

Deciding When Evidence Is Incomplete

Bayesian updating, asymmetric loss and governed action



The executive problem

- Decisions often mature before the evidence does
- Delay can create loss just as action can create loss
- A probability becomes useful only when connected to consequences and authority

Evidence



Action



Executive learning outcomes

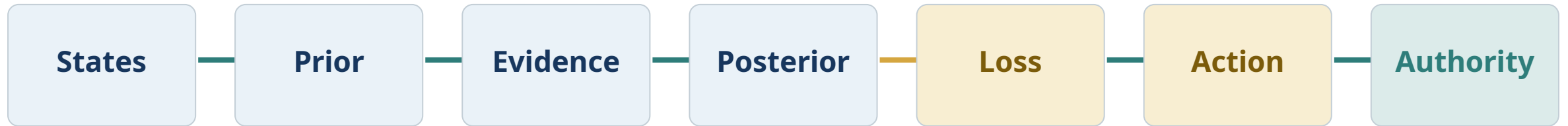
- Update prior beliefs with diagnostic evidence
- Choose actions by posterior expected loss
- Locate decision thresholds and credible reversals
- Compare the value of more evidence with cost and delay
- Record authority, monitoring, review and exit conditions

Terminal artifact

Evidence Update and Decision Loss Matrix

A decision record suitable
for approval and challenge

The governed decision system



- States describe consequential conditions, including omitted possibilities
- Losses make false-positive and false-negative consequences explicit
- Authority converts analysis into a bounded, reviewable decision

Agriculture under emerging evidence

A regional authority must decide whether to intervene before the true severity of a crop outbreak is known.

States	Limited outbreak	Severe outbreak
Prior	0.60	0.40
Positive signal likelihood	0.30	0.80
Monitor loss	0	20
Intervene loss	8	0

Prior beliefs and provenance

- A prior is a documented starting belief, not a guess to conceal
- Provenance includes population, period, source and disagreement range
- Prior sensitivity reveals whether the recommendation depends on a contested baseline

Prior record	
Estimate	0.40
Range	0.25 to 0.55
Source	Seasonal surveillance
Date	Before current signal

Evidence likelihoods and diagnostic weight

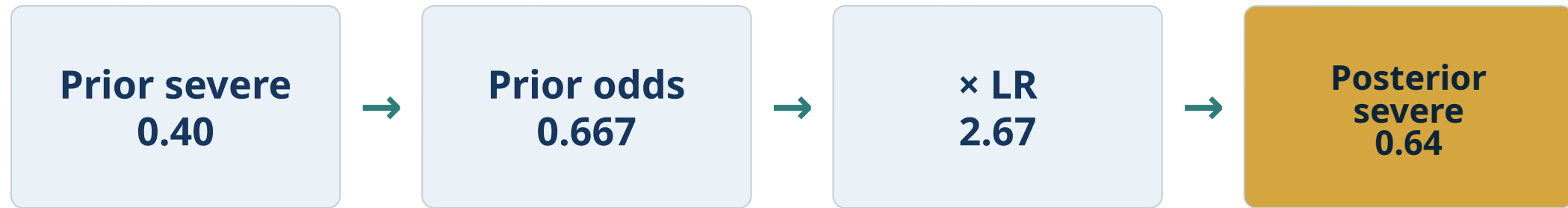
Likelihood ratio

$P(\text{signal} \mid \text{severe}) \div P(\text{signal} \mid \text{limited})$

$$0.80 \div 0.30 = 2.67$$

- The signal is 2.67 times as likely under a severe outbreak
- Diagnostic weight depends on calibration and context
- Correlated reports can overstate evidence when treated as independent

Bayesian updating in the canonical case



$$\text{Posterior odds} = \text{Prior odds} \times \text{Likelihood ratio}$$

- The positive signal increases severe-outbreak probability from 0.40 to 0.64
- The posterior remains conditional on the prior and likelihood model

A posterior is not a decision

0.64

Posterior probability
of severe outbreak

- Probability describes belief about a state
- Action depends on losses across all action-state pairs
- Hard constraints can remove an otherwise attractive action
- Authorization belongs to a named human authority

Loss functions and asymmetric consequences

Loss matrix

Action	Limited	Severe
Monitor	0	20
Intervene	8	0

- False negative: monitor during a severe outbreak
- False positive: intervene during a limited outbreak
- Loss units can combine money, delay, human harm and trust only when the aggregation rule is explicit

