# Background on Value of Information Analyses and Overview of Published Framework

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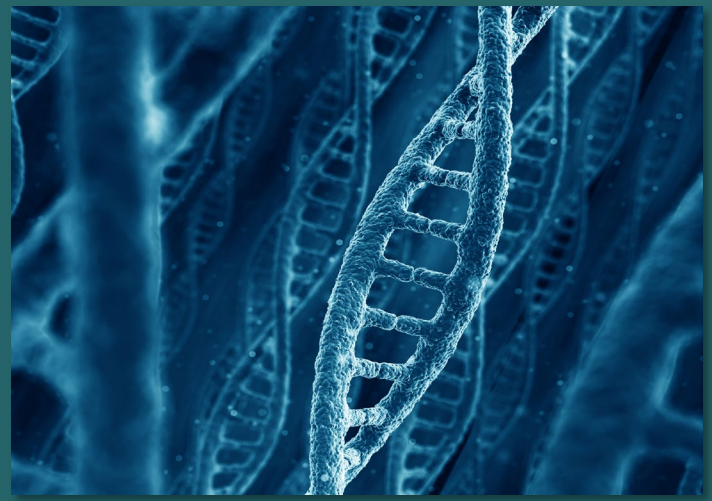


*The views expressed in this presentation are those of the presenters and do not necessarily reflect the views or policies of the U.S. EPA*

# Outline

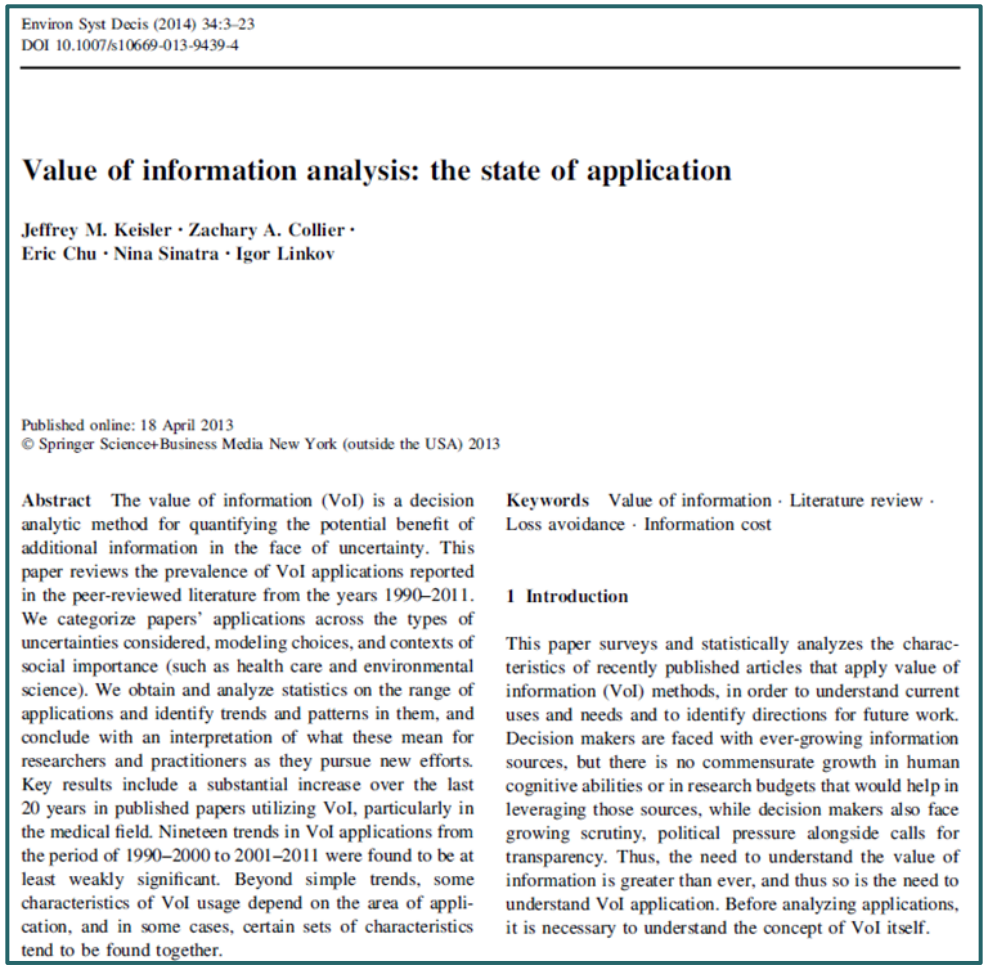
- What is VOI analysis?
- Overview of VOI framework
- Decision-making context
- VOI framework components
- Prior and posterior uncertainty in risk assessment
- Illustrative examples
- Summary

# WHAT IS VOI ANALYSIS?

# VOI Analysis

- Formal systematic approach to determine the “Value of Information” in economic terms
- Allows comparison of “*what we already know*” and “*what we will know*”
- Determines which data generation methodologies are most valuable for risk decision-making

# VOI is Applied in Multiple Disciplines



Environ Syst Decis (2014) 34:3–23
DOI 10.1007/s10669-013-9439-4

**Value of information analysis: the state of application**

Jeffrey M. Keisler · Zachary A. Collier · Eric Chu · Nina Sinatra · Igor Linkov

Published online: 18 April 2013


**Abstract** The value of information (VoI) is a decision analytic method for quantifying the potential benefit of additional information in the face of uncertainty. This paper reviews the prevalence of VoI applications reported in the peer-reviewed literature from the years 1990–2011. We categorize papers' applications across the types of uncertainties considered, modeling choices, and contexts of social importance (such as health care and environmental science). We obtain and analyze statistics on the range of applications and identify trends and patterns in them, and conclude with an interpretation of what these mean for researchers and practitioners as they pursue new efforts. Key results include a substantial increase over the last 20 years in published papers utilizing VoI, particularly in the medical field. Nineteen trends in VoI applications from the period of 1990–2000 to 2001–2011 were found to be at least weakly significant. Beyond simple trends, some characteristics of VoI usage depend on the area of application, and in some cases, certain sets of characteristics tend to be found together.

**Keywords** Value of information · Literature review · Loss avoidance · Information cost

**1 Introduction**

This paper surveys and statistically analyzes the characteristics of recently published articles that apply value of information (VoI) methods, in order to understand current uses and needs and to identify directions for future work. Decision makers are faced with ever-growing information sources, but there is no commensurate growth in human cognitive abilities or in research budgets that would help in leveraging those sources, while decision makers also face growing scrutiny, political pressure alongside calls for transparency. Thus, the need to understand the value of information is greater than ever, and thus so is the need to understand VoI application. Before analyzing applications, it is necessary to understand the concept of VoI itself.

VOI analysis has been proposed or applied in a wide range of disciplines, including:

- Agriculture
- Anthropology
- Chemistry
- Defense
- Ecology
- Economics
- Education
- Energy
- Environmental science
- Geology
- Information science
- Infrastructure
- Medicine
- Transportation

# Applications of VOI in Toxicology

A number of peer-reviewed papers have discussed potential application of VOI analysis in toxicology, including:

- Lave and Omenn (1986)
- Finkel and Evans (1987)
- Lave et al. (1988)
- Taylor et al. (1993)
- Thompson and Evans (1997)
- Yokota et al. (2004)
- Yokota and Thompson (2004)
- Leontaridou et al. (2016)

However, practical applications of VOI analysis in toxicology to real-world problems are lacking

*Unlike the present analysis, none of these previous papers incorporated a time dimension in the calculation of VOI*

# VOI Framework Paper

DOI: 10.1111/risa.13931

ORIGINAL ARTICLE

**A value of information framework for assessing the trade-offs associated with uncertainty, duration, and cost of chemical toxicity testing**

Shintaro Hagiwara[1,2] | Greg M. Paoli[1] | Paul S. Price[3] | Maureen R. Gwinn[4] | Annette Guiseppi-Elie[3] | Patrick J. Farrell[2] | Bryan J. Hubbell[5] | Daniel Krewski[1,6] | Russell S. Thomas[3]

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**Abstract**

A number of investigators have explored the use of value of information (VOI) analysis to evaluate alternative information collection procedures in diverse decision-making contexts. This paper presents an analytic framework for determining the value of toxicity information used in risk-based decision making. The framework is specifically designed to explore the trade-offs between cost, timeliness, and uncertainty reduction associated with different toxicity-testing methodologies. The use of the proposed framework is demonstrated by two illustrative applications which, although based on simplified assumptions, show the insights that can be obtained through the use of VOI analysis. Specifically, these results suggest that timeliness of information collection has a significant impact on estimates of the VOI of chemical toxicity tests, even in the presence of smaller reductions in uncertainty. The framework introduces the concept of the expected value of delayed sample information, as an extension to the usual expected value of sample information, to accommodate the reductions in value resulting from delayed decision making. Our analysis also suggests that lower cost and higher throughput testing also may be beneficial in terms of public health benefits by increasing the number of substances that can be evaluated within a given budget. When the relative value is expressed in terms of return-on-investment per testing strategy, the differences can be substantial.

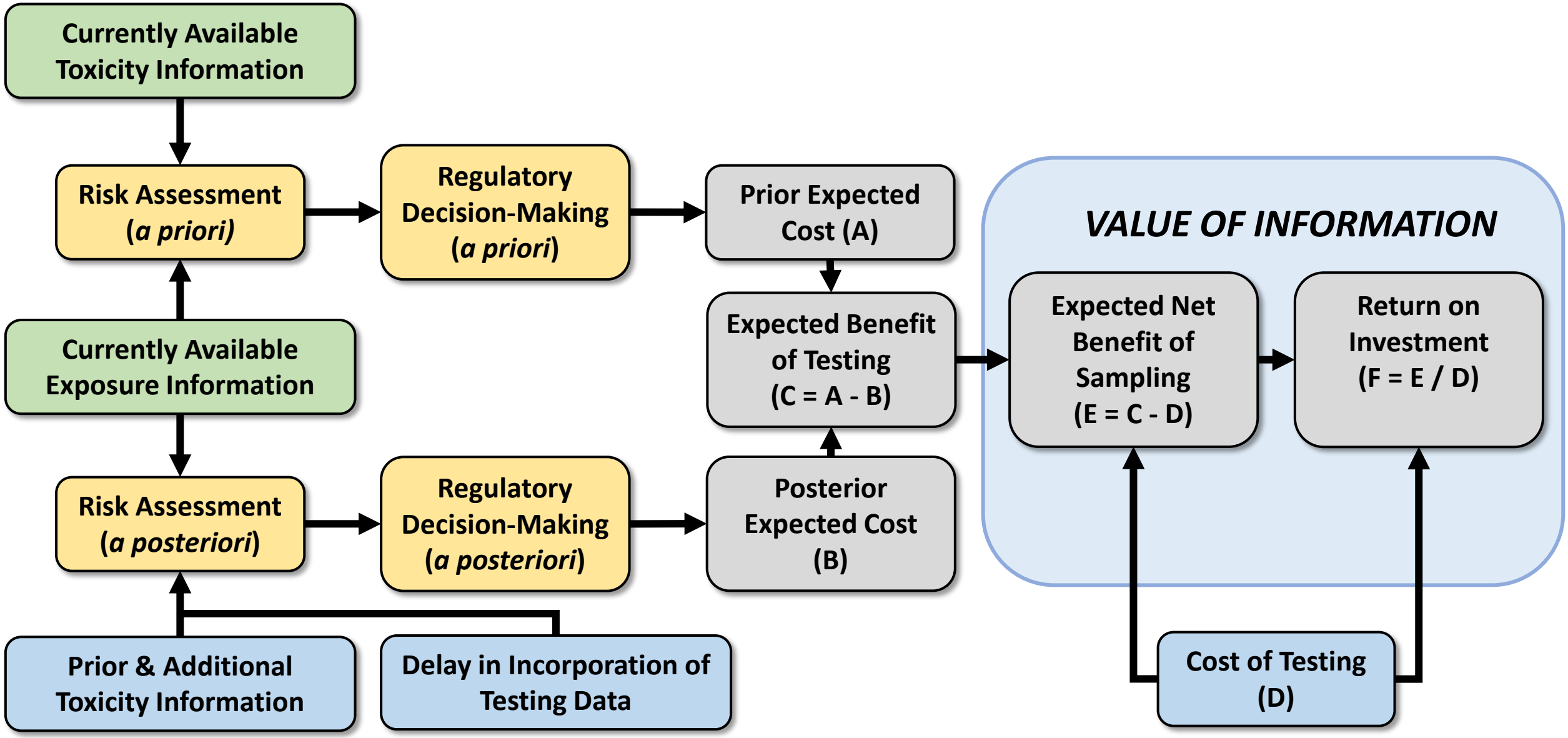
KEYWORDS
cost of delay, return on investment, risk decision making, social cost, toxicity testing, value of information

The present framework extends previous work by explicitly considering the impact of delay in decision-making due to performing additional toxicity testing and then evaluating the test results.

The framework takes into account:

- Amount of **uncertainty** reduced
- **Cost** of additional toxicity testing
- **Delay** in obtaining and evaluating additional toxicity testing data

# OVERVIEW OF VOI FRAMEWORK


Currently Available Toxicity Information
Risk Assessment (*a priori*)
Regulatory Decision-Making (*a priori*)
Prior Expected Cost (A)
Currently Available Exposure Information
Expected Benefit of Testing (C = A - B)
VALUE OF INFORMATION
Expected Net Benefit of Sampling (E = C - D)
Return on Investment (F = E / D)
Risk Assessment (*a posteriori*)
Regulatory Decision-Making (*a posteriori*)
Posterior Expected Cost (B)
Prior & Additional Toxicity Information
Delay in Incorporation of Testing Data
Cost of Testing (D)

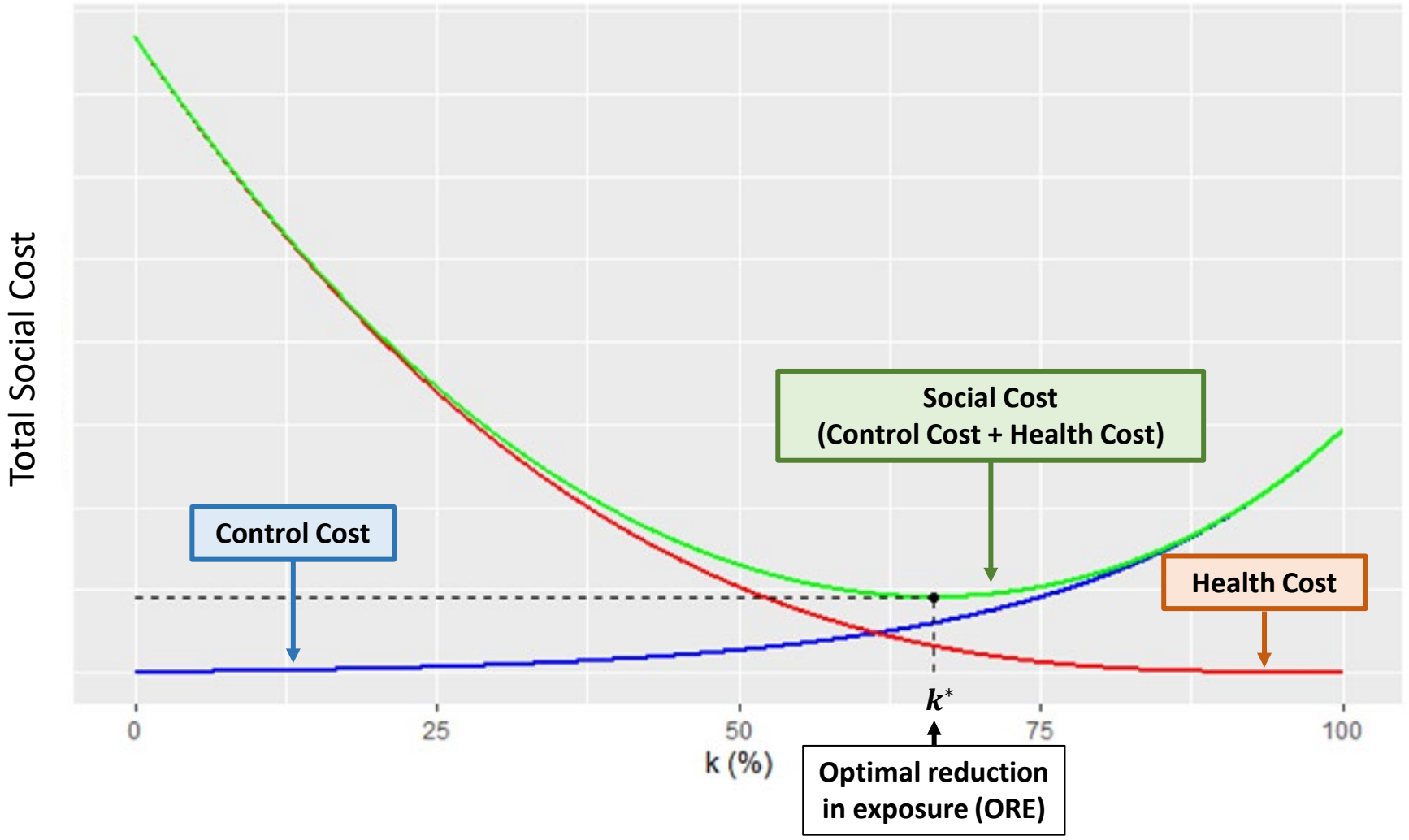
# DECISION-MAKING CONTEXTS

# Benefit-Risk Decision-Maker (BRDM)

- The BRDM seeks to balance population health risks and the societal costs of risk reduction

