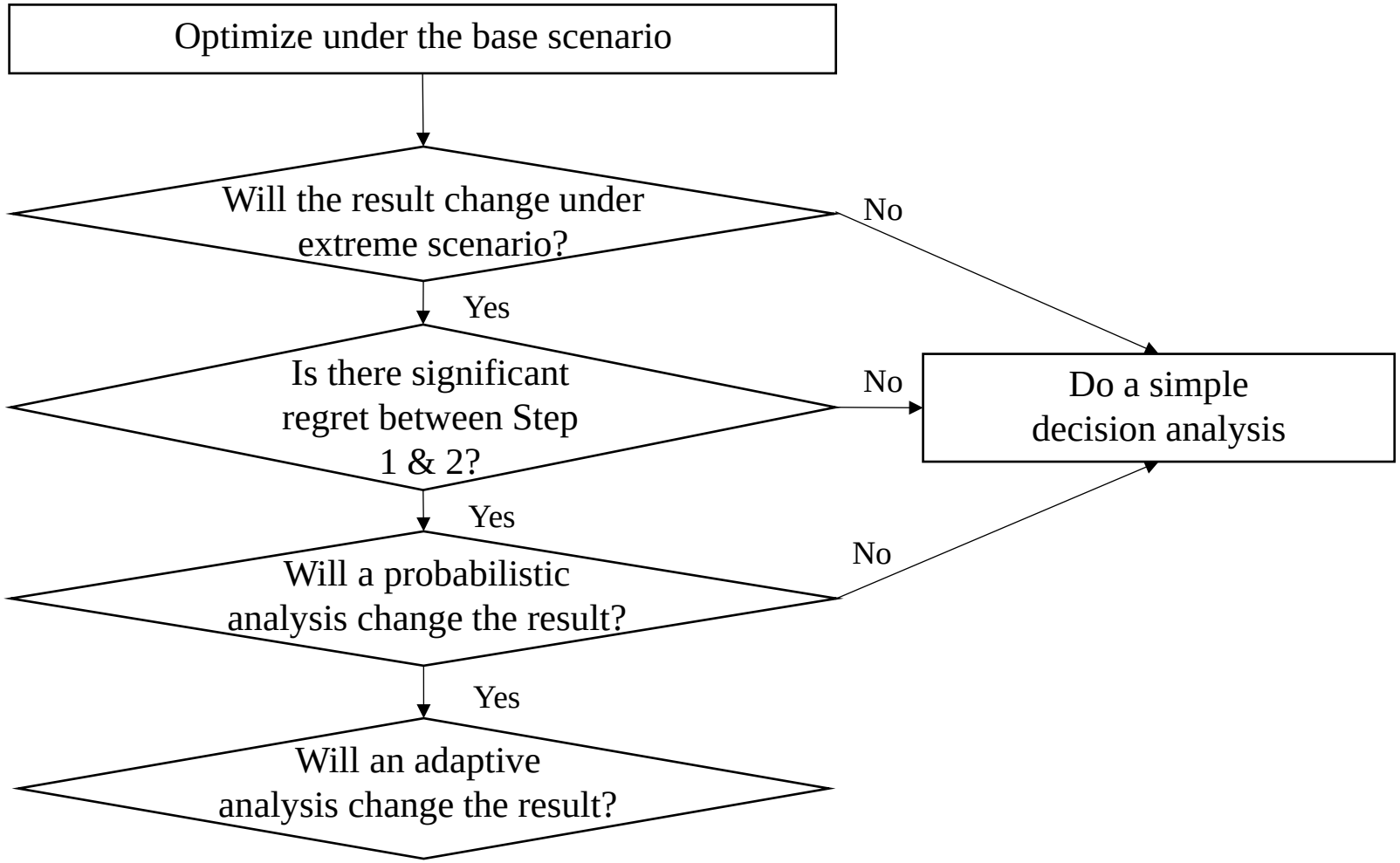
Step 1 Deterministic Base Case

Step 2 Deterministic Extreme Case

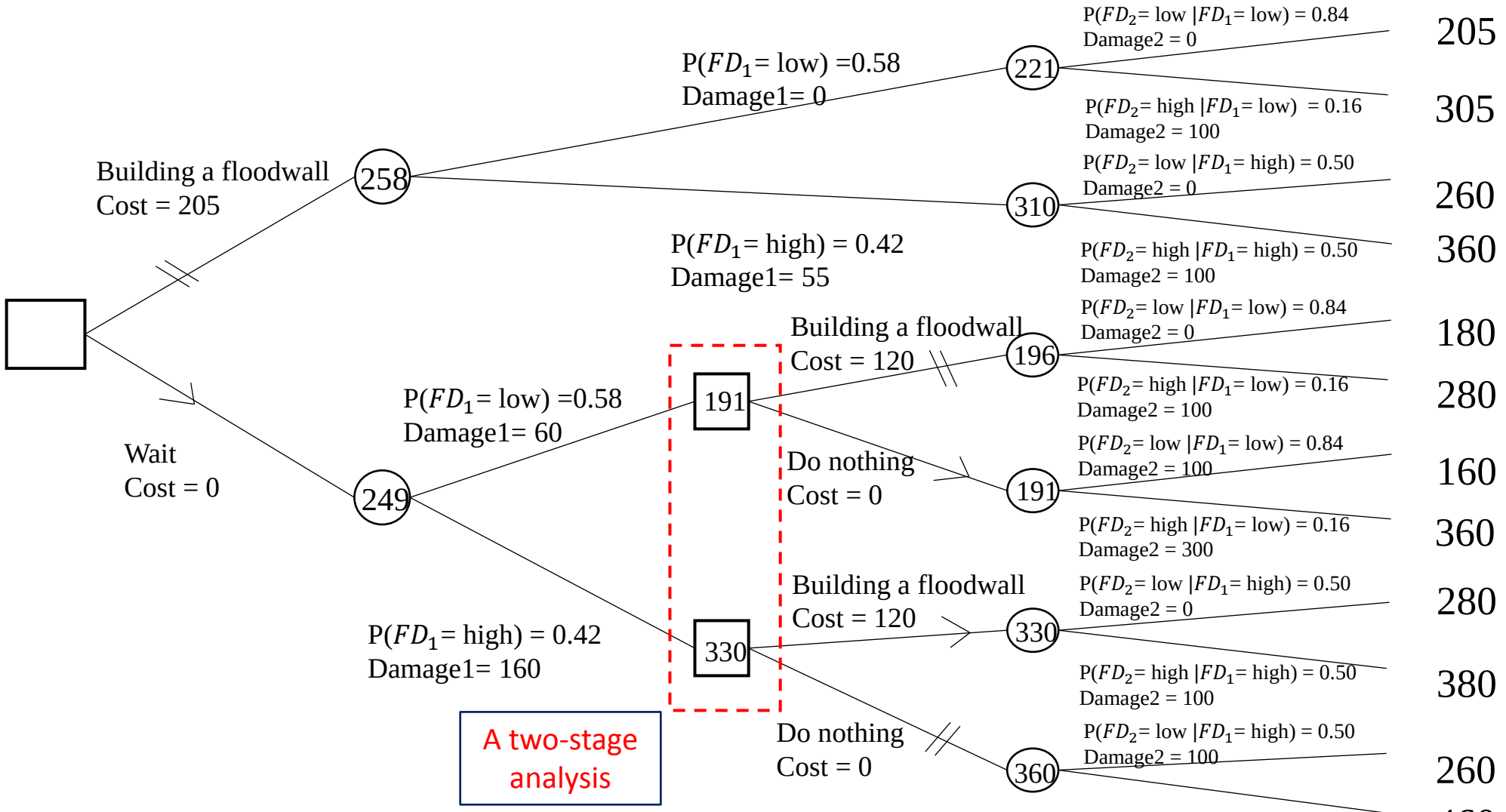
Step 3 Regret Significance Check

Step 4 Multi-Scenario Stochastic Analysis

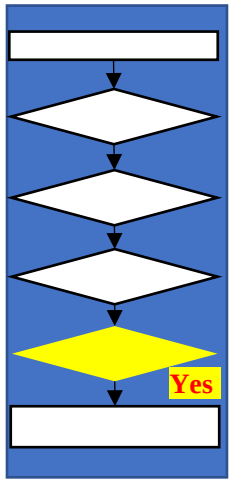
Step 5 Multi-Stage Adaptive Analysis



Step 5: Multi-Stage Adaptive Analysis



Step 5: Multi-Stage Adaptive Analysis



Building a floodwall
Cost = 205

Wait
Cost = 0

258

249

P(FD_1= low) =0.58
Damage1= 0

P(FD_1= high) = 0.42
Damage1= 55

P(FD_1= low) =0.58
Damage1= 60

P(FD_1= high) = 0.42
Damage1= 160

221

310

191

330

Building a floodwall
Cost = 120

Do nothing
Cost = 0

Building a floodwall
Cost = 120

Do nothing
Cost = 0

196

191

330

360

P(FD_2= low |FD_1= low) = 0.84
Damage2 = 0

P(FD_2= high |FD_1= low) = 0.16
Damage2 = 100

P(FD_2= low |FD_1= high) = 0.50
Damage2 = 0

P(FD_2= high |FD_1= high) = 0.50
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P(FD_2= low |FD_1= low) = 0.84
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P(FD_2= high |FD_1= low) = 0.16
Damage2 = 300

P(FD_2= low |FD_1= high) = 0.50
Damage2 = 0

P(FD_2= high |FD_1= high) = 0.50
Damage2 = 100

P(FD_2= low |FD_1= high) = 0.50
Damage2 = 100

P(FD_2= high |FD_1= high) = 0.50
Damage2 = 300

205
305
260
360
180
280
160
360
280
380
260
460

Value of information: make decisions based on the first-phase observation!

