Uncertainty analysis frameworks linked to asset management decisions in integrated catchment modelling

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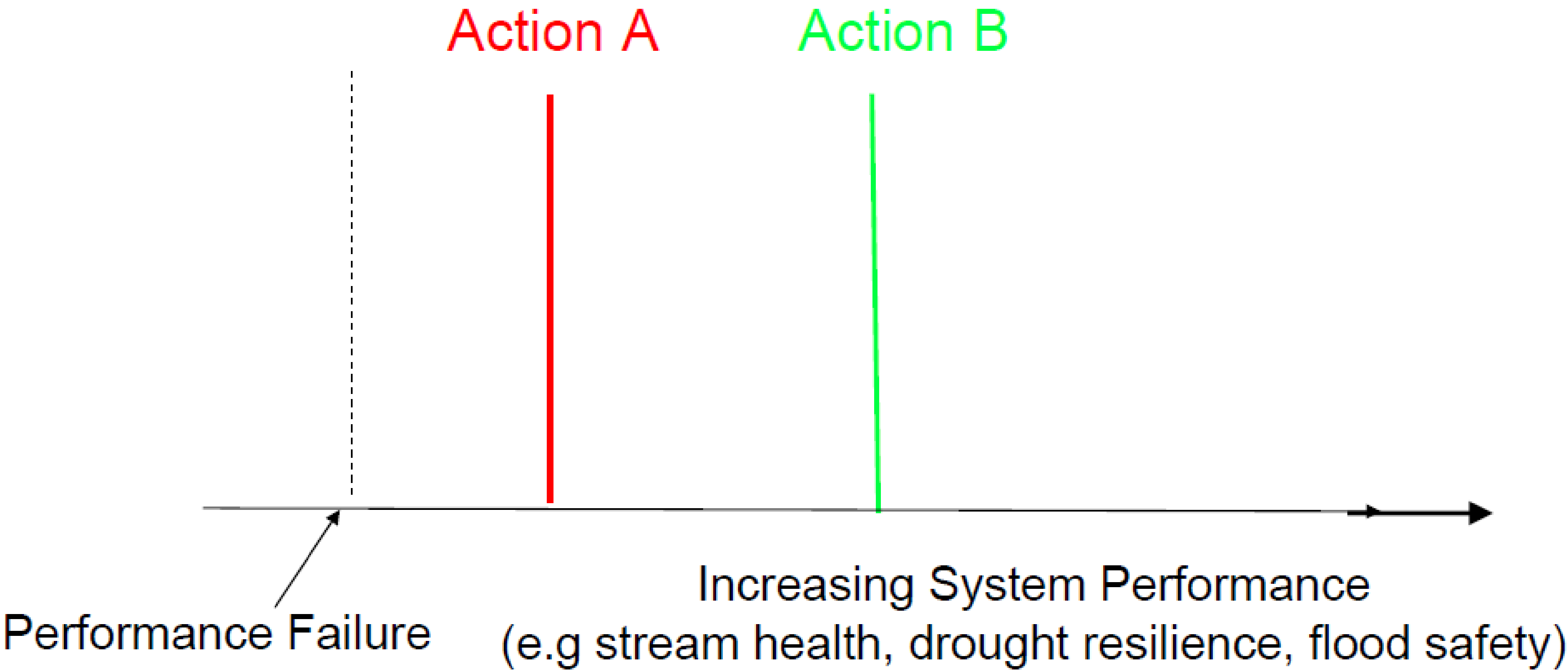
Uncertainty in decision-making

Consequences of **action A** vs **action B**



* Dmitri Kavetski, University of Adelaide, Australia (June2015, Eawag)