Bayes actions use posterior expected loss

Monitor

$$0 \times 0.36 + 20 \times 0.64$$

12.80

Intervene

$$8 \times 0.36 + 0 \times 0.64$$

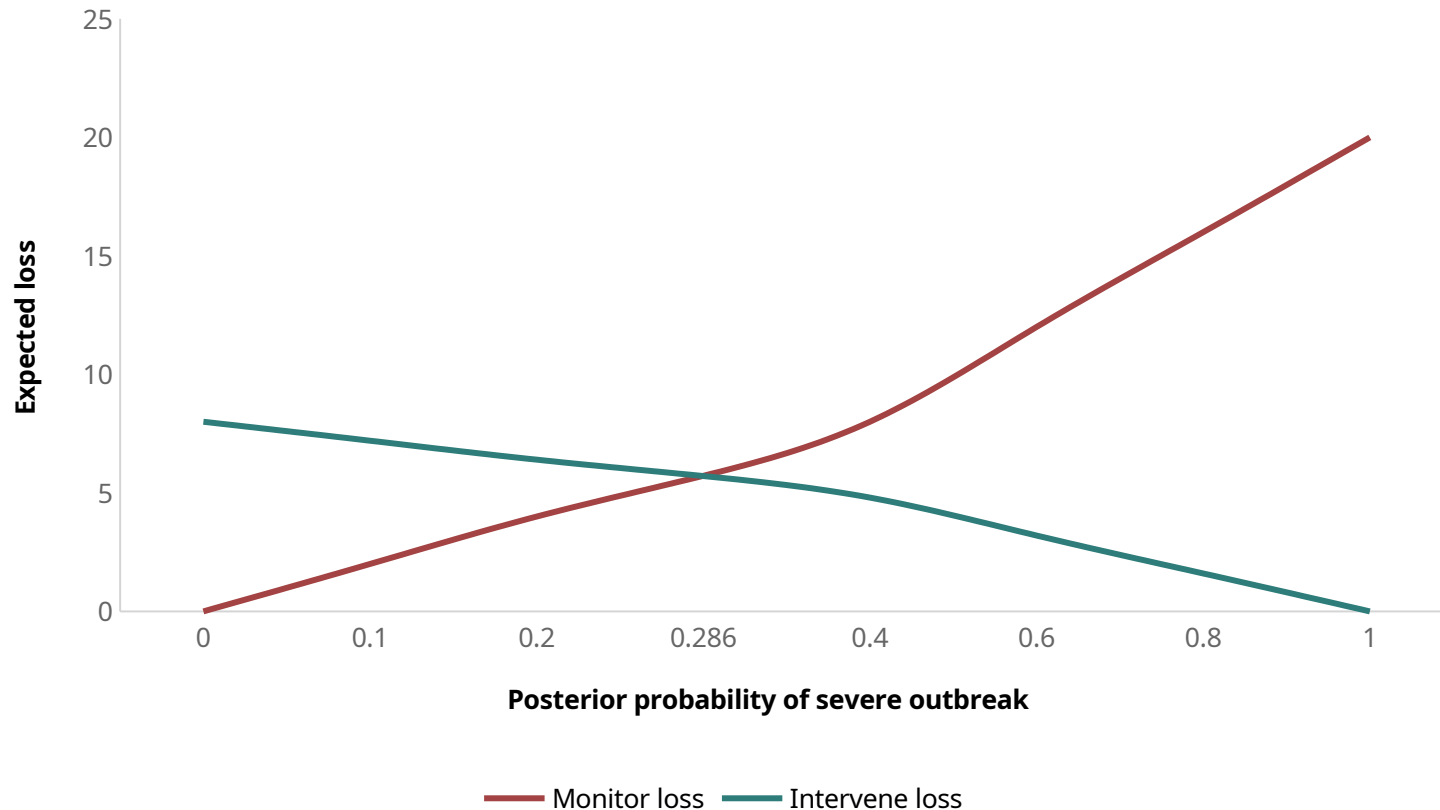
2.88

**Preferred
action
INTERVENE**

Expected-loss advantage = 9.92 units

- The decision follows the lower expected loss, subject to admissibility
- The 9.92-unit advantage provides a margin for challenge