- To do this, the BRDM minimizes the expected total social cost (ETSC), which is the sum of economic value of the public health benefits of risk reduction and the cost of exposure mitigation

# Minimizing Total Social Cost



# Annualized Social Cost (ASC)

- The ASC is the sum of the annualized control cost (ACC) and health cost (AHC)

$$ASC_k = ACC_k + AHC_k = C_k + NVR_k$$

where

- $N$ is the number of exposed persons
- $C_k$ is the annual cost of control due to the reduction in exposure by $k\%$
- $R_k$ is the residual risk of the adverse effect after the exposure is reduced by $k\%$
- $V$ represents the cost of the specific health detriment being predicted

# Total Social Cost (TSC)

- The TSC is the sum of the health cost and control cost over a given time horizon:

$$TSC_k = \underbrace{\sum_{y=y_{\mathrm{imp},j,k}}^{y_{TH}} C_k}_{\text{Total Control Cost}} + \underbrace{\left[\sum_{y=1}^{y_{TH}} NB_y RV}_{\text{Total Health Cost w/o intervention}} - \underbrace{\sum_{y_{\mathrm{imp},j,k}}^{y_{TH}} NB_y (R - R_k)V\right]}_{\text{Total Health Benefit with intervention}}$$

where

- $y_{\mathrm{imp},j,k}$ is the time to implement the decision based on the $j^{\mathrm{th}}$ toxicity testing to reduce exposure by $k\%$
- $y_{TH}$ is the time horizon
- $R$ is the risk of the adverse effect due to exposure without control strategy
- $B_y$ is the risk annualization factor to convert $R$ (e.g., from lifetime risk to annual risk)

# Application of Social Discount Rate

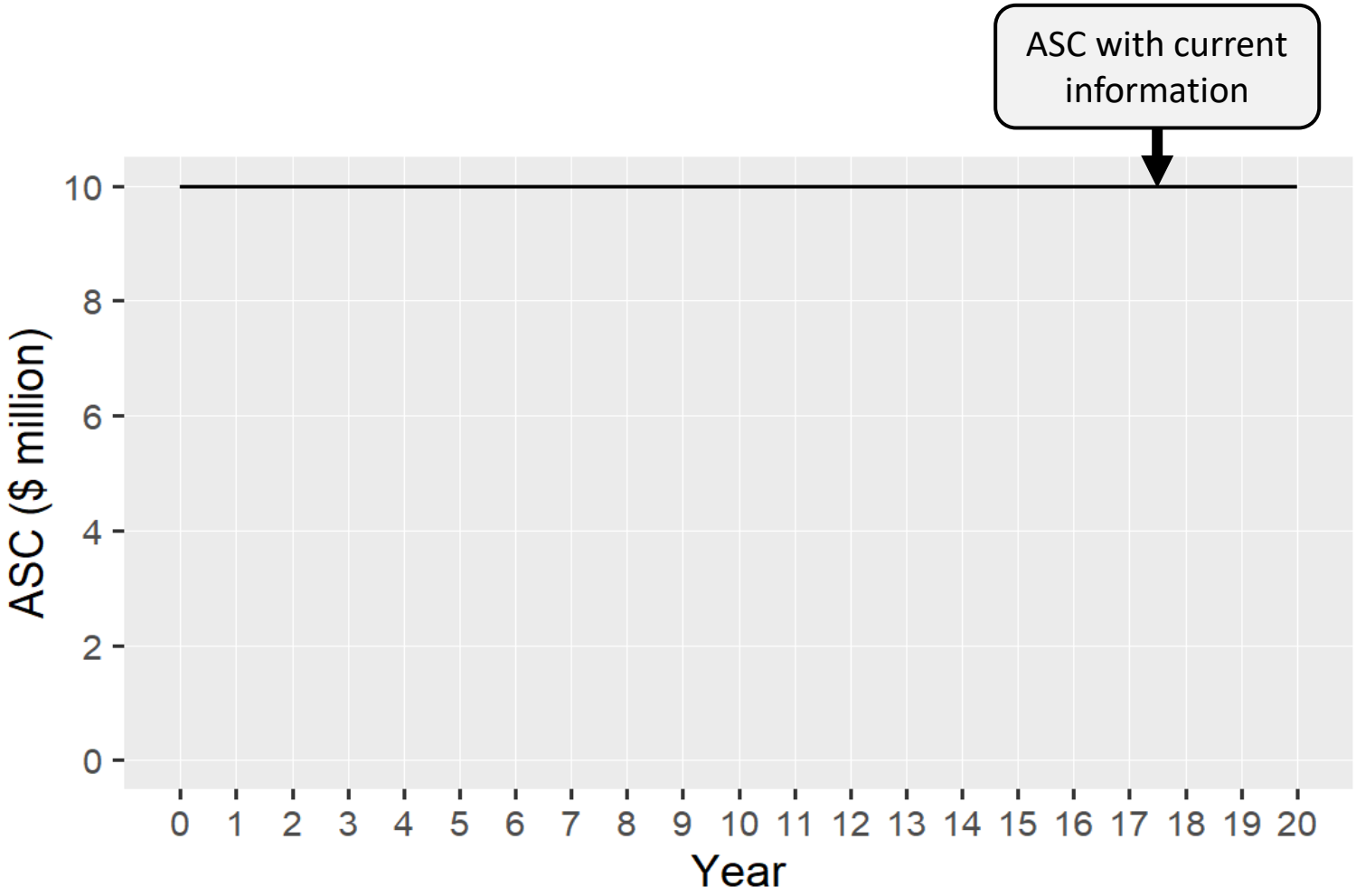
- The TSC is the sum of the health cost and control cost over a given time horizon:

$$TSC_k = \underbrace{\sum_{y=y_{\text{imp},j,k}}^{y_{TH}} \frac{C_k}{(1+r)^{y-1}}}_{\text{Total Control Cost}} + \underbrace{\left[\sum_{y=1}^{y_{TH}} \frac{NB_y RV}{(1+r)^{y-1}}}_{\text{Total Health Cost w/o intervention}} - \underbrace{\sum_{y_{\text{imp},j,k}}^{y_{TH}} \frac{NB_y (R-R_k)V}{(1+r)^{y-1}}}_{\text{Total Health Benefit with intervention}}\right]$$

where

- $y_{\text{imp},j,k}$ is the time to implement the decision based on the $j^{\text{th}}$ toxicity testing to reduce exposure by $k\%$
- $y_{TH}$ is the time horizon
- $R$ is the risk of the adverse effect due to exposure without control strategy
- $B_y$ is the risk annualization factor to convert $R$ (e.g., from lifetime risk to annual risk)
- **$r$ is the discount rate used to determine the net present value of future benefits and costs**

# Illustrative Example: No Additional Testing

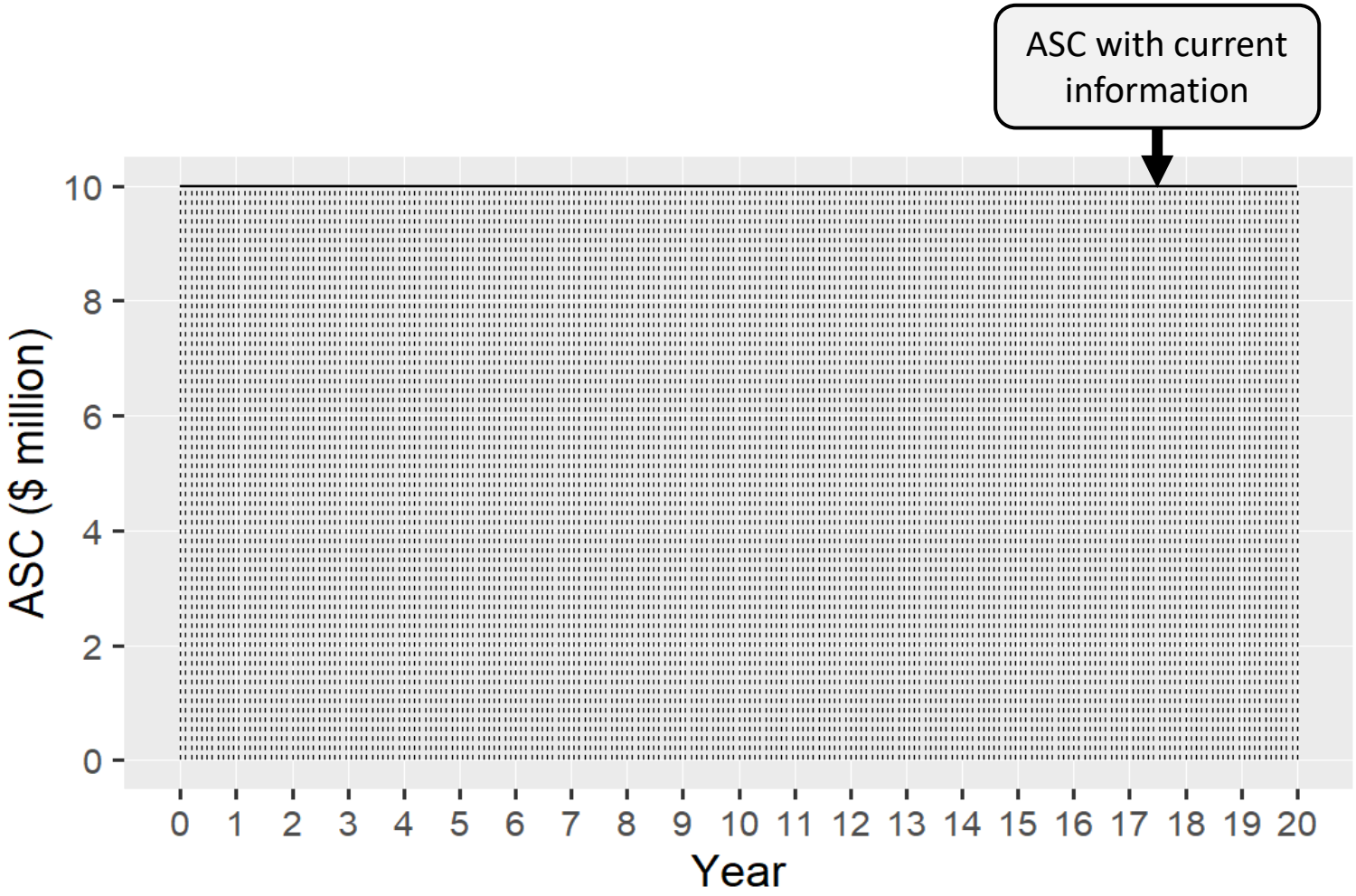



**With Current Information (black)**

- Expected annual social cost (ASC) of $10M
- Time horizon is 20 years

ASC: Annual Social Cost

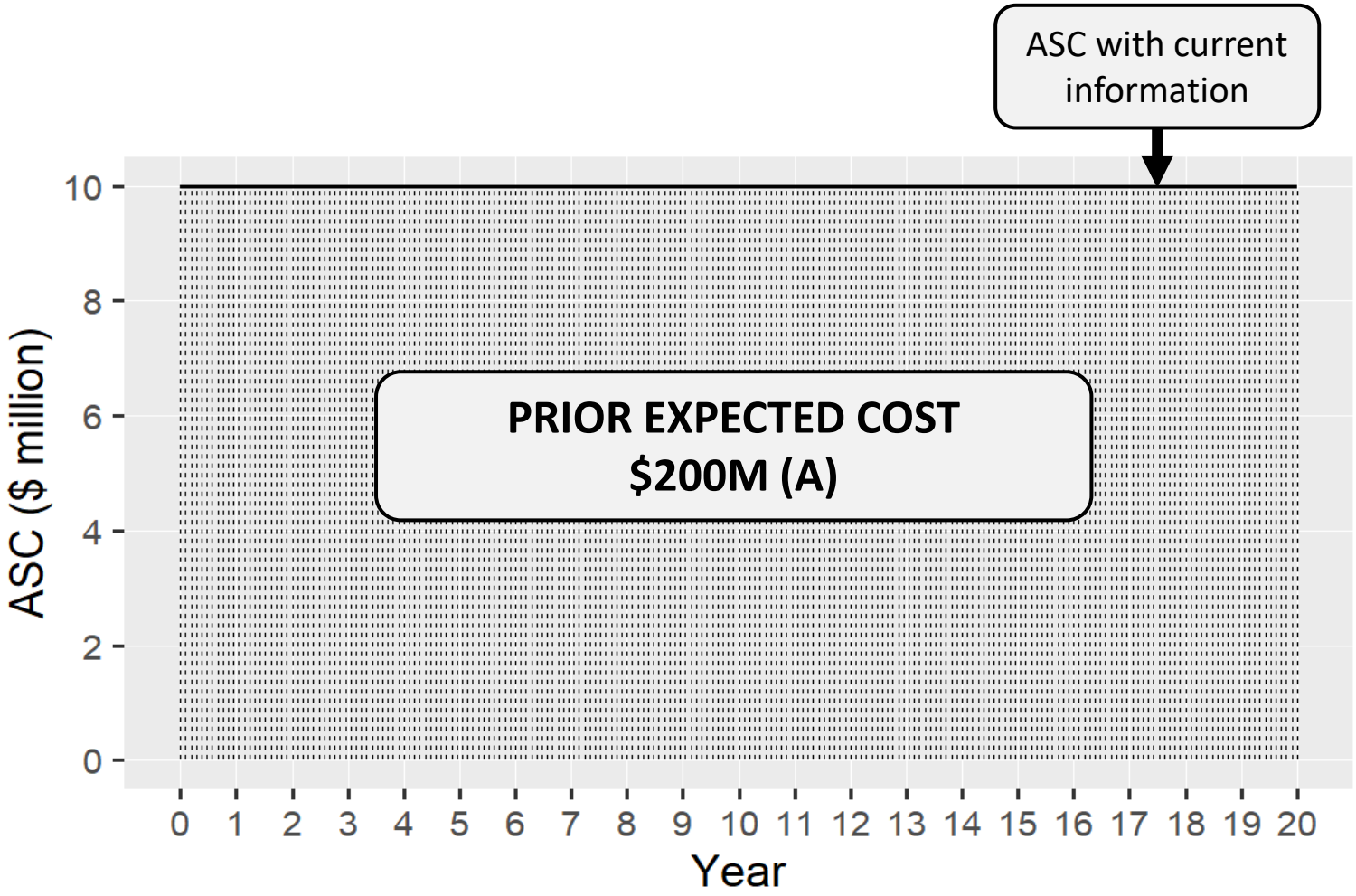
# Illustrative Example: No Additional Testing




**With Current Information (black)**

- Expected annual social cost (ASC) of $10M
- Time horizon is 20 years
- Prior expected total social cost (**A**) is **$200M** over 20-year time horizon