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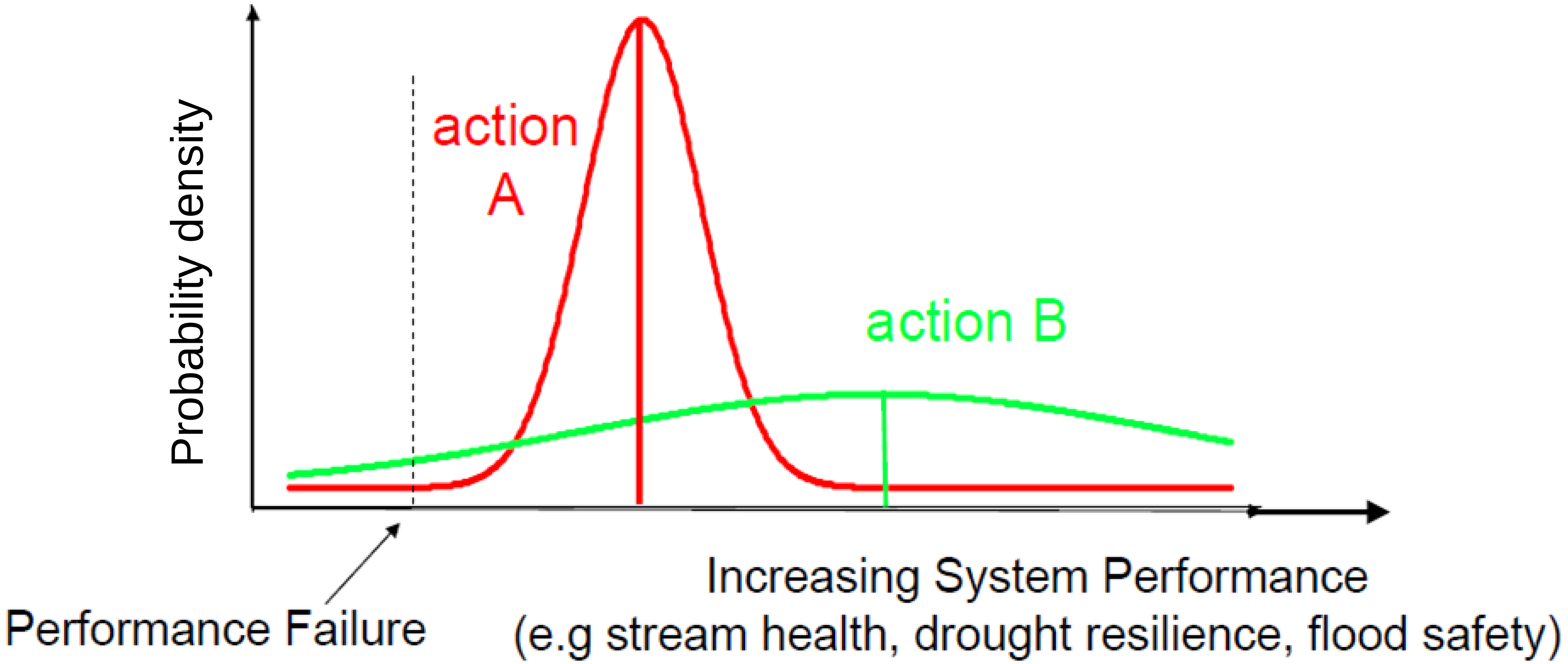
Consequences of action A vs action B



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Decision Analysis

- Decisions are mostly taken based on an economic analysis of the alternatives

- Decision analysis provides the link between the economic framework and the technical analyses

- For each alternative, decision analysis considers

- Costs
- Benefits
- Associated Risks

Example: Decision Making in Engineering design

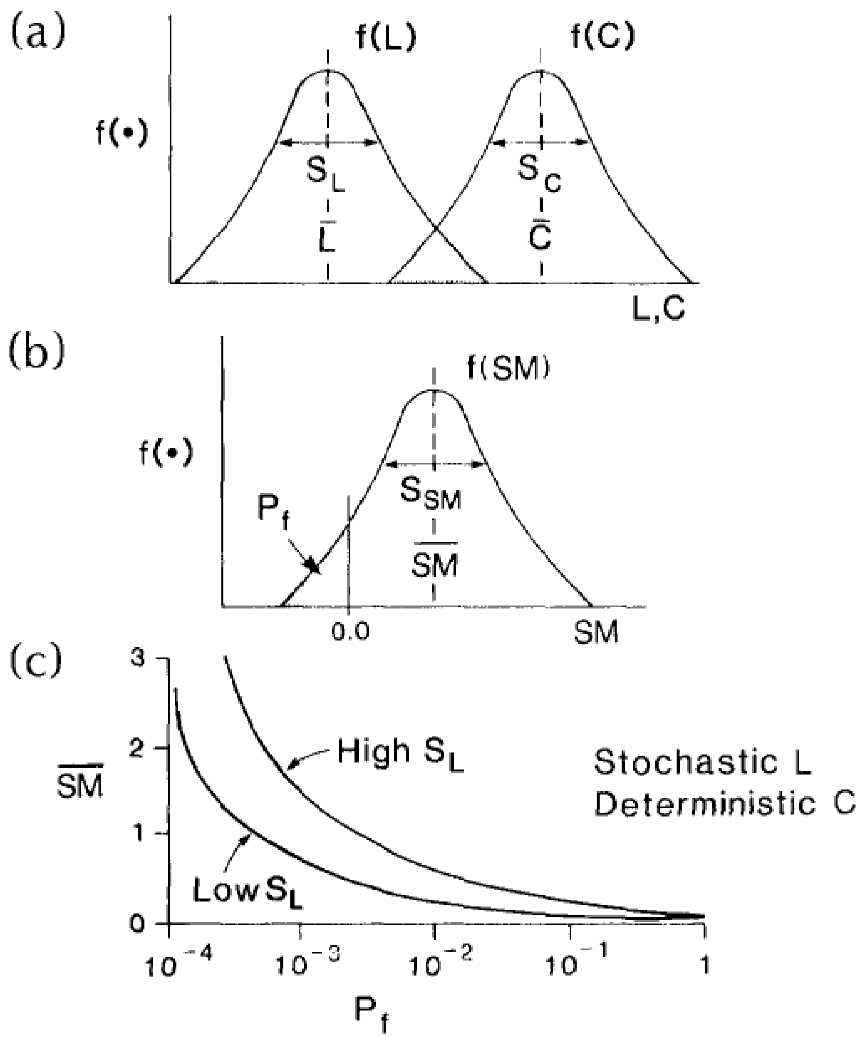
- **Deterministic Safety factor approach**