Decision threshold

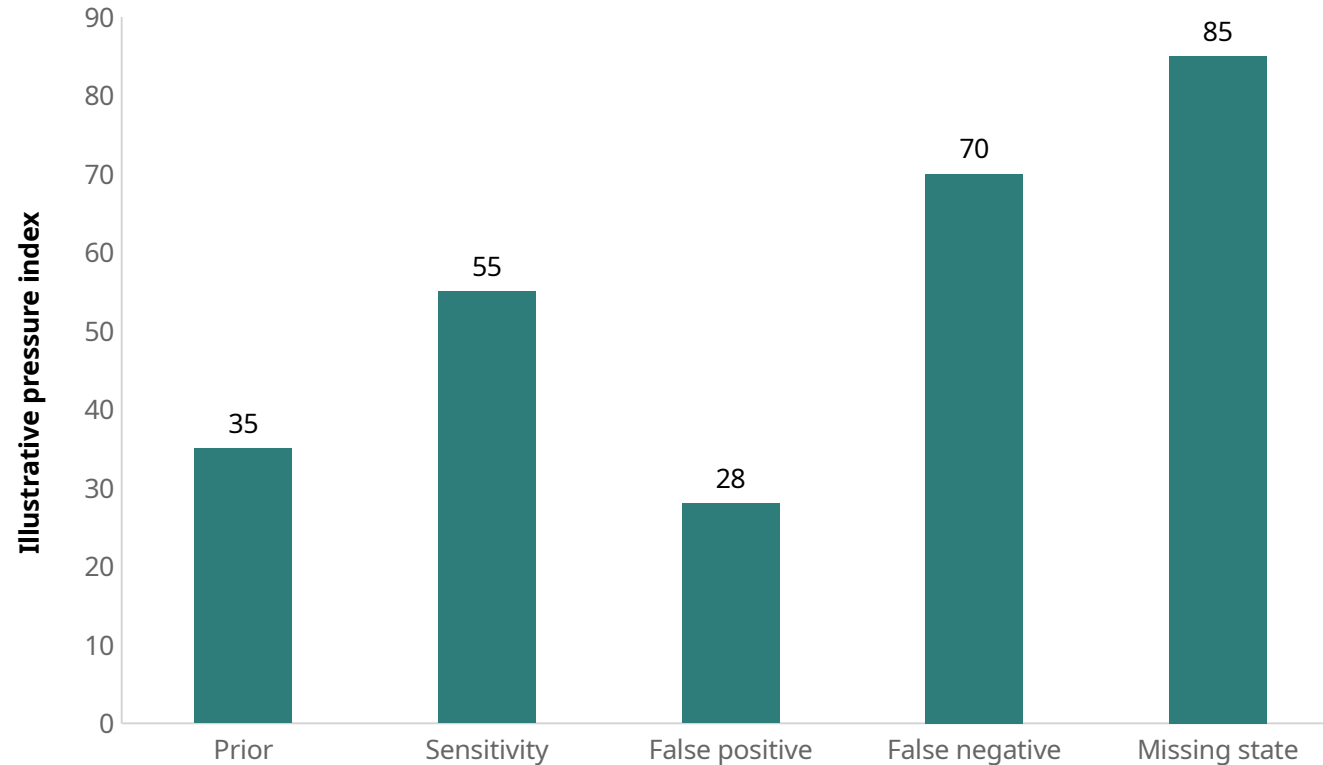


Threshold

0.286

- Below the threshold, monitor
- Above the threshold, intervene
- Near the threshold, small credible changes can reverse the decision

Sensitivity and reversal analysis



- Vary priors within a credible provenance range
- Vary likelihoods for measurement error and transportability
- Vary losses where value judgments remain contested
- Add plausible missing states before approving scale

Illustrative diagnostic, not empirical evidence

Likelihood and model uncertainty

- Diagnostic sensitivity and false-positive rates are themselves uncertain
- Evidence sources may share errors or incentives
- Model averaging can hide disagreement unless components remain visible
- Simulation should report decision frequency, not only posterior averages

5,000 simulations

**Intervene selected
4,230 times**

Decision frequency 84.6%

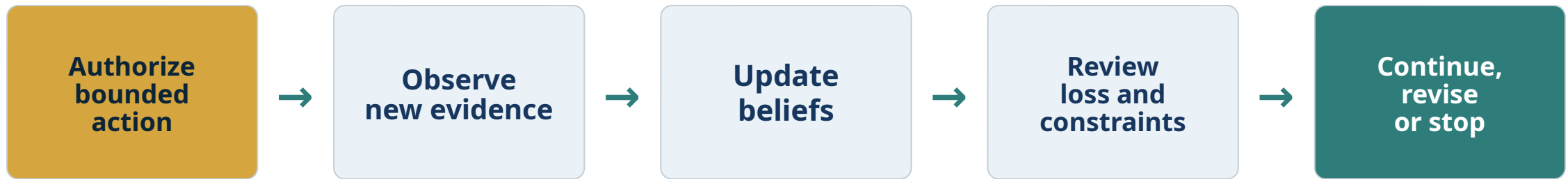
Illustrative output from the companion notebook