# Illustrative Example: No Additional Testing




**With Current Information (black)**

- Expected annual social cost (ASC) of $10M
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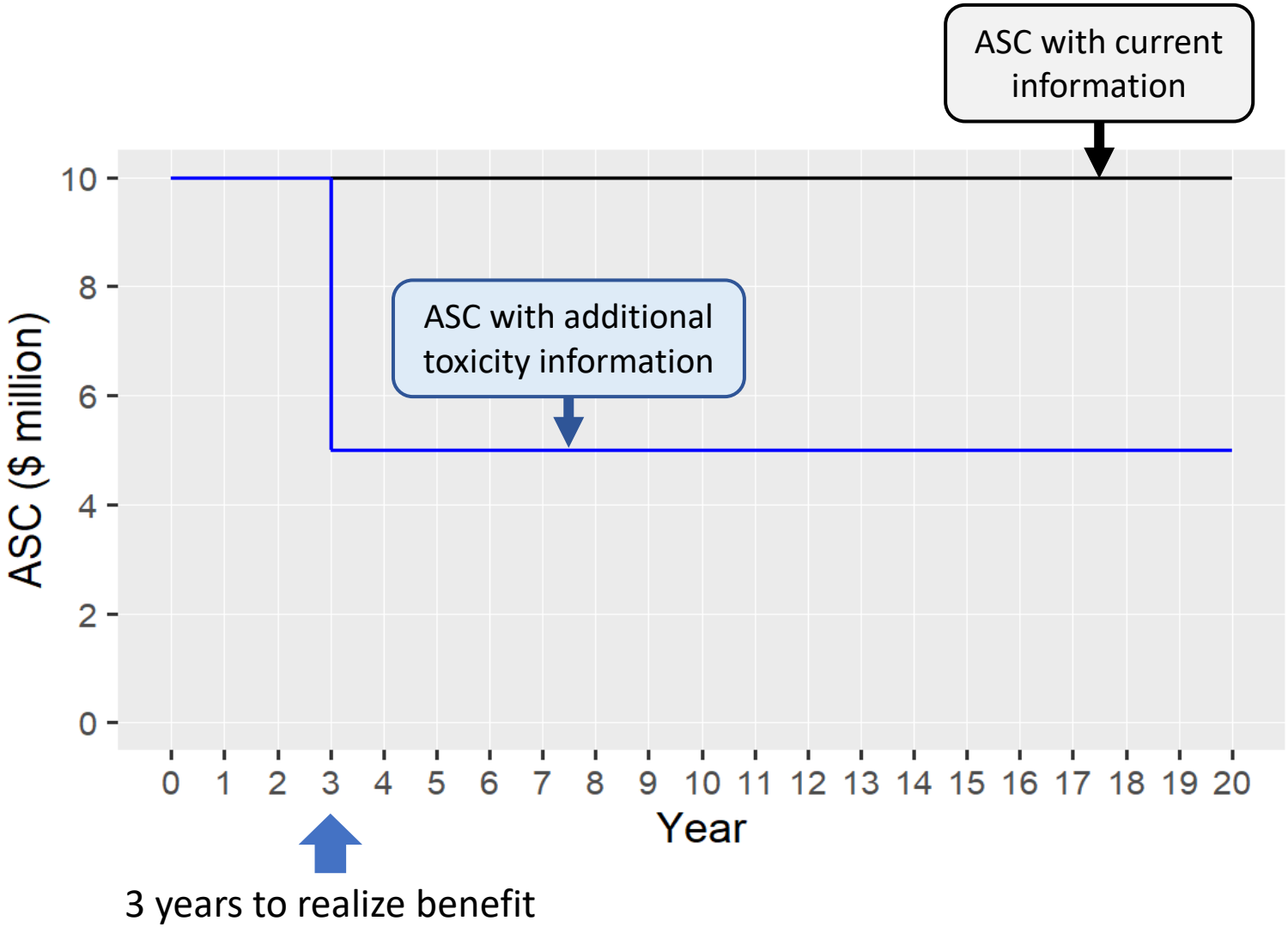
# Illustrative Example: Shorter Testing and Assessment Time (T1)



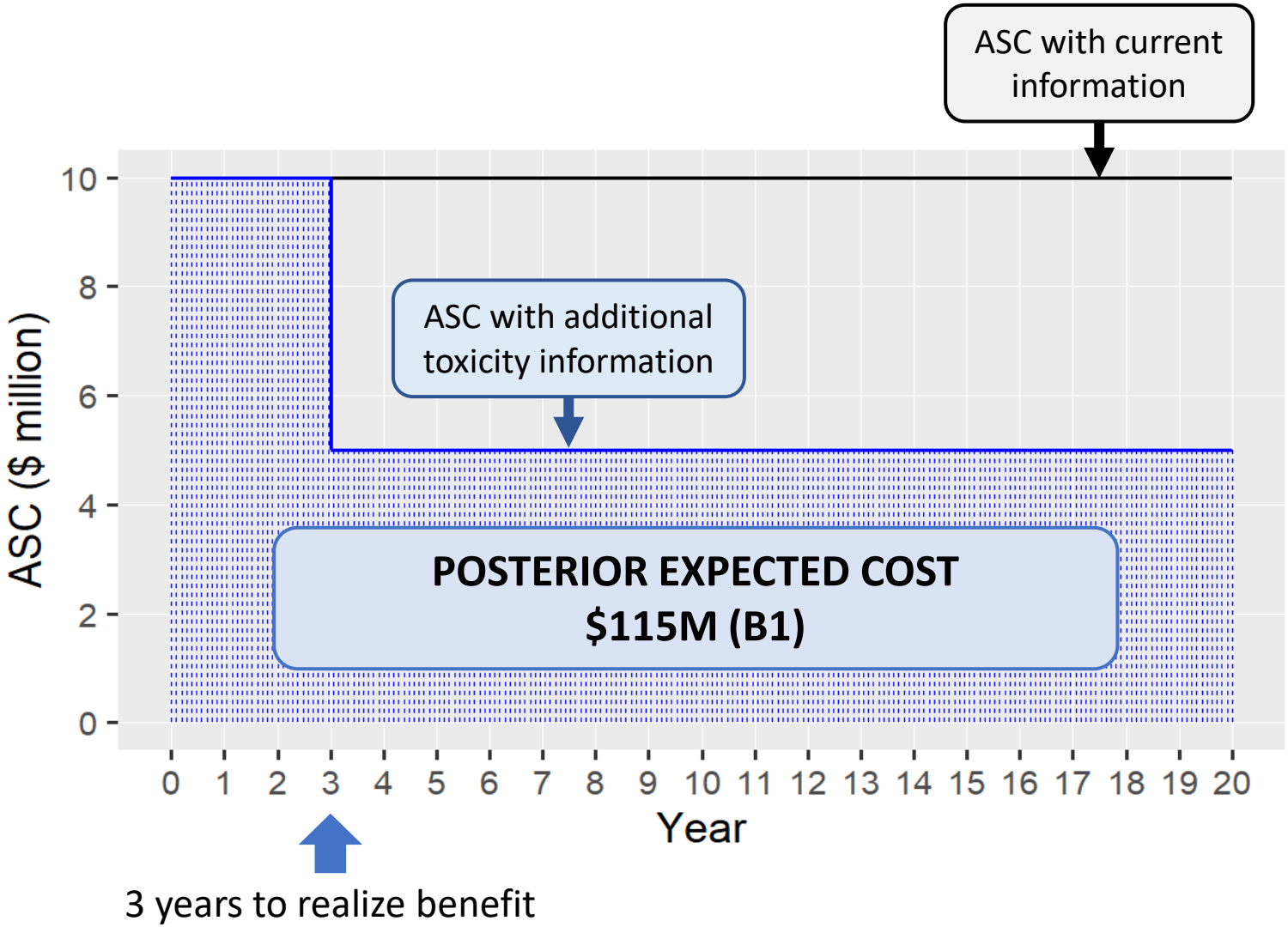

**With Current Information (black)**

- Expected annual social cost (ASC) of $10M
- Prior expected total social cost (**A**) is **$200M** over 20-year time horizon

**With Additional Information (blue)**

- 1 year to conduct and incorporate T1
- 2 years to implement regulation
- Expected ASC reduced to $5M

# Illustrative Example: Shorter Testing and Assessment Time (T1)




**With Current Information (black)**

- Expected annual social cost (ASC) of $10M
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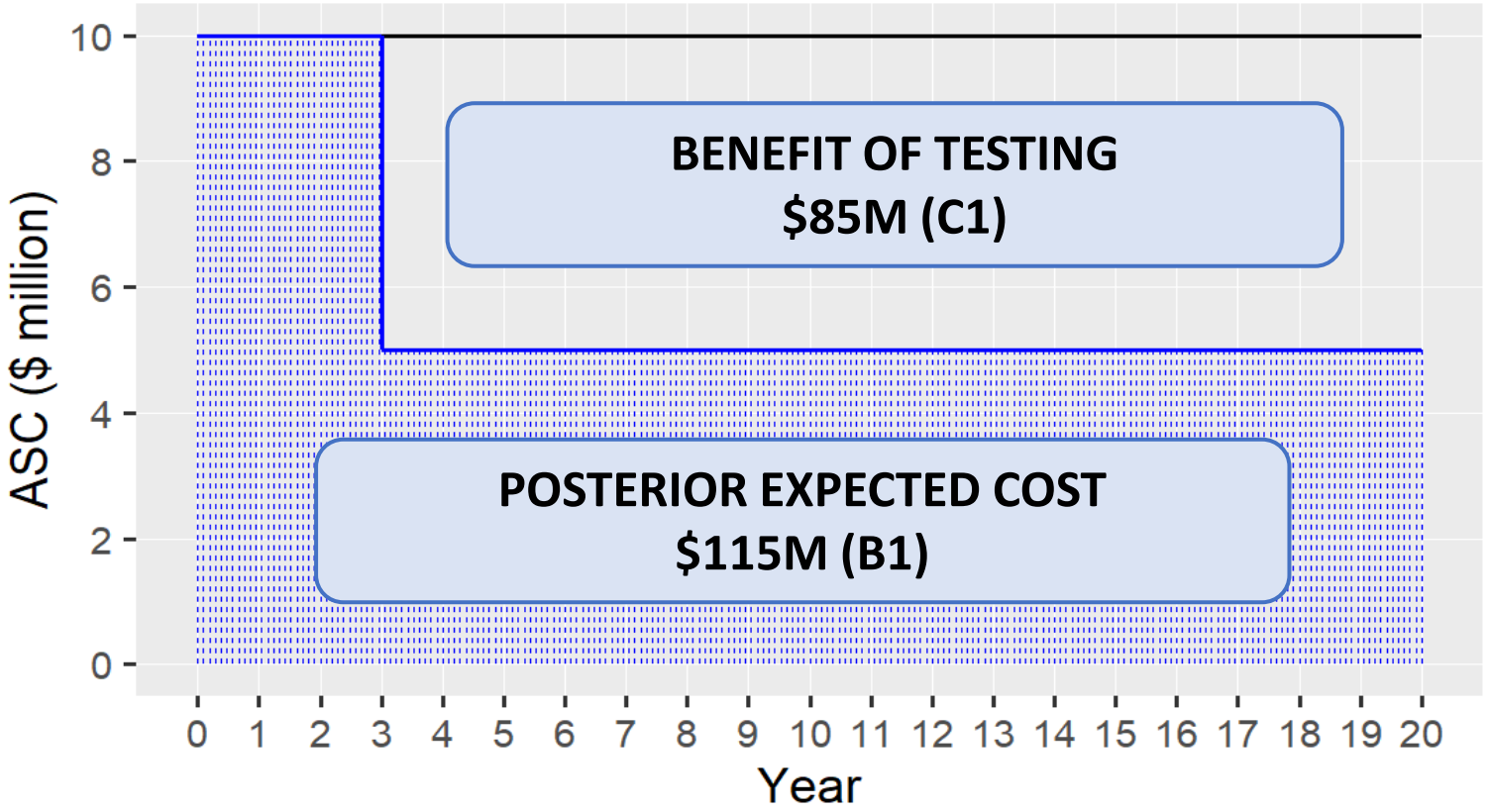
**With Additional Information (blue)**

- 1 year to conduct and incorporate T1
- 2 years to implement regulation
- Expected ASC reduced to $5M
- Posterior ETSC (**B1**) = **$115M** = $10M x 3 years + $5M x 17 years

# Illustrative Example: Shorter Testing and Assessment Time (T1)

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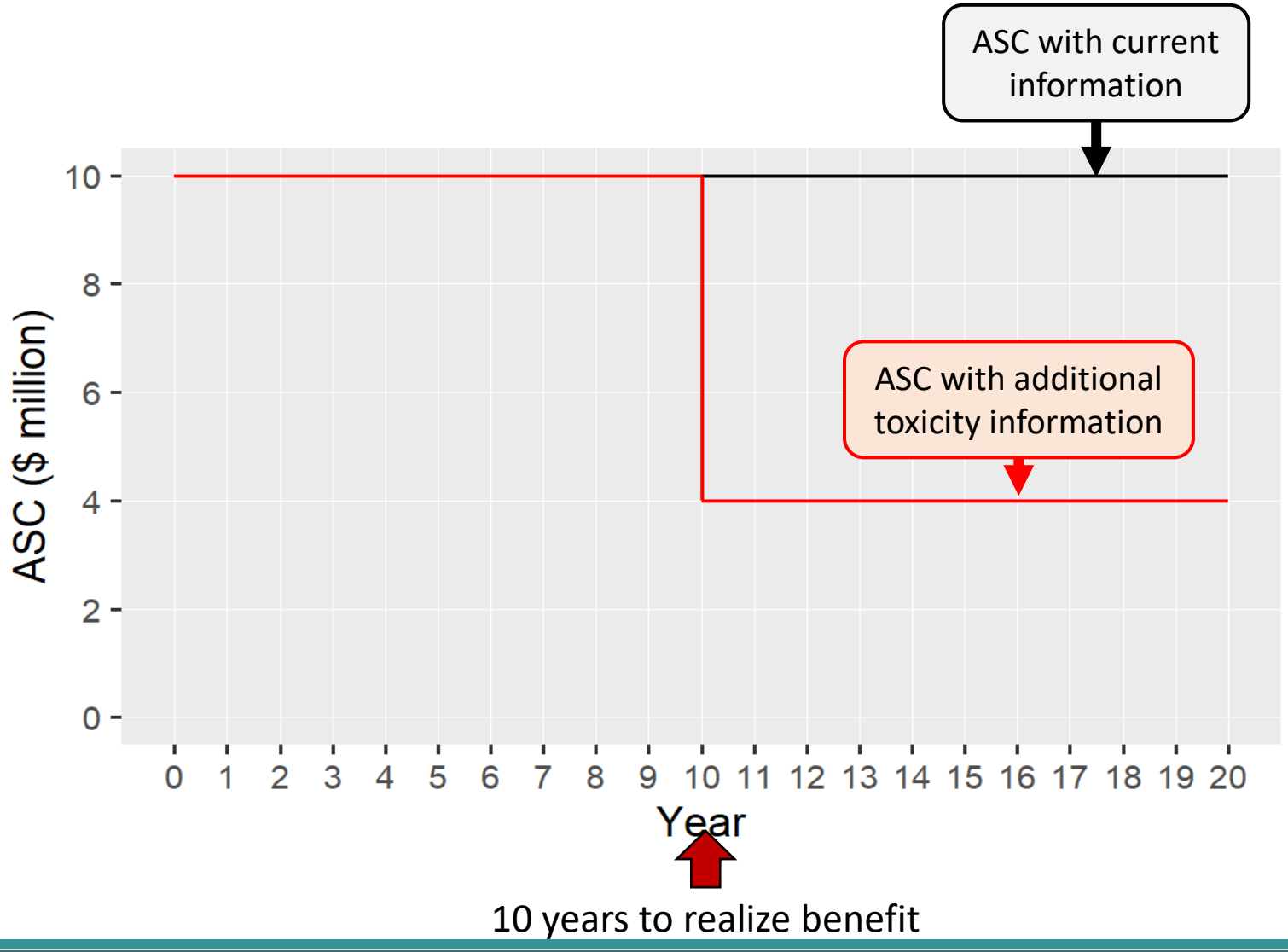
**With Additional Information (blue)**