$$F = \frac{Capacity\ C}{Load\ L}$$

- **Stochastic Risk-balancing approach**

- C & L are represented as Probability density functions.
- Safety Margin $\mathrm{SM} = \mathrm{C} - \mathrm{L}$
- Probability of failure $\mathrm{P_f} =$ Probability that L exceeds C
- $\mathrm{P_f} =$ Probability that $\mathrm{SM} < 0$

Example: Decision Making in Engineering design



Assuming L and C are normally distributed and independent

-> SM is also normally distributed

with Mean $\overline{SM} = \bar{C} - \bar{L}$

and Standard Deviation

$$S_{SM} = \sqrt{{S_C}^2 + {S_L}^2}$$

Freeze, R. A., et al. (1990), Hydrogeological Decision-Analysis .1. a Framework, *Ground Water, 28(5), 738-766*

Example: Decision Making in Engineering design

Owner's/Operator's Perspective

- Technical objective = satisfying regulatory standard
- Economic objective = meet the technical objective with minimum possible loss.

Objective function can be defined as

$$\emptyset_j = \sum_{t=0}^{T} \left(\frac{1}{(1+i)^t} [B_j(t) - C_j(t) - R_j(t)] \right)$$

Where,

$\emptyset_j$= objective function for alternative j [$]; $B_j(t)$ = benefits of alternative j in year t [$];

$C_j(t)$ = costs of alternative j in year t [$]; $R_j(t)$ = risks of alternative j in year t [$];

T = time horizon [years]; and i = discount rate [decimal fraction].

$R(t)$ can be defined as the expected costs associated with probability of failure:

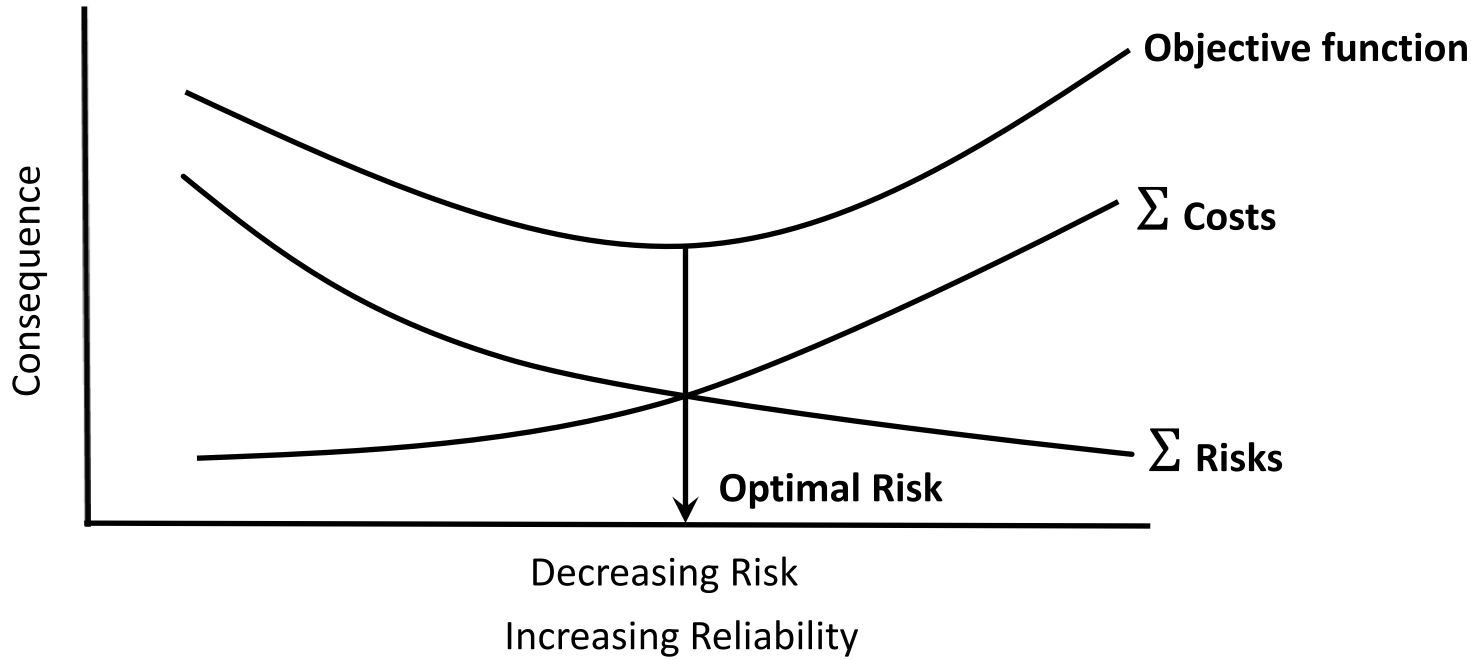
$$R(t) = P_f(t) C_f(t)\, \gamma(C_f)$$

Where, $\gamma(C_f)$ = normalized utility function and ≥ 1 for risk-averse decision makers.

Crouch, E. A. C. and R. Wilson. Risk/Benefit Analysis. Cambridge, MA: Ballinger Publishing, 1982.