Value of information

Current minimum expected loss	2.88
Expected loss after sample information	1.712
EVSI	1.168
Test cost plus delay	1.600
Net value	-0.432

Decision: do not wait for this test under the stated assumptions

Sequential and adaptive decisions



- Use review dates and evidence triggers
- Predefine expansion, pause and exit rules
- Protect reversibility when uncertainty remains high

Missing states and model misspecification

Modeled

Limited outbreak
Severe outbreak

Plausible omissions

Toxic intervention effect
Co-occurring pest
Supply failure
Strategic reporting

- Name at least one missing state
- Specify the signal that would reveal it
- Assign an escalation route outside the current model

Distribution, rights and hard constraints



- Average expected loss can hide who bears harm
- Rights and safety constraints may be non-compensatory
- Subgroup reversals can differ from the population recommendation
- Authorization must name affected groups and remedies

Agriculture application

- State: severe crop outbreak before confirmation
- Evidence: field reports, remote sensing and diagnostic tests
- Dominant loss: delayed control versus unnecessary treatment
- Constraint: ecological exposure and smallholder livelihood
- Governance response: staged intervention with district triggers

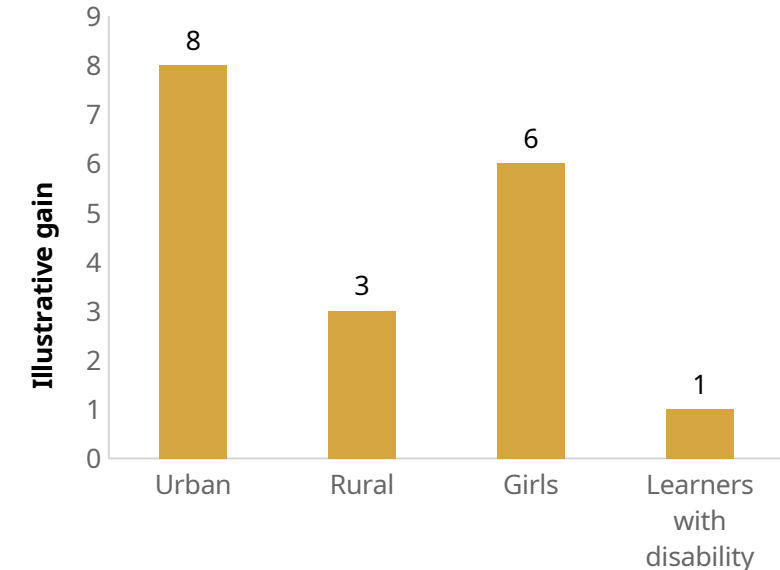
Decision threshold

$p(\text{severe}) > 0.286$

Current posterior 0.64

Education application

- State: the intervention produces a meaningful learning gain
- Evidence: pilot outcomes, attendance and implementation fidelity
- Dominant loss: failed scale-up versus delayed benefit
- Constraint: equity, teacher burden and data rights
- Governance response: stratified pilot before broad authorization



Subgroup results may reverse a population conclusion

Health application

- State: the patient or population faces clinically significant risk
- Evidence: diagnostic performance and local prevalence
- Dominant loss: missed treatment versus overtreatment
- Constraint: safety, consent, referral capacity and clinical authority
- Governance response: threshold linked to an executable care pathway

Posterior after alert

0.321

**A useful alert can still
overload referral capacity**

Habitat application

- State: a structure or settlement faces unsafe exposure
- Evidence: inspection, sensors, weather and community reports
- Dominant loss: missed failure versus unnecessary displacement
- Constraint: life safety, tenure rights and vulnerable residents
- Governance response: emergency threshold with relocation safeguards

Evacuation threshold

$$p(\text{unsafe}) > 0.20$$

**Safety duties may require
a lower operational
threshold**

Evidence Update and Decision Loss Matrix

Decision and authority

States and actions

Prior and provenance

Evidence and likelihoods

Posterior and range

Loss matrix and constraints

Bayes action

Reversal conditions

Value of information

Distributional effects

Monitoring and exit rules

Review date and sign-off

A defensible decision makes uncertainty visible

ACT

Evidence and losses support bounded action

PILOT

Learning can change the decision at acceptable cost

WAIT AND LEARN

Delay has lower loss than premature action

ESCALATE

Missing states, constraints or authority exceed the model

Name the owner. Set the trigger. Date the review. Preserve the record.