- 1 year to conduct and incorporate T1
- 2 years to implement regulation
- Expected ASC reduced to $5M
- Posterior ETSC (**B1**) = **$115M** = $10M x 3 years + $5M x 17 years

Expected benefit of testing (**C1**)

**$85M** = $200M - $115M

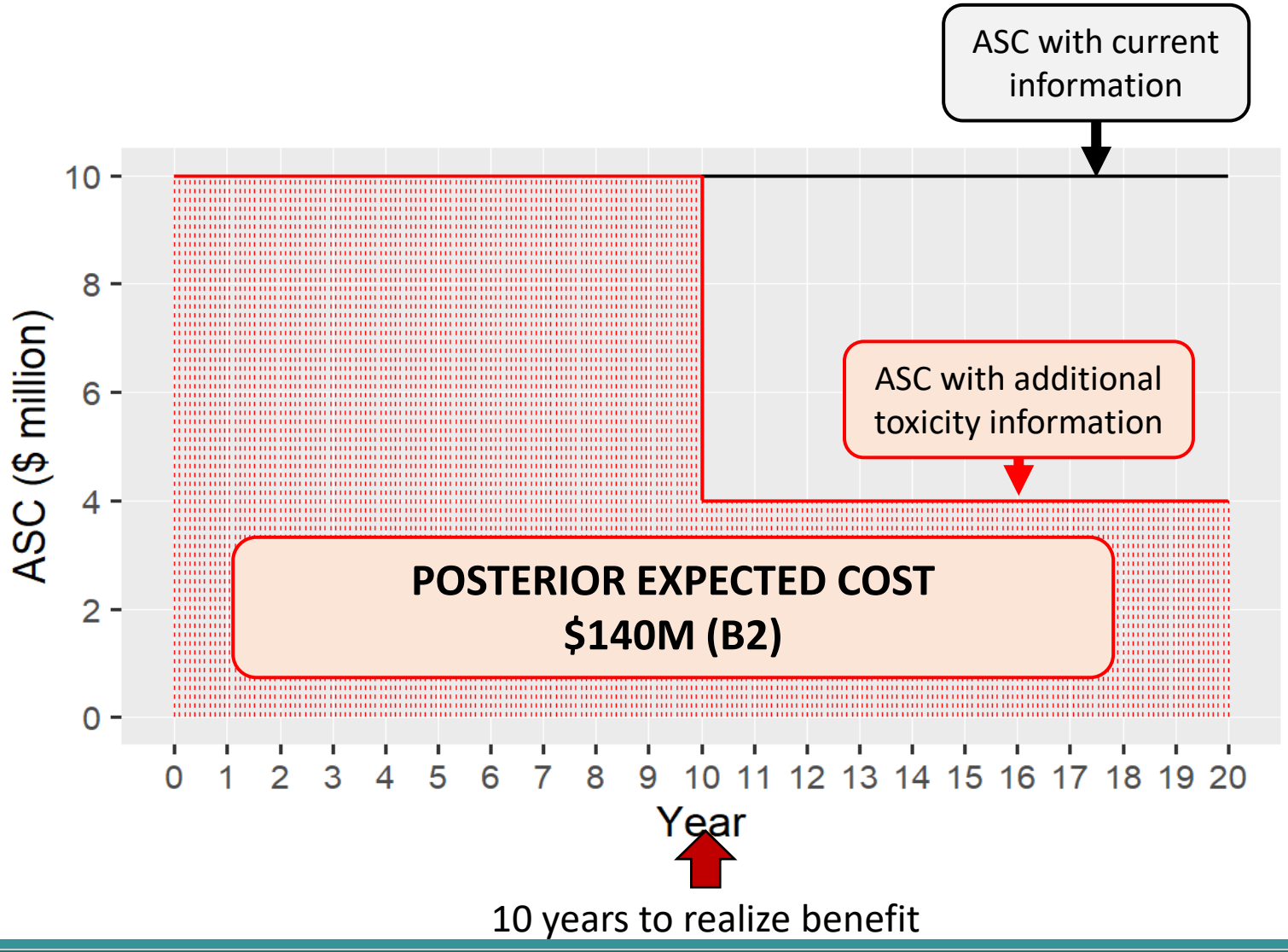
# Illustrative Example: Longer Testing and Assessment Time (T2)




**With Additional Information (red)**

- 8 years to conduct and incorporate T2
- 2 years to implement regulation
- Expected ASC reduced to $4M

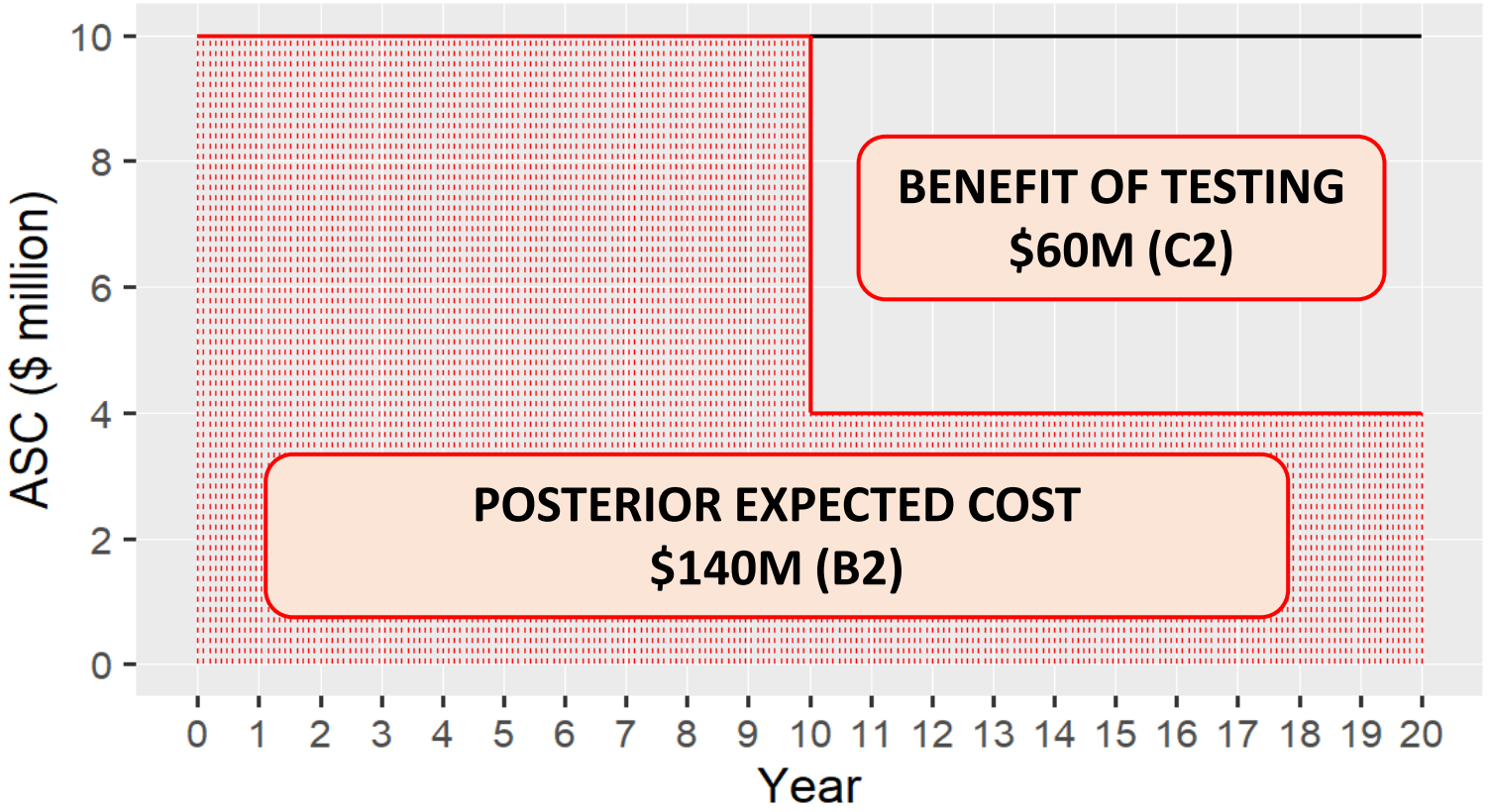
# Illustrative Example: Longer Testing and Assessment Time (T2)




**With Additional Information (red)**

- 8 years to conduct and incorporate T2
- 2 years to implement regulation
- Expected ASC reduced to $4M
- Posterior ETSC (**B2**) = **$140M** = $10M x 10 years + $4M x 10 years

# Illustrative Example: Longer Testing and Assessment Time (T2)

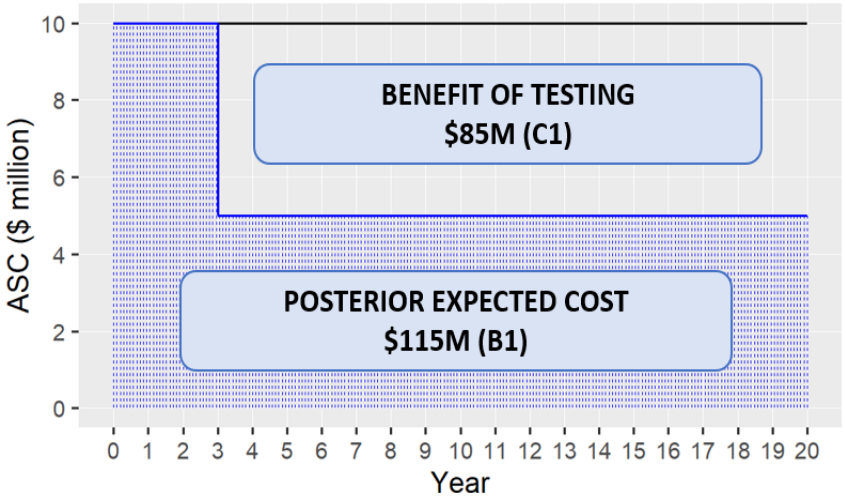



**With Additional Information (red)**

- 8 years to conduct and incorporate T2
- 2 years to implement regulation
- Expected ASC reduced to $4M
- Posterior ETSC (**B2**) = **$140M** = $10M x 10 years + $4M x 10 years

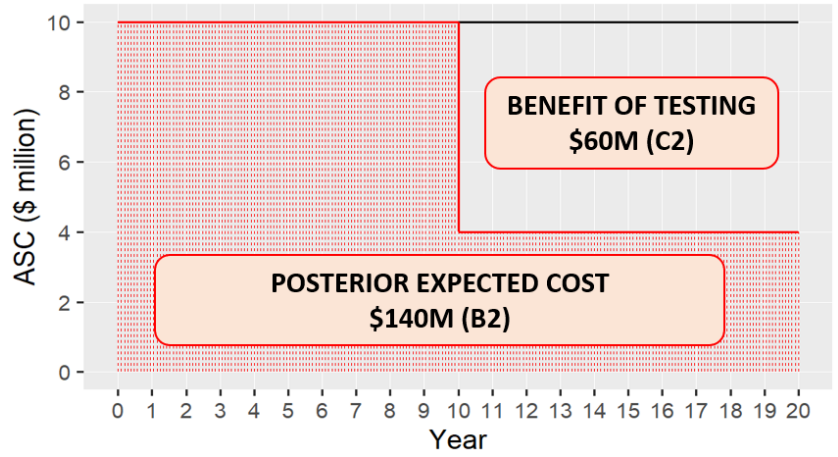
Expected benefit of testing (**C2**) is **$60M** = $200M - $140M

# Comparison of Two Toxicity Paradigms (T1 vs. T2)




**With Additional Information (blue)**

- 1 year to conduct and evaluate T1
- 2 years to implement regulation
- Expected benefit of testing (**C1**) is **$85M** ($200M - $115M)




**With Additional Information (red)**

- 8 years to conduct and evaluate T2
- 2 years to implement regulation
- Expected benefit of testing (**C2**) is **$60M** ($200M - $140M)

Since **C1** > **C2**, T1 is preferred

# Target-Risk Decision-Maker (TRDM)

The objective of the target-risk decision maker (TRDM) is to control potential health risks **whenever the risk (R) is anticipated to exceed a specified target risk level (TRL).** *More on how risk is quantified to be discussed later.*

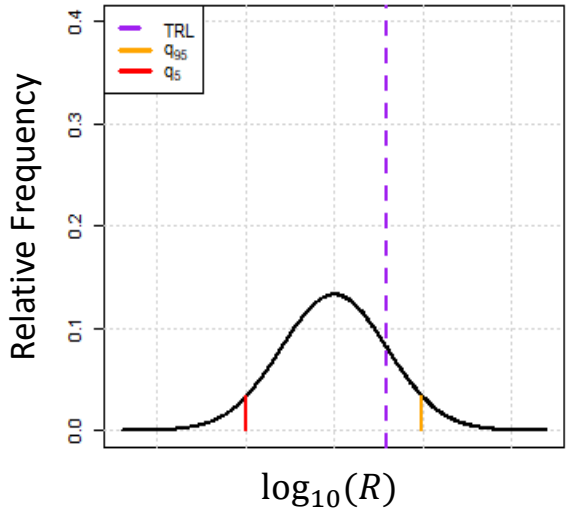
# Target-Risk Decision-Maker (TRDM)

The objective of the target-risk decision maker (TRDM) is to control potential health risks **whenever the risk (R) is anticipated to exceed a specified target risk level (TRL).**

$$q_{05} \leq TRL \leq q_{95}$$

Additional information required

A.



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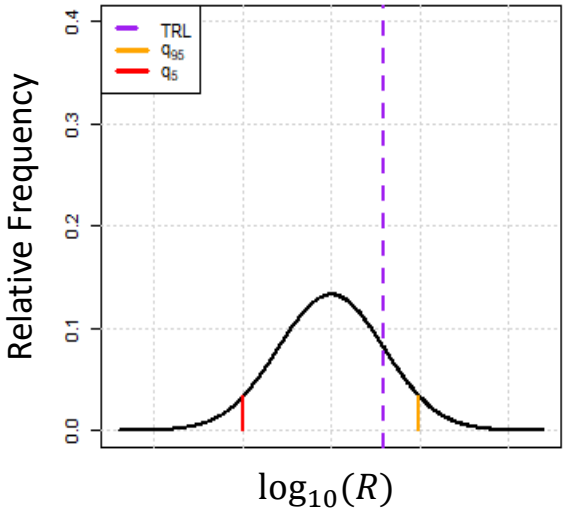
$q_{05} \leq TRL \leq q_{95}$

Additional information required

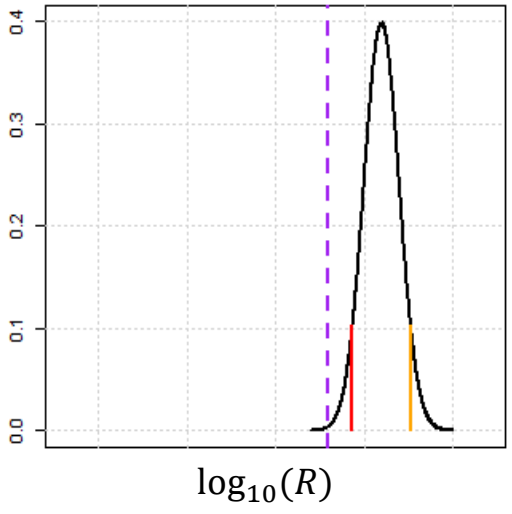
$TRL \leq q_{05}$

No regulatory action is required

A.




B.