Time = 0 **Time = 10** **Time = 30**

A Five-Step Screening Tool

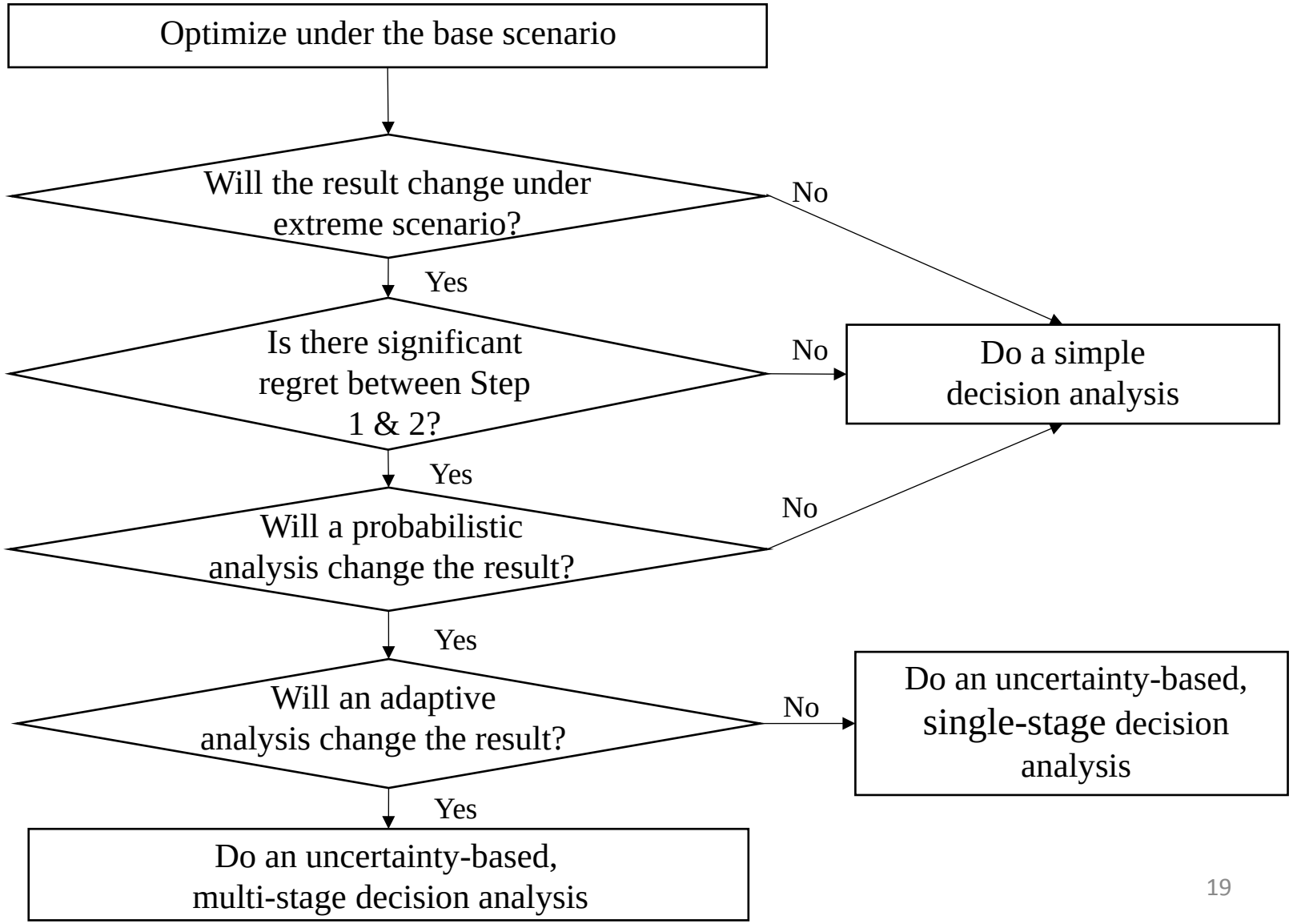
Step 1 Deterministic Base Case

Step 2 Deterministic Extreme Case

Step 3 Regret Significance Check

Step 4 Multi-Scenario Stochastic Analysis

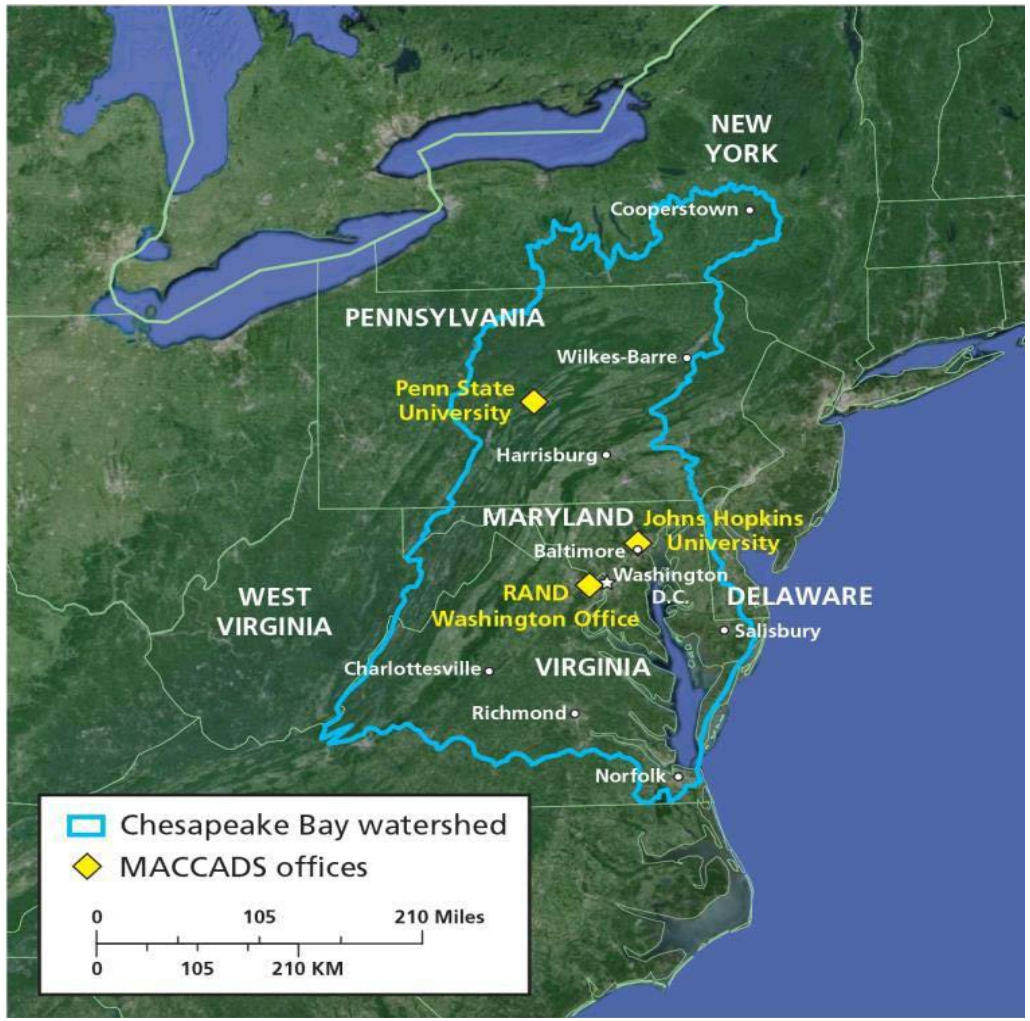
Step 5 Multi-Stage Adaptive Analysis



Prioritization Framework

Goal: rank multiple adaptation problems in terms of potential benefit from decision analysis

Prioritizing multiple problems



Mid-Atlantic Regional Integrated Sciences and Assessments (MARISA)

- Regional Adaptation Planning
- Multiple Adaptation Problems (> 40 cases)
- Limited Resources (personnel and time)

Which problems should we devote limited decision analysis resources to?

General Climate Adaptation Problems

Risk type	Adaptation Problem
A. Coastal Flooding	A1. electric substation protection
	A2. coastal protective construction
	A3. coastal land acquisition or easements
	A4. living shorelines investment
	A5. coastal marshes protection
	A6. vulnerability reduction for rural roads
	A7. vulnerability reduction for urban transportation
	A8. dams reconstruction/remove
B. Inland Stormwater	B1. urban green infrastructure investment
	B2. total maximum daily loads (TMDLs) management
C. Urban Heat	C1. heat resistant pavement investment
	C2. urban heat island effect mitigation