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The objective of the target-risk decision maker (TRDM) is to control potential health risks **whenever the risk (R) is anticipated to exceed a specified target risk level (TRL).**

$q_{05} \leq TRL \leq q_{95}$

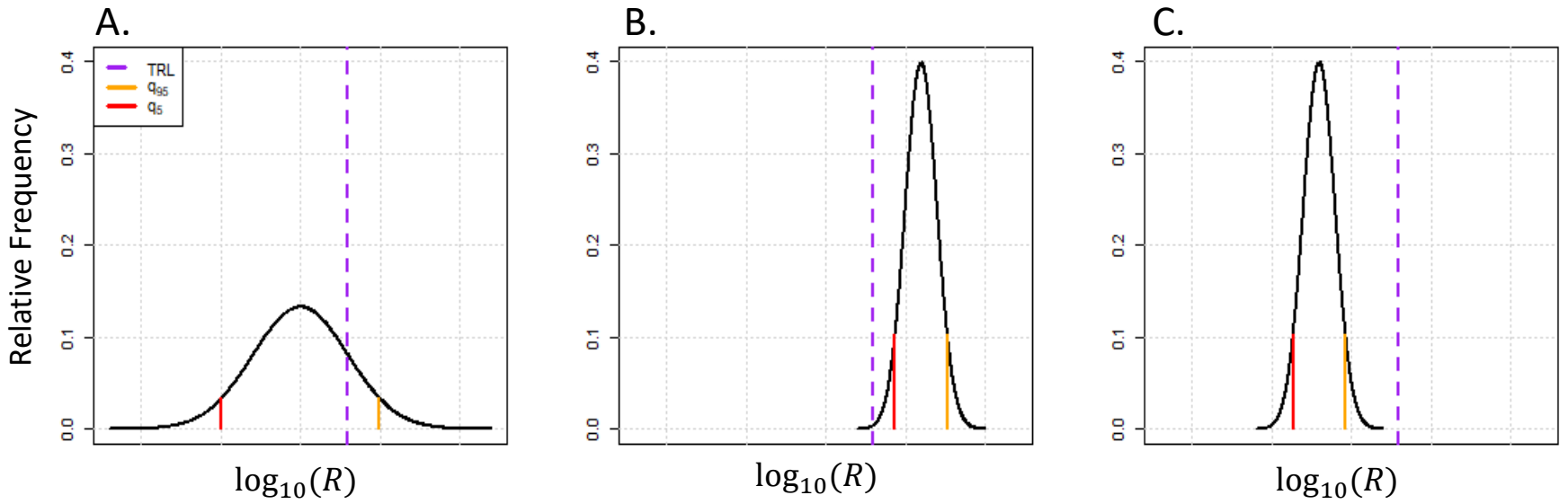
Additional information required

$TRL \leq q_{05}$

No regulatory action is required

$q_{95} \leq TRL$

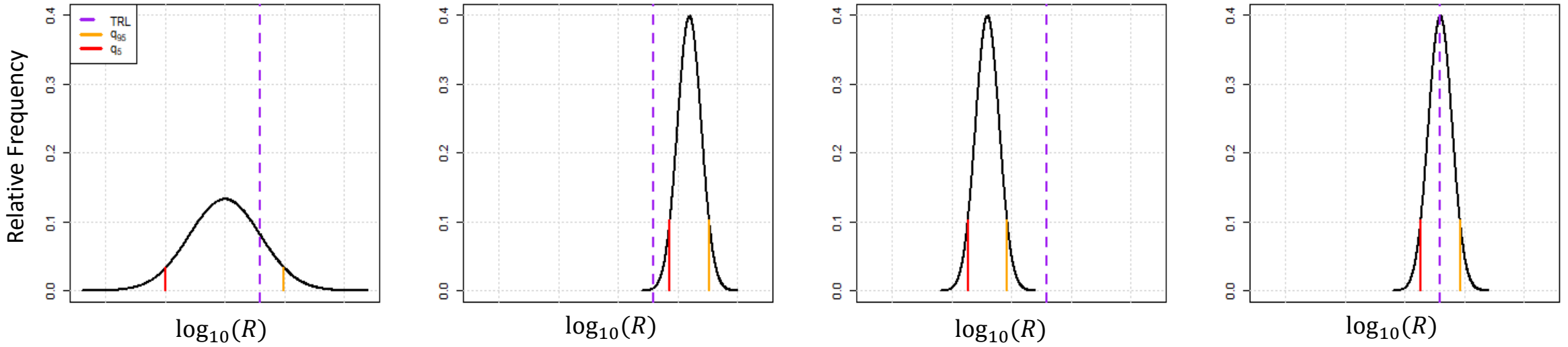
Regulatory action will be taken



# Target-Risk Decision-Maker (TRDM)

The objective of the target-risk decision maker (TRDM) is to control potential health risks **whenever the risk (R) is anticipated to exceed a specified target risk level (TRL).**

| A. | B. | C. | D. |
|---|---|---|---|
| $q_{05} \leq TRL \leq q_{95}$ | $TRL \leq q_{05}$ | $q_{95} \leq TRL$ | $q_{05} \leq TRL \leq q_{95}$ |
| Additional information required | No regulatory action is required | Regulatory action will be taken | Additional information required |



# VOI FRAMEWORK COMPONENTS

# Defining Risk

The **average population risk $\boldsymbol{R}$** can be defined as

$$R = \int_0^{\infty} \underbrace{G_{\text{tox}}(x|\boldsymbol{\theta})}_{\textbf{Toxicity}} \underbrace{f_{\text{exp}}(x|\boldsymbol{\theta})}_{\textbf{Exposure}} dx$$

where

- $x$ denotes the level of exposure to the chemical
- $G_{\text{tox}}(x|\boldsymbol{\theta})$ is the **probability of an adverse effect** present at exposure level $x$
- $f_{\text{exp}}(x|\boldsymbol{\theta})$ is the **probability density of exposure** across population

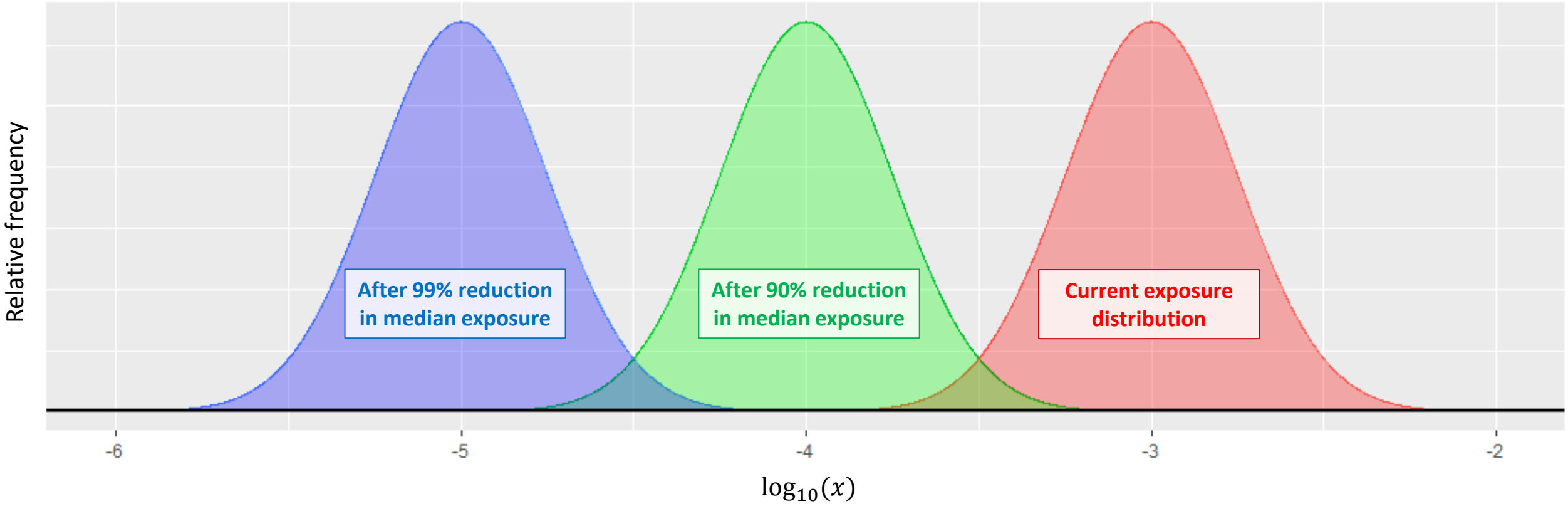
# Risk – Assumptions

Following Chiu and Slob (2015) and Chiu et al. (2018), assume that both the inter-individual variation in susceptibility to the toxicity as well as variation in exposures to the chemical can be described using log-normal distribution

$$R = \Phi\left(\frac{\mu_{\text{exp}} - \mu_{\text{tox}}}{\sqrt{\sigma_{\text{exp}}^2 + \sigma_{\text{tox}}^2}}\right)$$

where $\Phi(\cdot)$ denotes the standard normal cumulative distribution function

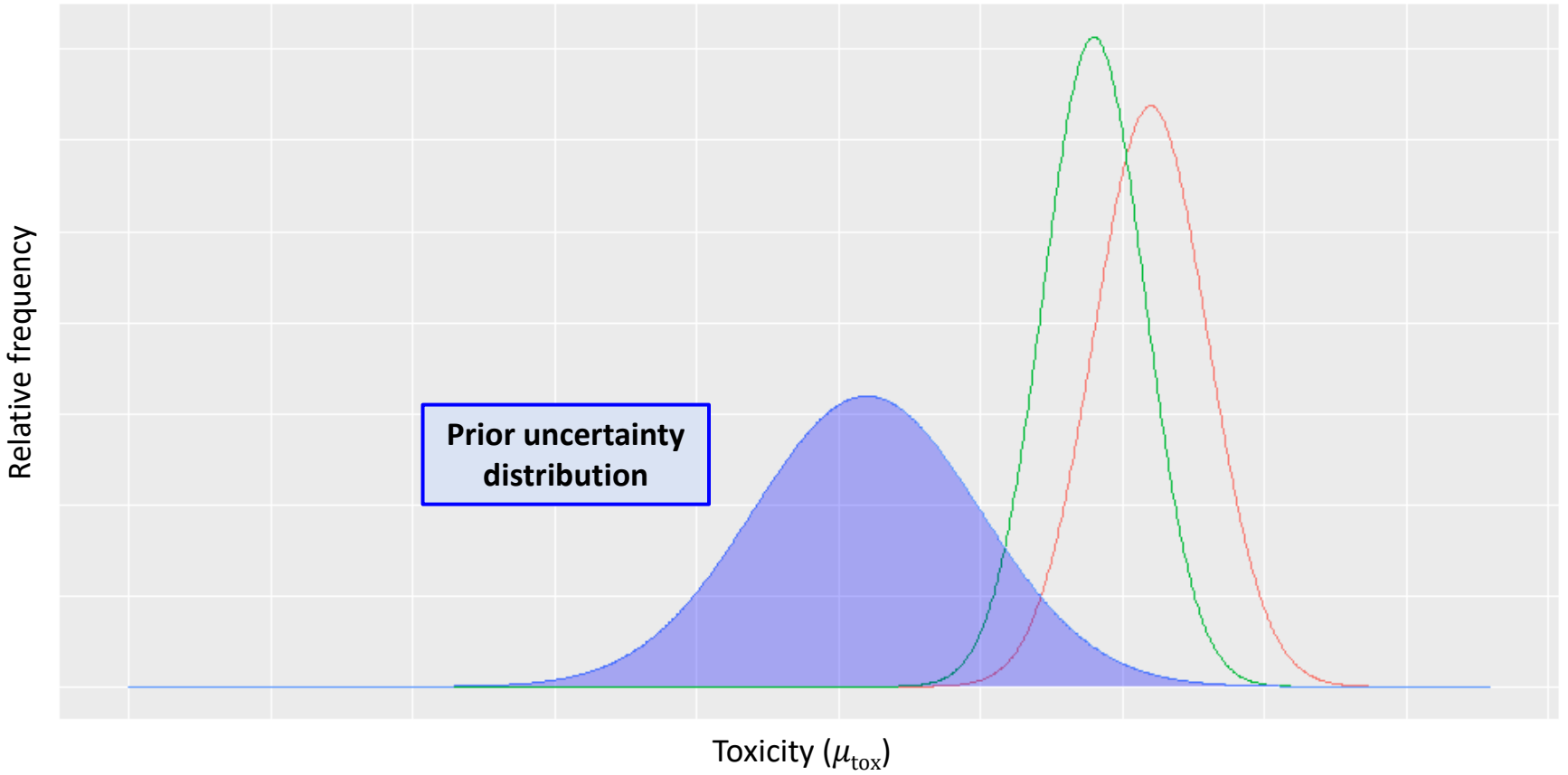
# Exposure Mitigation Action



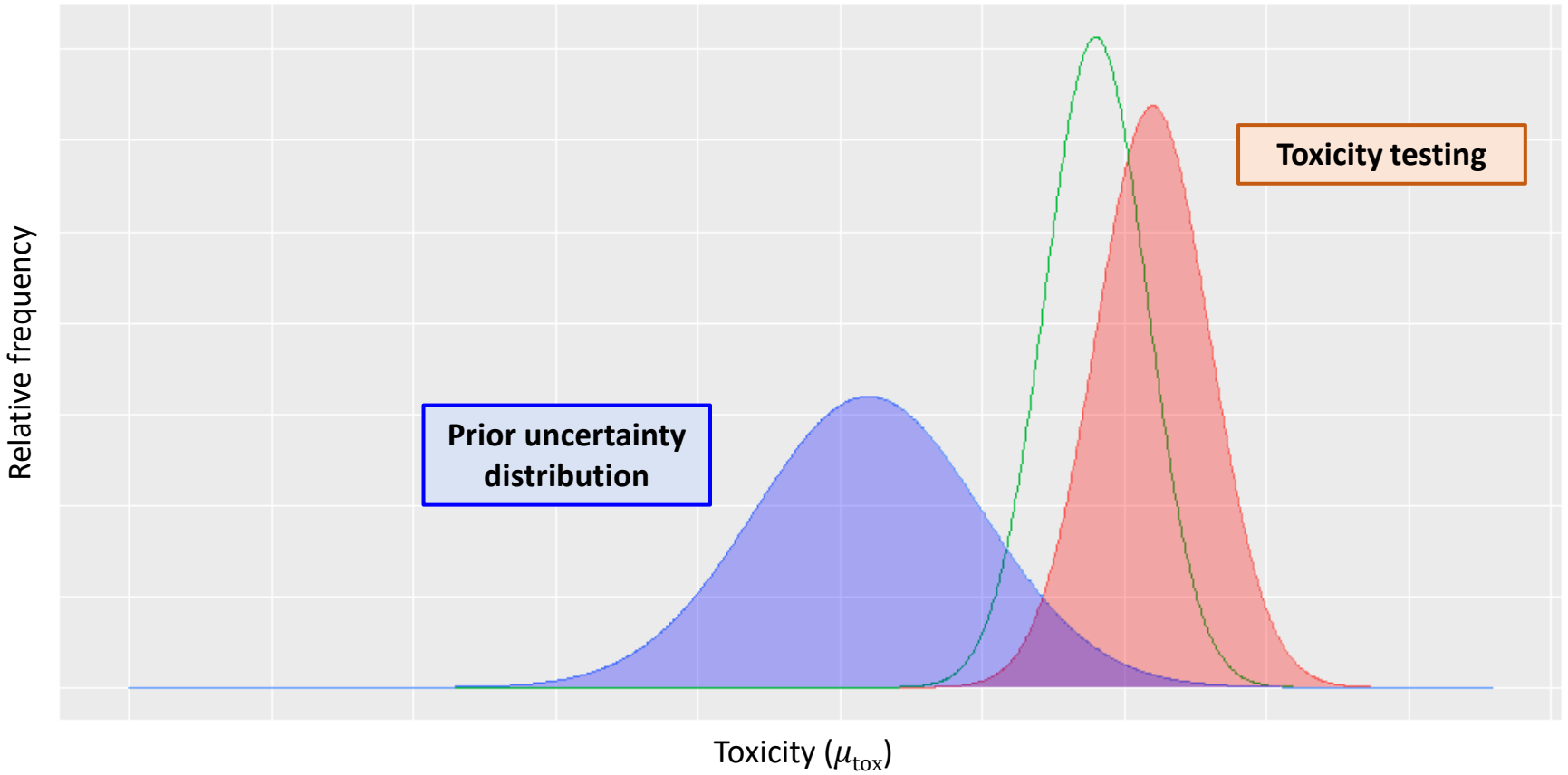
# Uncertainty, Information Collection, and Bayesian Updating

- Uncertainty in toxicity and/or exposure necessarily implies that there must therefore be uncertainty in the estimate of risk, $R$
- Uncertainty in $R$, in turn, leads to sub-optimal decision-making
- Additional toxicity testing can reduce uncertainty and improve decision-making
- Combining current knowledge and additional information can be achieved via Bayesian updating

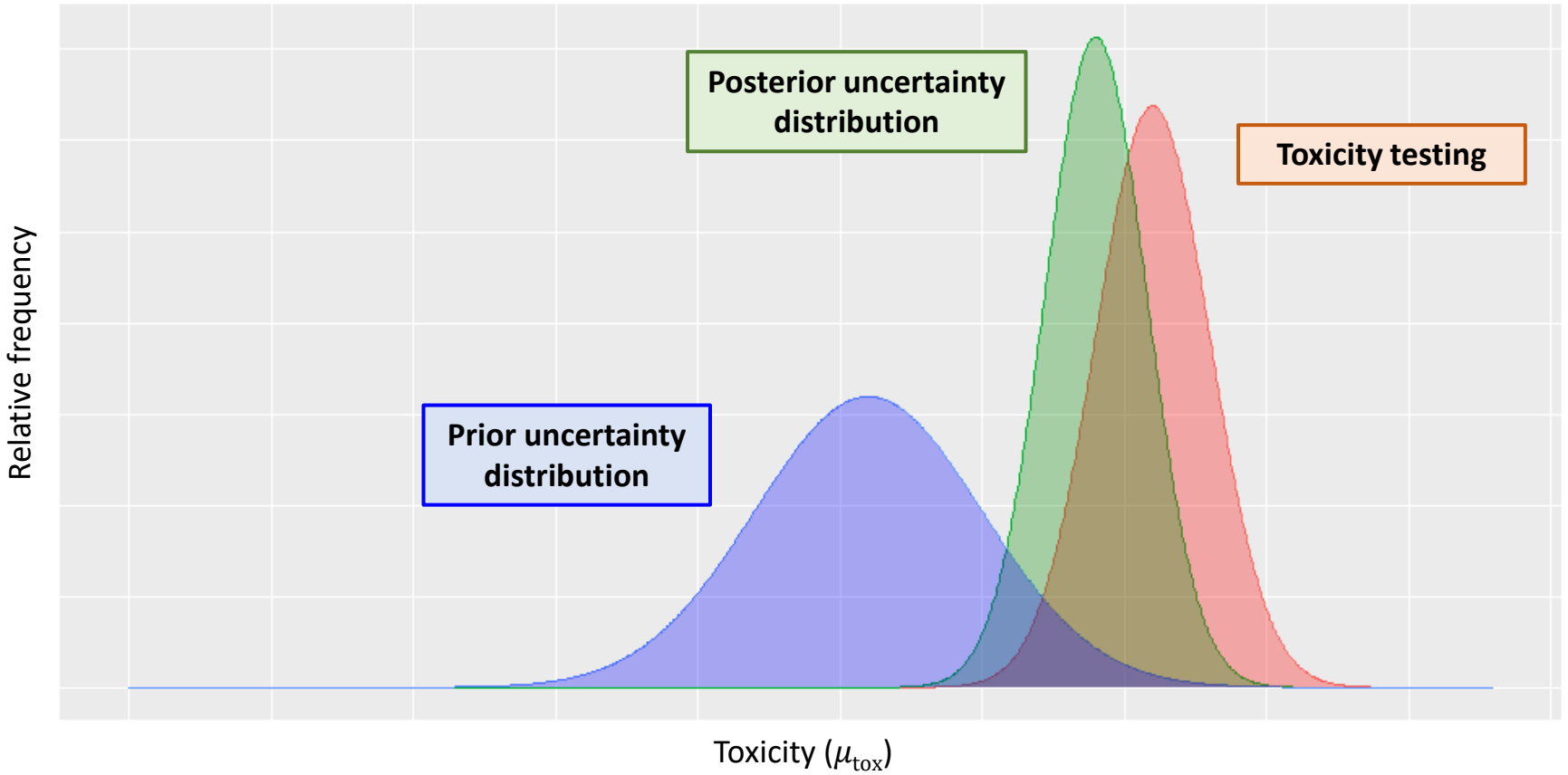
# Uncertainty, Information Collection, and Bayesian Updating



# Uncertainty, Information Collection, and Bayesian Updating



# Uncertainty, Information Collection, and Bayesian Updating



# VOI METRICS

# Expected Total Social Cost (ETSC)

The ETSC based on currently available information is given by

$$\mathrm{ETSC}_k^0(R) = E\left[\mathrm{TSC}_k^0(R)\right] = \int \mathrm{TSC}_k^0(R) h^0(R) dR$$

where $h^0(R)$ denote the prior uncertainty distribution

*If exposure is reduced by $k\%$ right away, what is the expected TSC based on currently available information?*

# Expected Value Given Current Information (EV|CI)

The EV|CI is the minimum ETSC value based on currently available information

$$\mathrm{EV|CI} = \min[\mathrm{ETSC}_k^0(R)]$$

*What is the ETSC associated with "best" decision based on what we already know?*

# Expected Value of Immediate Perfect Information (EVIPI)

Let $k^{0*} = k^{0*}|R = \underset{k}{\operatorname{argmin}}\ \mathrm{TSC}_k^0(R)$, then

$$\mathrm{EV|IPI} = \int TSC_{k^{0*}}^{0}(R)h^0(R)dR$$

and

$$\mathrm{EVIPI} = \mathrm{EV|CI} - \mathrm{EV|IPI}$$

*If we can make an optimal decision 100% of the time without delay, how much will this reduce the ETSC?*

# Expected Value of Immediate Sample Information (EVISI)

Additional toxicity testing will not eliminate uncertainty, but can reduce it

$$\mathrm{EV|ISI}^{j} = \int \left\{ \min\left[ \mathrm{ETSC}_{k}^{0}\left(R \middle| s_j\right) \right] \right\} f\left(s_j\right) ds_j$$

with

$$\mathrm{EVISI}^{j} = \mathrm{EV|CI} - \mathrm{EV|ISI}^{j}$$

*How much of a reduction in the ETSC can be achieved by reducing uncertainty?*

# Expected Value of Delayed Sample Information (EVDSI) and Cost of Delay (CoD)

Additional data collection and analysis takes time and thus the decision-making will be delayed

$$\mathrm{EV|DSI}^{j} = \int \mathrm{ETHC}_{k}^{j}(R|s_j) f(s_j)\, ds_j$$

$$\mathrm{CoD}^{j} = \mathrm{EV|DSI}^{j} - \mathrm{EV|ISI}^{j}$$

$$\mathrm{EVDSI}^{j} = \mathrm{EVISI}^{j} - \mathrm{CoD}^{j}$$

*What is the benefit of collecting additional information when the delay in decision-making is taken into account?*

# Expected Net Benefit of Sampling (ENBS) and Return on Investment (ROI)

While the EVDSI include the effect of delay in decision-making, it does not consider the direct cost of testing (CoT)

$$\mathrm{ENBS}^j = \mathrm{EVDSI}^j - \mathrm{CoT}^j$$

To determine the value of additional information per dollar spent on toxicity testing, the return on investment is calculated as

$$\mathrm{ROI}^j = \frac{\mathrm{ENBS}^j}{\mathrm{CoT}^j}$$

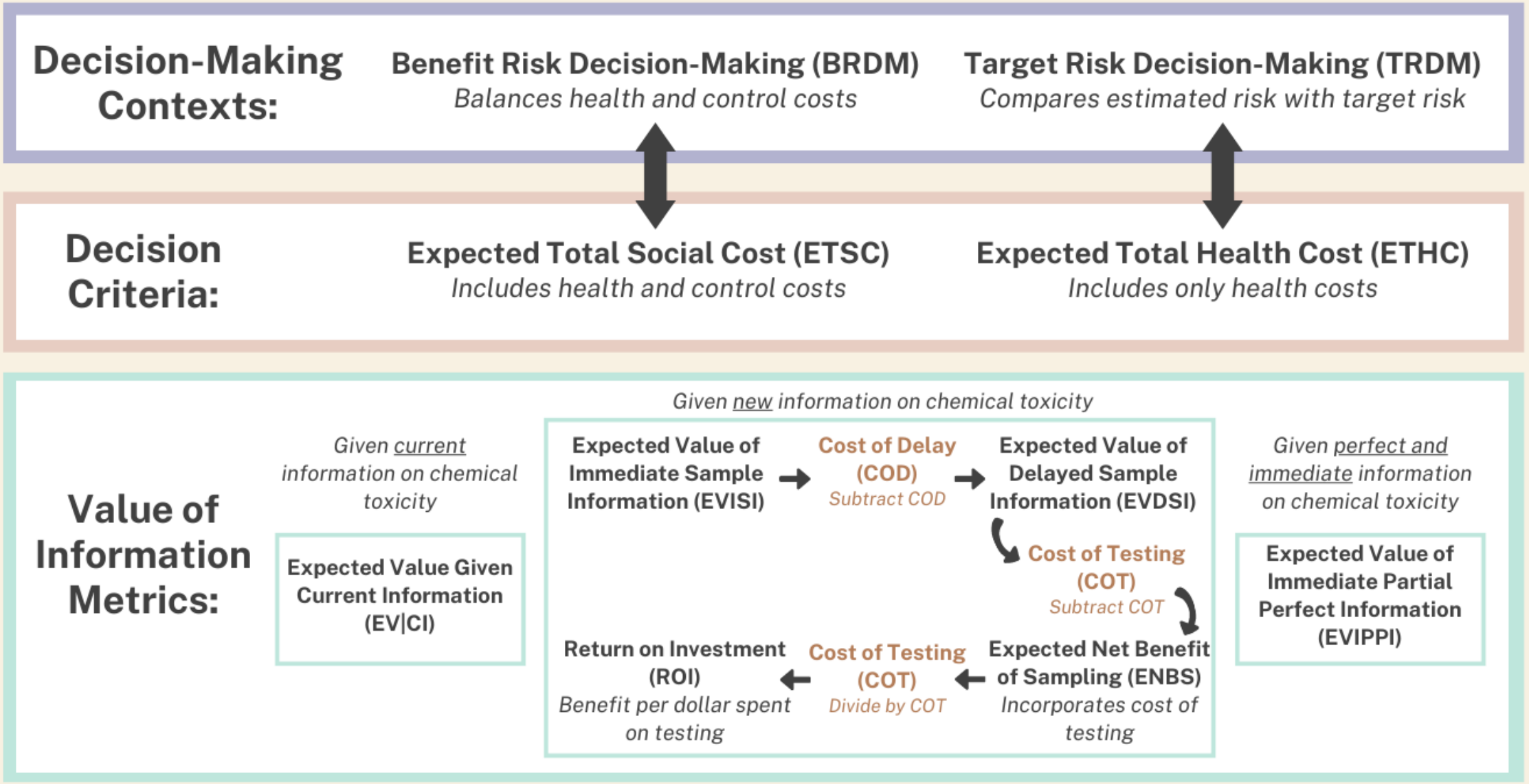
*ENBS – What is the VOI per toxicity test?*

*ROI – What is the return on investment in toxicity testing?*

# Key VOI Metrics

| Metric | Description |
|---|---|
| EVISI | The expected value of immediate sample information. This is a measure of the value of information if it could be received and immediately update the estimate of risk. [Larger EVISI values are preferred.] |
| COD | The cost of delay. This is a measure of the reduction in benefit associated with the delay in the decision-making process. [Smaller COD values are preferred.] |
| EVDSI = EVISI - COD | The expected value of delayed sample information. This is a measure of the value of the information which combines the quality of the information and the delay associated with it. [Larger EVDSI values are preferred.] |
| COT | The cost of testing and assessment process. [Smaller COT values are preferred.] |
| ENBS = EVDSI - COT | The expected net benefit of sampling. This is a measure of the value of the information taking into account the cost of acquiring the information, in addition to its quality and delay properties. The ENBS measures the benefit accrued per testing. [Larger ENBS values are preferred.] |
| ROI = ENBS / COT | The return on investment. This is a measure of the value of the information expressed as the ratio of the benefit accrued per dollar expended. [Larger ROI values are preferred.] |

# VOI Framework for Comparing Test A and Test B



# ILLUSTRATIVE APPLICATIONS

# Illustrative Scenario

- All US population is exposed to the chemical ⇒ $\mathbf{350M}$ **people**
- Adverse effect is mortality ⇒ $\mathbf{\$8.8M}$ **per fatality**
- Median risk is 1 in 100M ⇒ $\boldsymbol{R = 10^{-8}}$
- Very little knowledge about chemical toxicity ⇒ $\mathbf{Range}\left[u^0(\mu_{tox})\right] = \mathbf{7\ OM}$
- Time horizon ⇒ $\mathbf{20\ years}$

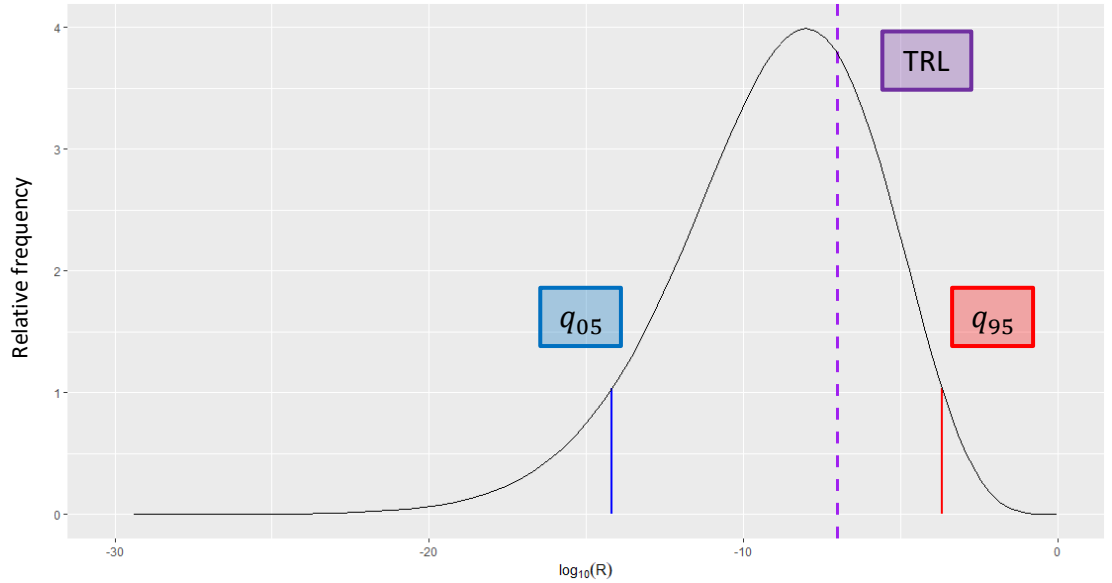
- Test A: $\$5K$, 1-year delay ⇒ reduces uncertainty to $\mathbf{4\ OM}$
- Test B: $\$5M$, 5-year delay ⇒ reduces uncertainty to $\mathbf{2\ OM}$

M: Million | K: Thousand | OM: Orders of Magnitude

# 🎯 TRDM RESULTS

# Prior Uncertainty Distribution

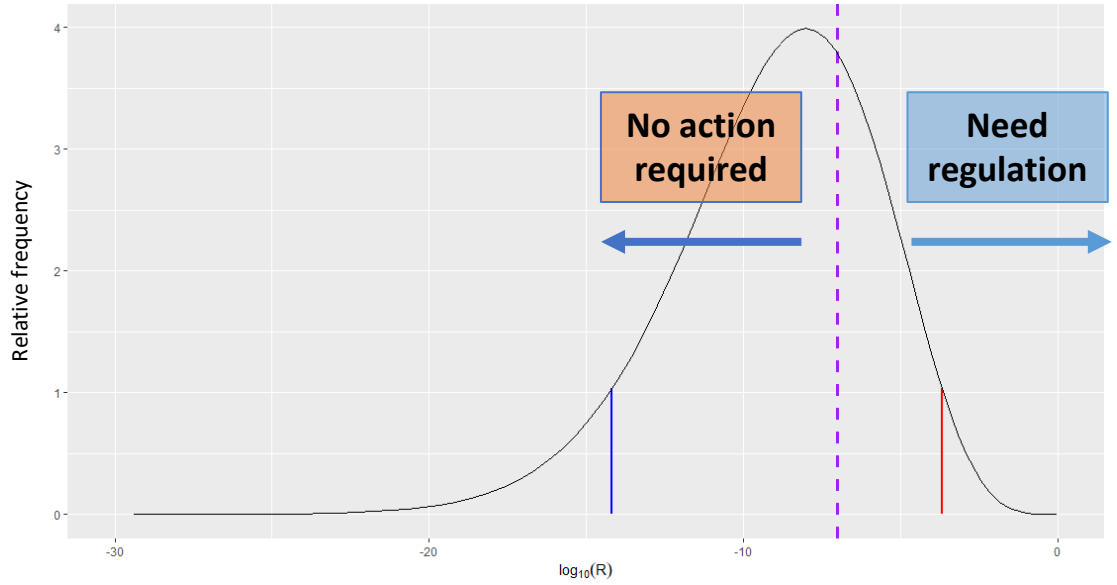
- Since $q_{05} \leq TRL \leq q_{95}$, TRDM cannot make a decision without collecting additional information