Criteria

Fitness

(a) Climate relevance

(b) Various climate scenarios

(c) Multiple near-term alternatives

(d) Long-term flexibility

Importance

(a) Short-term urgency

(b) Size of benefits/costs

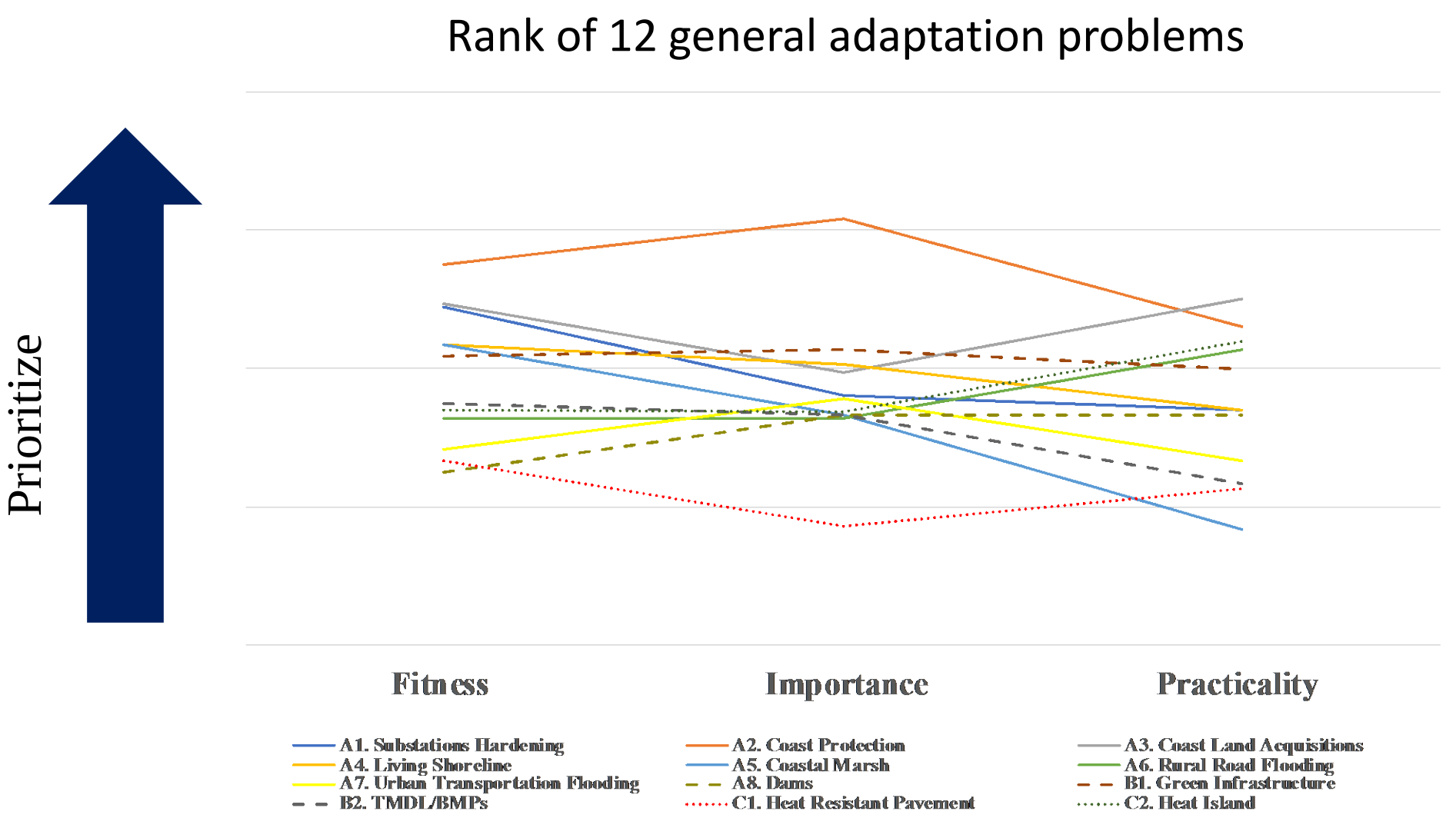
(c) Significance of co-benefits

Practicality

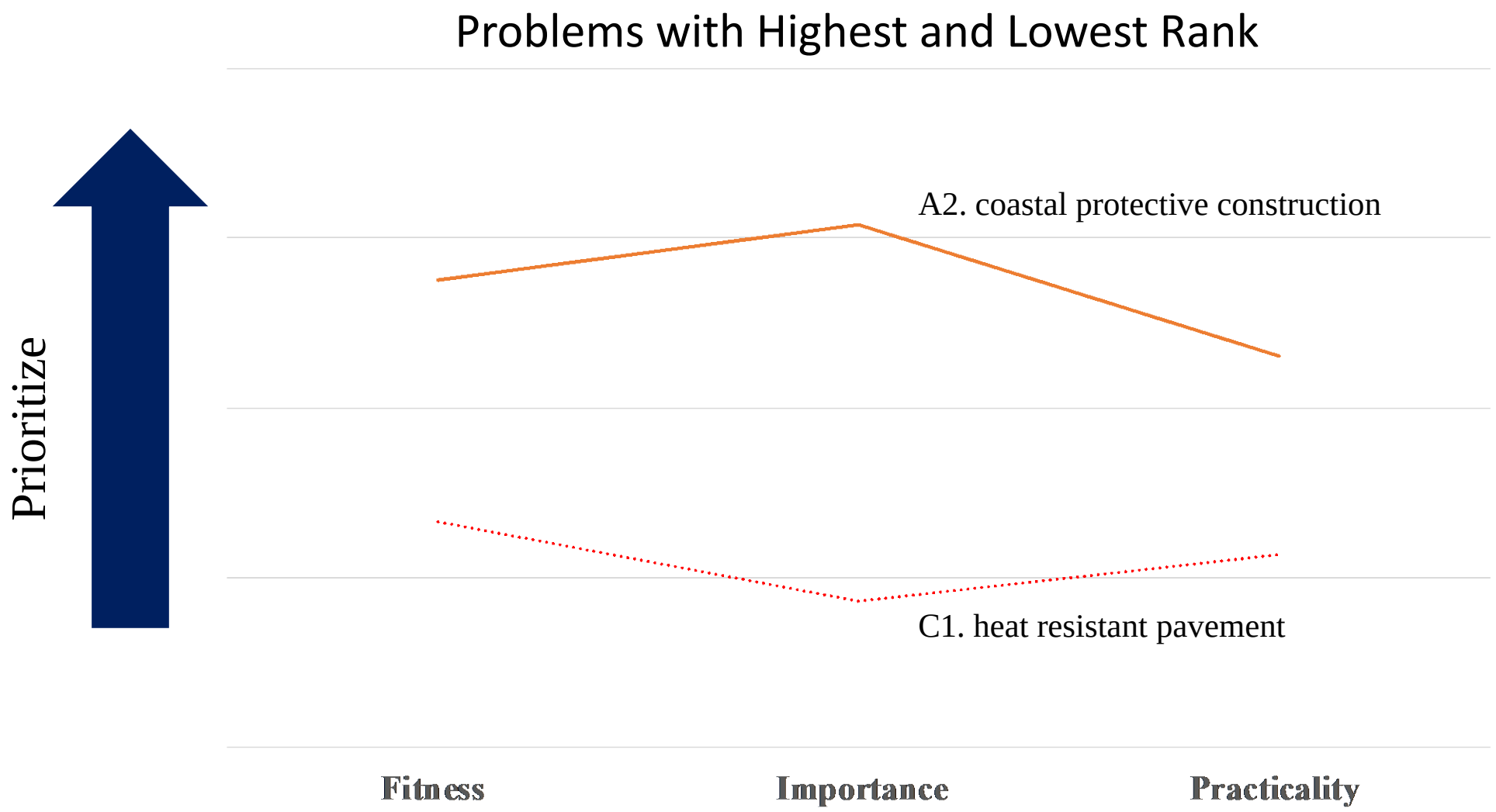
(a) Quantification difficulty

(b) Partnership availability

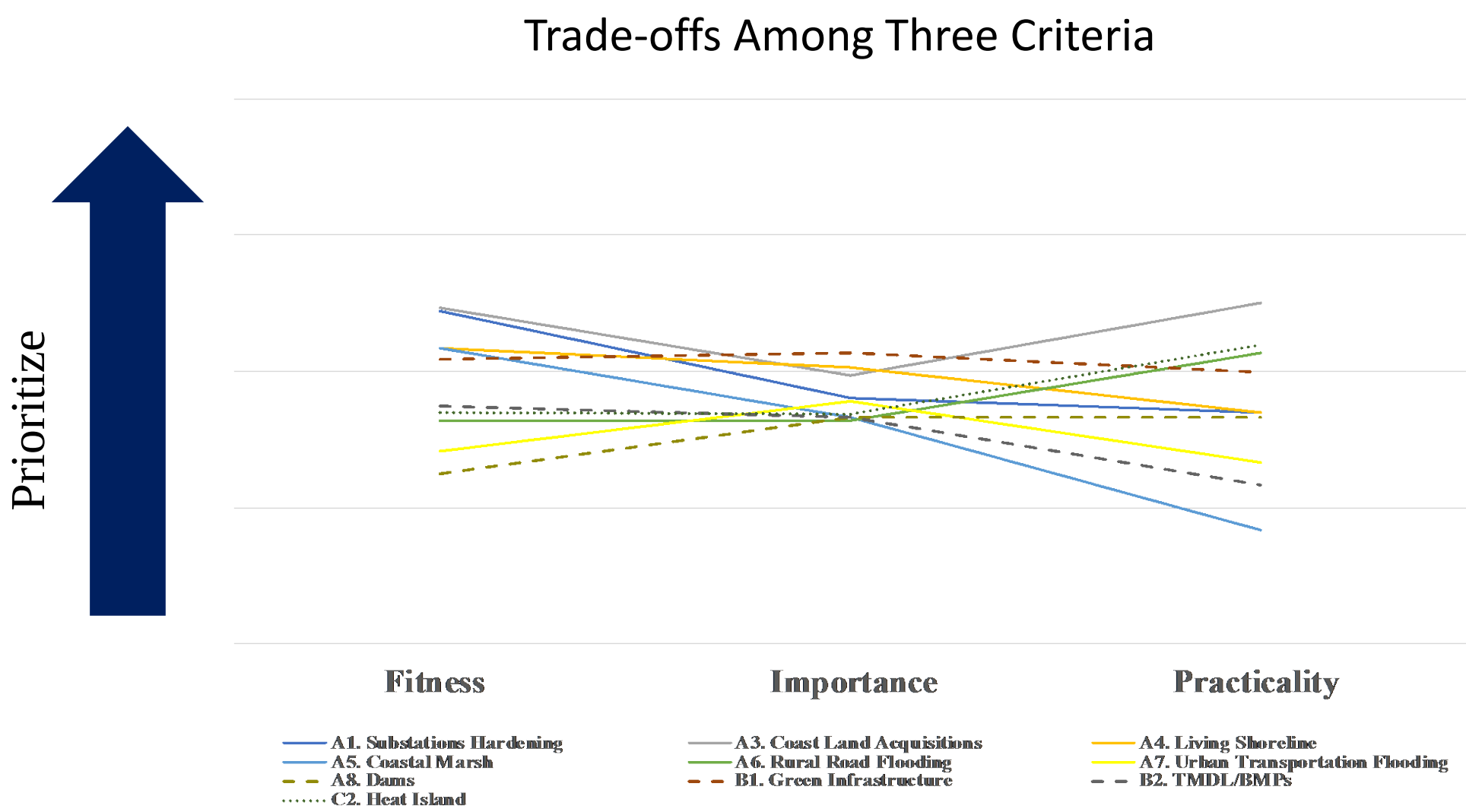
Ranks of Three Criteria



Ranks of Three Criteria



Ranks of Three Criteria



Overall Rank

Rank	Adaptation problem