TRL: Target Risk Level | TRDM: Target-Risk Decision-Maker

# Prior Uncertainty Distribution

- Based on prior uncertainty distribution, 35% chance that risk is greater than the TRL
- The expected health cost associated with no decision (EV|CI) is $\$\mathbf{45B}$




TRL: Target Risk Level | EV|CI: Expected Value Given Current Information | B: Billion

# Probability of Making a Decision

## Test A

- Sufficient evidence to require regulation **6%** of the time
- Sufficient evidence to consider the chemical “safe” **25%** of the time
- Insufficient evidence to conclude either the chemical is “safe” or the regulation is required **69%** of the time

## Test B

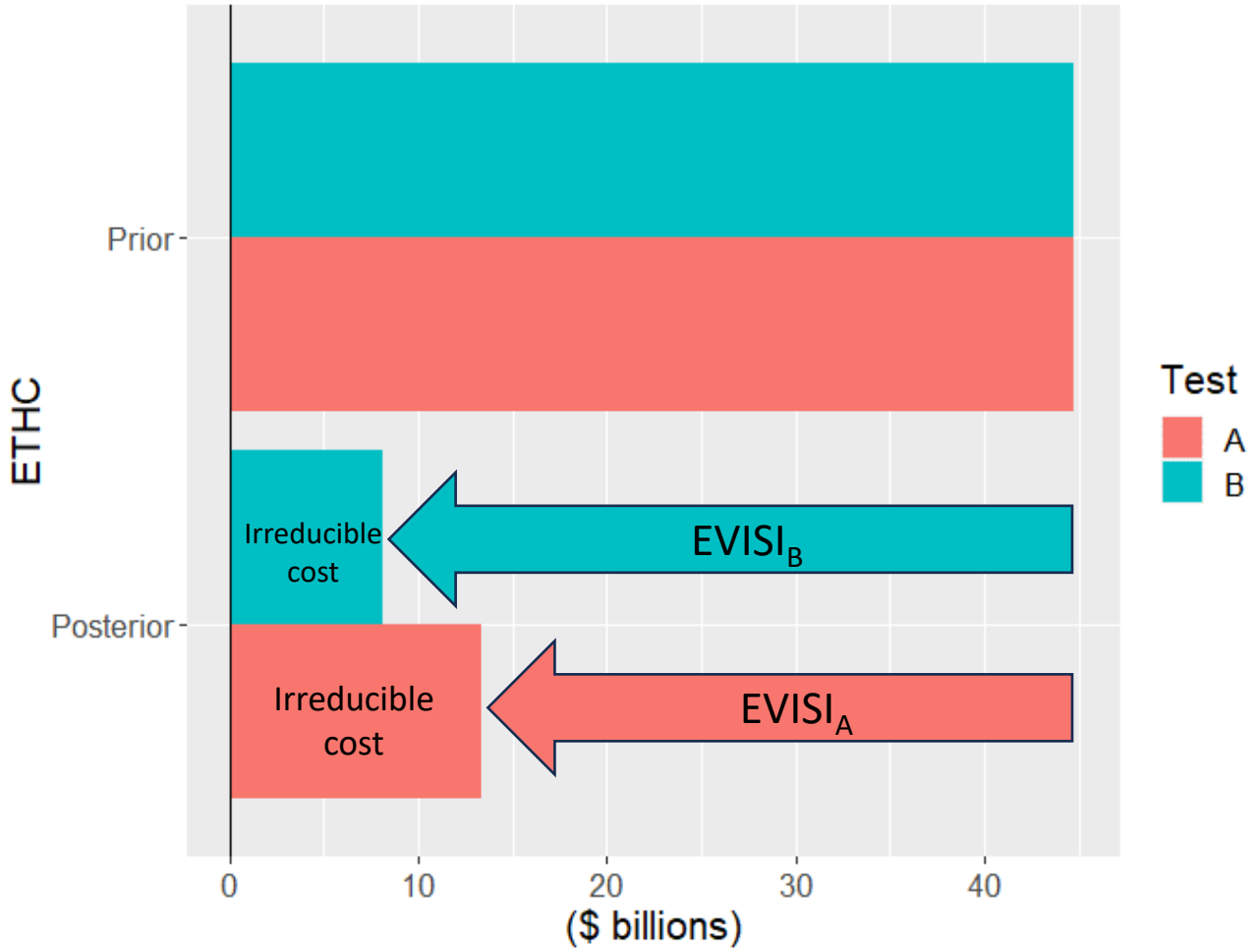
- Sufficient evidence to require regulation **19%** of the time
- Sufficient evidence to consider the chemical “safe” **45%** of the time
- Insufficient evidence to conclude either the chemical is “safe” or the regulation is required **36%** of the time

# Expected Value of Immediate Sample Information

Assuming no delay in obtaining and incorporating testing information

- Test A would result in a reduction of $\$\mathbf{31B}$ ($EVISI_A$).
- Test B would result in a reduction of $\$\mathbf{37B}$ ($EVISI_B$).

**Test B** is preferred since it reduces more uncertainty



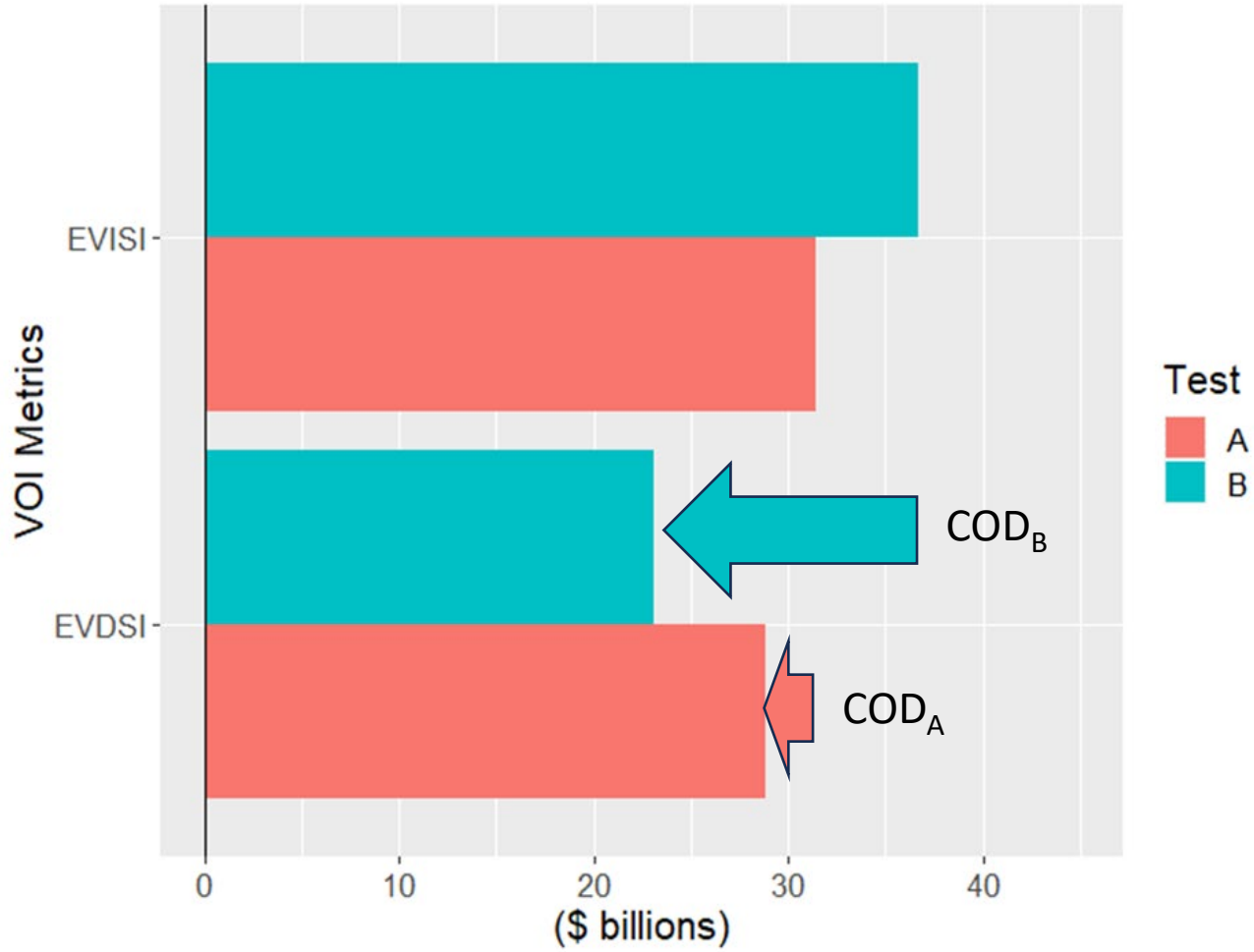

ETHC: Expected Total Health Cost | EVISI: Expected Value of Immediate Sample Information

*Smaller ETHC values are preferred.*

# Expected Value of Delayed Sample Information

- 1-year delay in decision-making results in a $\$\mathbf{3B}$ loss in benefit, reducing the $EVDSI_A$ to $\$\mathbf{29B}$.
- 5-year delay in decision-making results in a $\$\mathbf{14B}$ loss in benefit, reducing the $EVDSI_B$ to $\$\mathbf{24B}$.

**Test A** is preferred
due to smaller COD



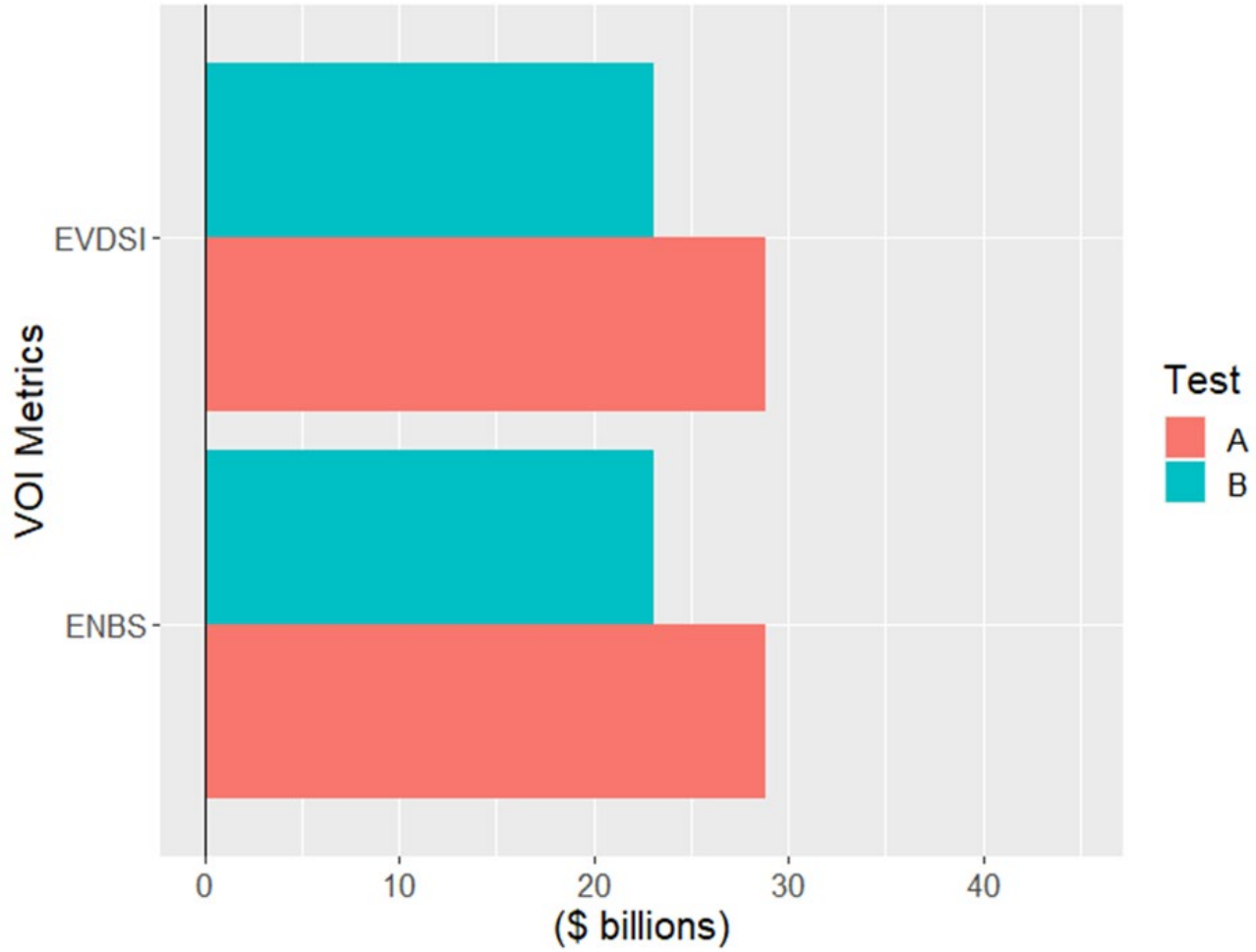

COD: Cost of Delay| EVISI: Expected Value of Immediate Sample Information | EVDSI: Expected Value of Delayed Sample Information

*Larger EVISI/EVDSI values are preferred.*

# Expected Net Benefit of Sampling and Return on Investment

- $\mathrm{EVDSI} \approx \mathrm{ENBS}$ for both Tests A and B
- $\mathrm{ROI_A}$ is much greater than $\mathrm{ROI_B}$ (as $\mathrm{CoT_B} = 1000 \times \mathrm{CoT_A}$)

ENBS and ROI prefer **Test A**




ROI: Return on Investment| COT: Cost of Testing | EVDSI: Expected Value of Delayed Sample Information | ENBS: Expected Net Benefit of Sampling

*Larger EVDSI/ENBS values are preferred.*

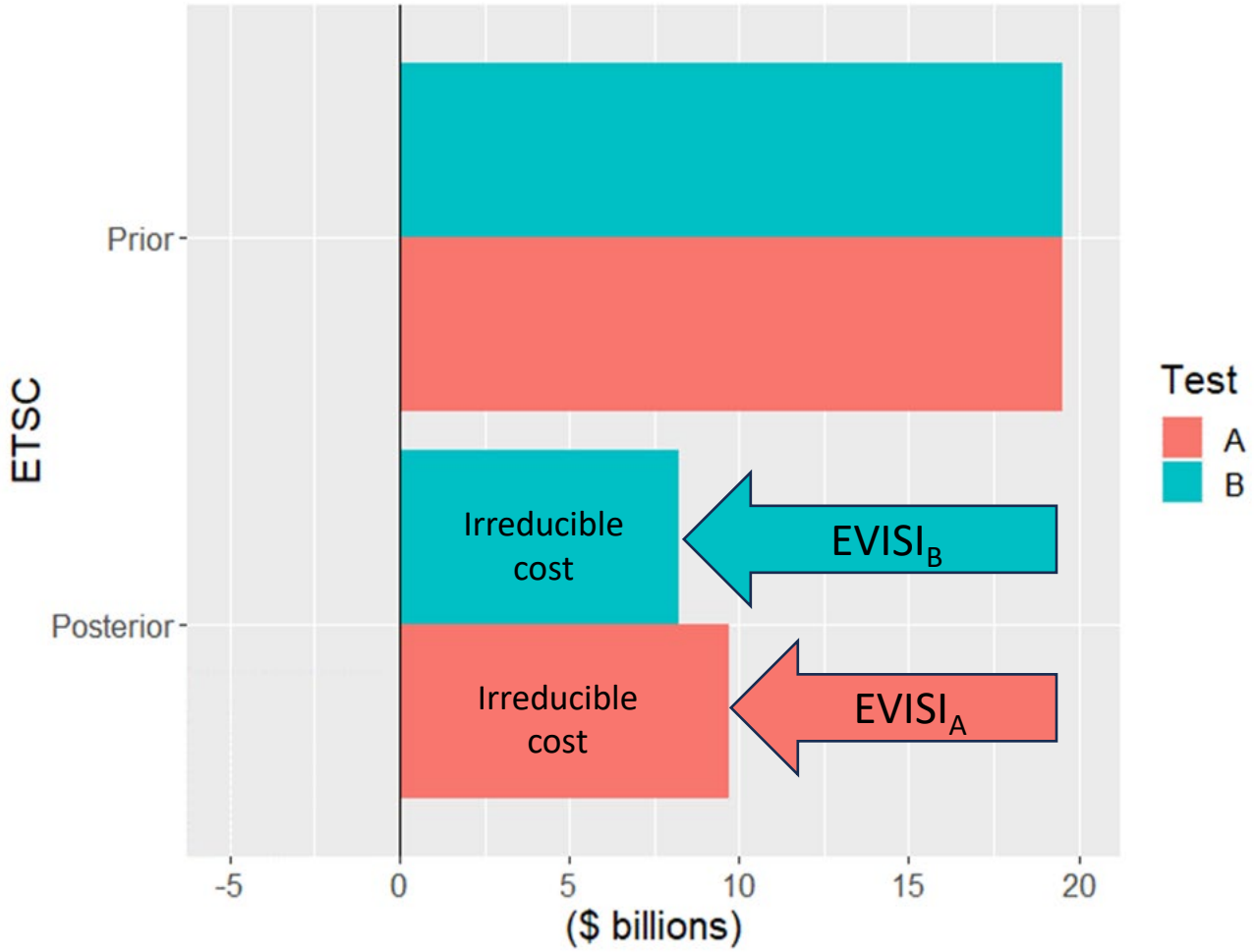
# BRDM RESULTS

# Expected Value of Immediate Sample Information

Assuming no delay in obtaining and incorporating testing information

- Test A would result in a reduction of $\$\mathbf{9.8B}$ ($EVISI_A$).
- Test B would result in a of $\$\mathbf{11.3B}$ ($EVISI_B$).

**Test B** is preferred since it reduces more uncertainty




ETSC: Expected Total Social Cost | EVISI: Expected Value of Immediate Sample Information

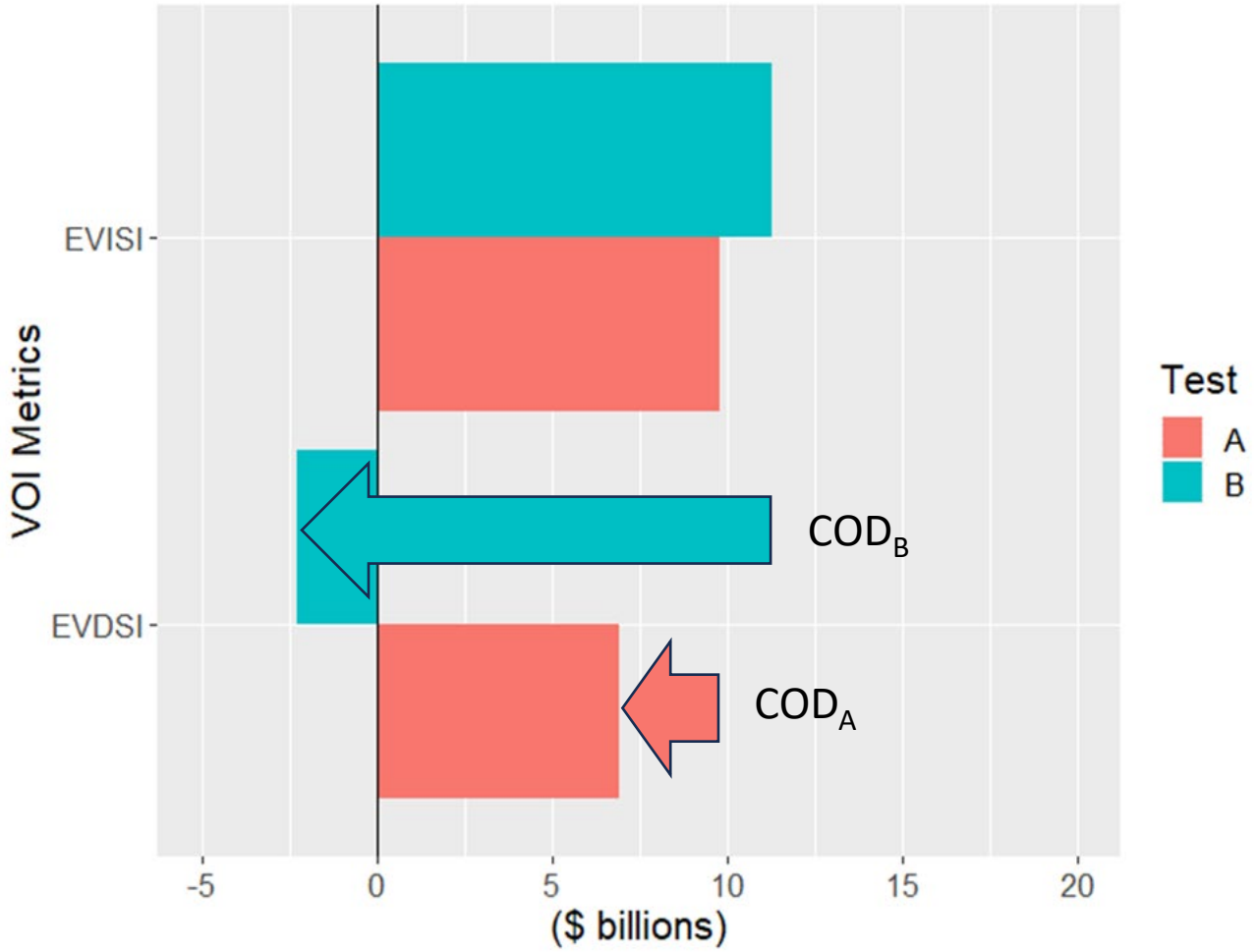
*Smaller ETSC values are preferred.*

# Expected Value of Delayed Sample Information

- 1-year delay in decision-making results in a $\$\mathbf{2.9B}$ loss in benefit, reducing the $EVDSI_A$ to $\$\mathbf{7.0B}$.

- 5-year delay in decision-making results in a $\$\mathbf{13.5B}$ loss in benefit, resulting a negative $EVDSI_B$ of $-\$\mathbf{2.3B}$.

**Test A** is preferred due to smaller COD



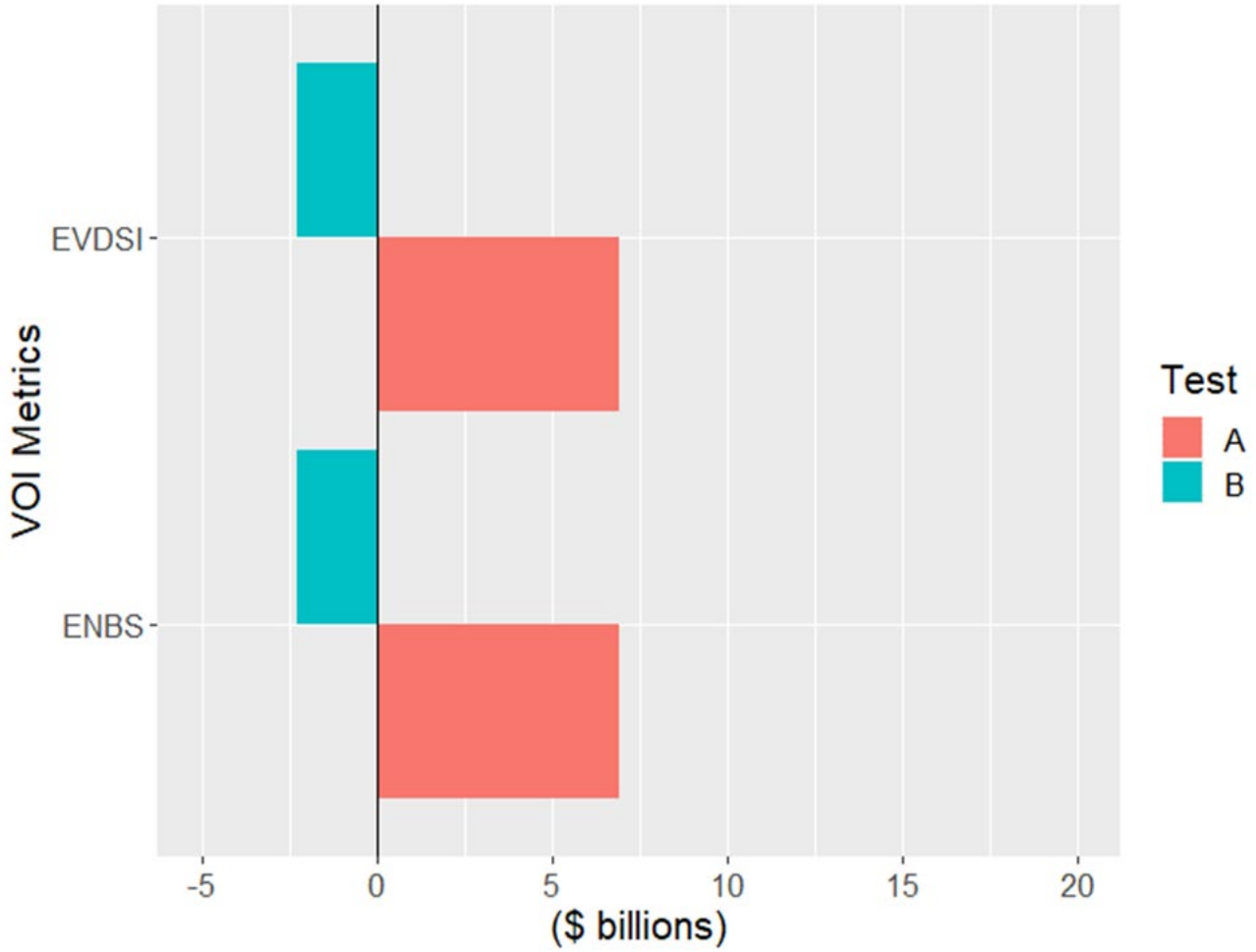

COD: Cost of Delay| EVISI: Expected Value of Immediate Sample Information | EVDSI: Expected Value of Delayed Sample Information

*Larger EVISI/EVDSI values are preferred.*

# Expected Net Benefit of Sampling and Return on Investment

- EVDSI, ENBS and ROI are **negative** for Test B, indicating cost of delay outweighs the benefit of uncertainty reduction
- Test A is beneficial even when the cost of delay and cost of testing are taken into account

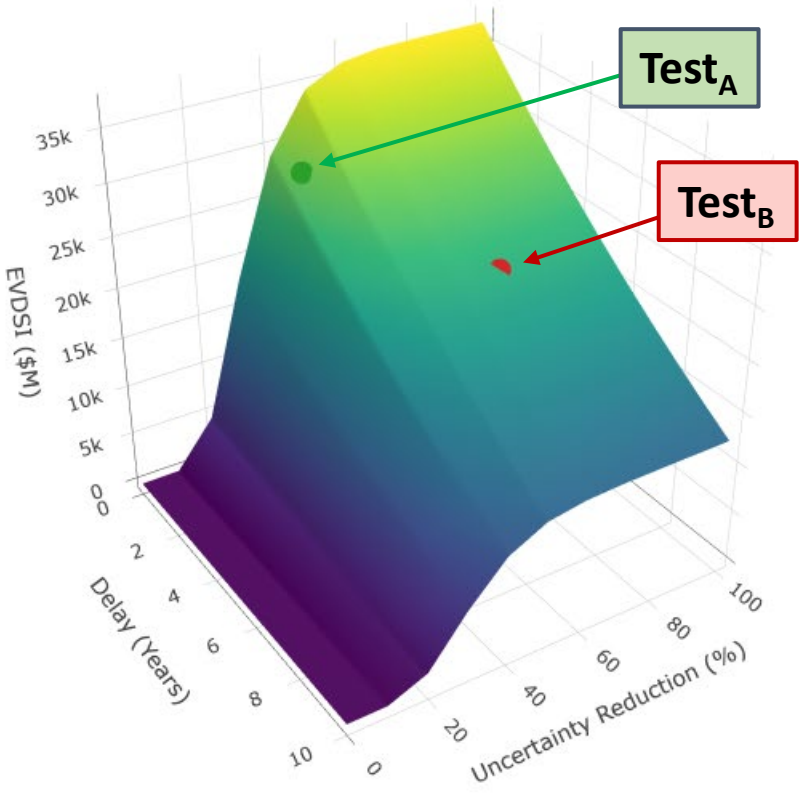
ENBS and ROI prefer **Test A**



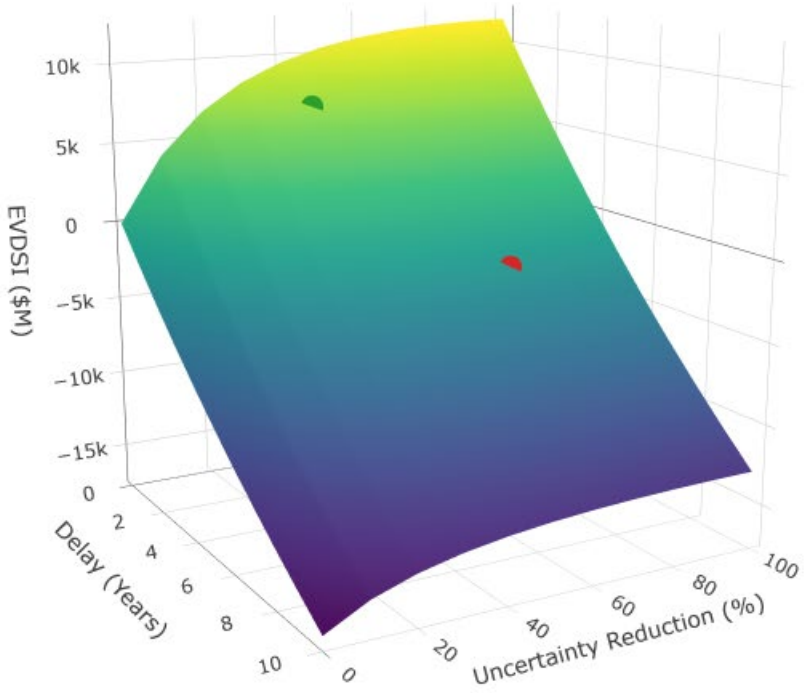

ROI: Return on Investment| COT: Cost of Testing | EVDSI: Expected Value of Delayed Sample Information | ENBS: Expected Net Benefit of Sampling

*Larger EVDSI/ENBS values are preferred.*

# Trade-offs between Uncertainty Reduction and Timeliness




TRDM




BRDM

# Summary

- VOI analysis is a **well-established analytical technique** that can be used to evaluate the value-of-information associated with improvements in decision-making associated with reductions in uncertainty.
- A new framework that incorporates the **cost**, **timeliness** and **reduction in uncertainty** associated with different toxicity testing strategies has been developed by Hagiwara et al. (2022), meeting an important methodological need identified in the NRC (2009) silver book, *Science and Decisions*.

  *A novel feature of this framework is the inclusion of a time dimension that permits incorporation of the cost of delay in incorporating additional information.*

- Of the multiple VOI metrics available, **ENBS** and **ROI** may be most useful in determining the overall utility of the alternative tests being compared.