1	A2. Coastal Protective Construction
2	A3. Coast Land Acquisitions
3	B1. Green Infrastructure
4	A4. Living Shoreline
5	A1. Substations Hardening
6	C2. Heat Island

Conclusion

- **Adaptation problems can benefit from multi-stage, risk-based decision analysis**
  - what commitment to make now to minimize expected costs?
  - is it worthwhile to pay or wait for more information?
  - what is additional flexibility worth?

- **Five-step screening tool for single problem:**
  - identify decision analysis type that's the best fit
  - more rigorous

- **Prioritization framework for multiple problems:**
  - identify a subset of adaptation problems to focus on
  - no need for simple decision trees

Photo Credit: VCCCAR

- **Both tools can improve efficiency & effectiveness of decision analysis**

Thank You!
Q&A

Backup Slides

Hypothetical dataset

Construction cost and flooding damage

	damage magnitude	building a floodwall	doing nothing
Damage1: Near-term damage (M$) Year 1 – 10	$FD_1 = low$	0	60
	$FD_1 = moderate$	20	80
	$FD_1 = high$	55	160
Damage 2: Long-term damage (M$) Year 11 – 30	$FD_2 = low$	0	100
	$FD_2 = moderate$	40	160
	$FD_2 = high$	100	300
Cost (M$)	$n.a.$	205 Yr 0 / 120 Yr 10	0

Probability distribution for flooding damage scenarios

Prior Distribution P(FD_2)	
FD_2 = low	0.70
FD_2 = high	0.30

Conditional Distribution P($FD_1|FD_2$)		
	FD_2 = low	FD_2 = high
FD_1 = low	0.70	0.30
FD_1 = high	0.30	0.70

Bayes Law
Learning

Posterior Distribution P($FD_2|FD_1$)		
	FD_2 = low	FD_2 = high
FD_1 = low	0.84	0.16
FD_1 = high	0.50	0.50

Pre-posterior Distribution P(FD_1)	
FD_1 = low	0.58
FD_1 = high	0.42

Reference

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