Objective function

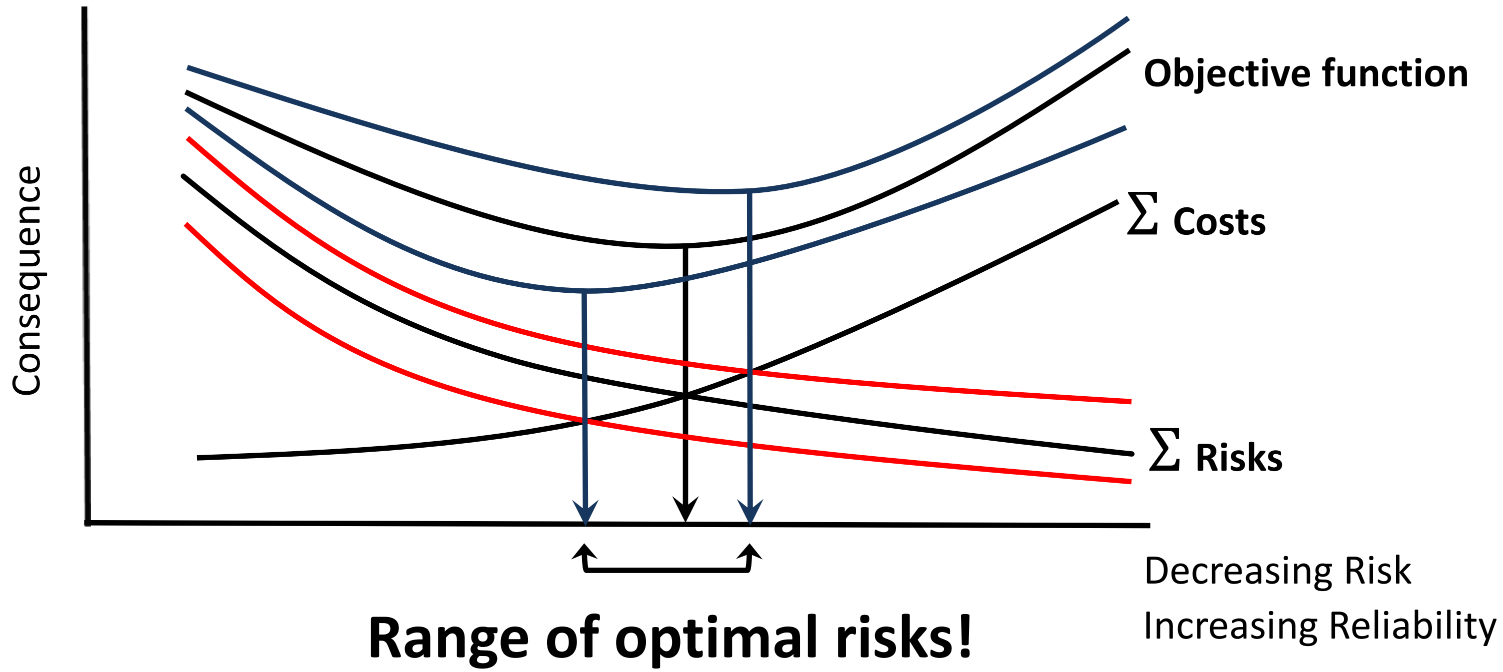
Optimal Risk



Acceptable Risk

- Set by regulatory bodies

Optimal Selection



$R =$ The expected costs associated with probability of failure

$$R(t) = P_f(t)C_f(t)\gamma(C_f)$$

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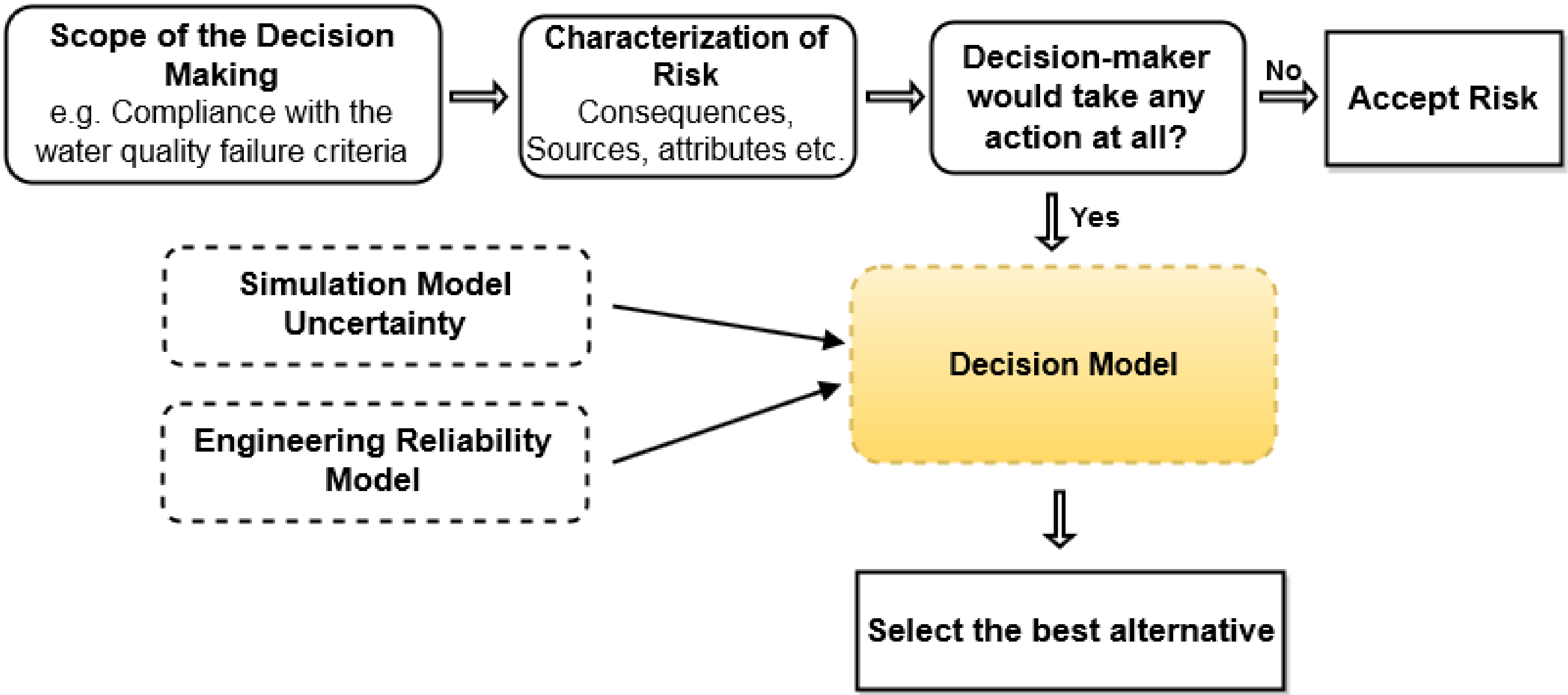
Objectives:

- Develop advice for end-users on the feasibility of application of uncertainty analysis frameworks and methods

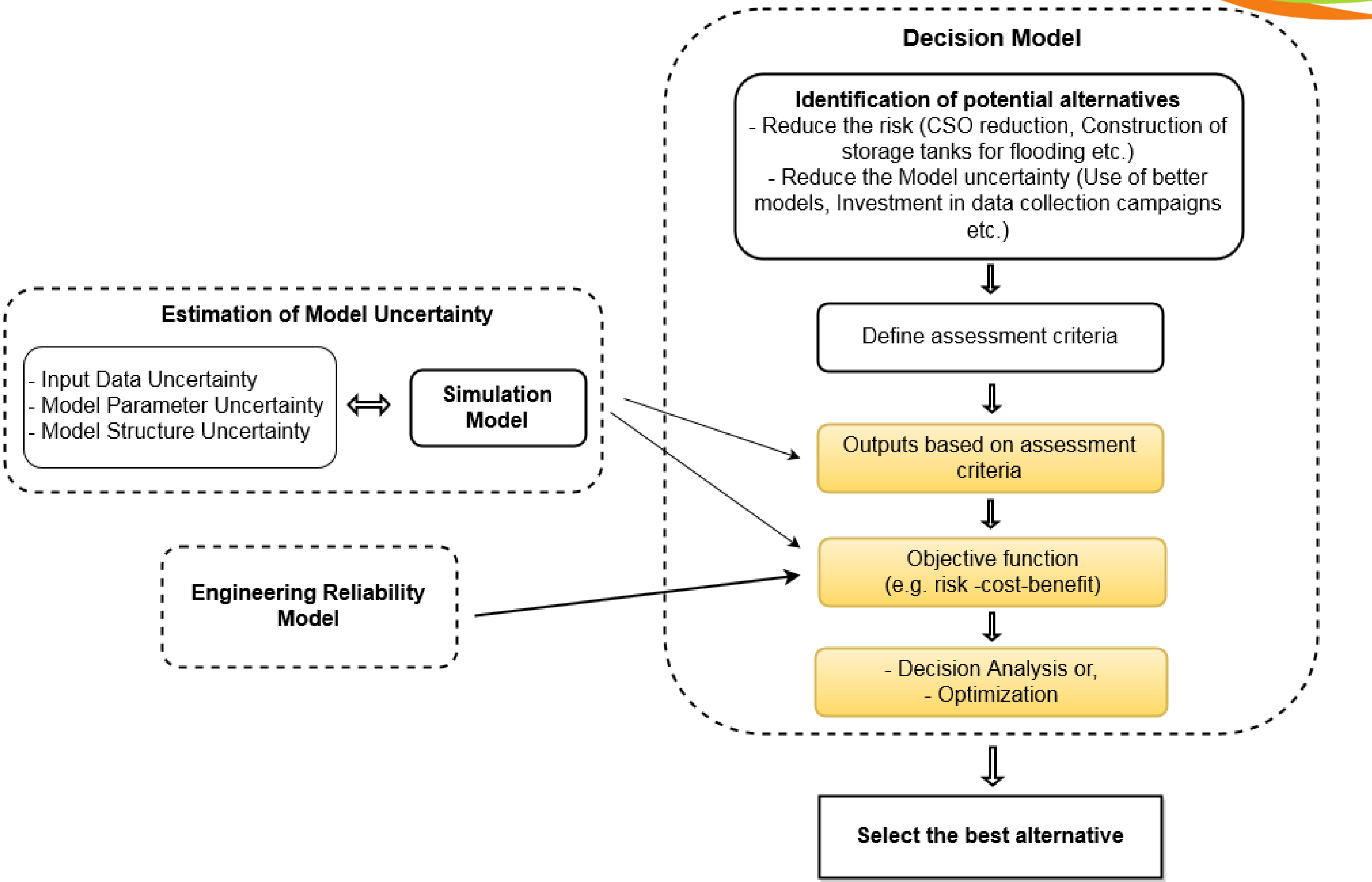
- Develop a framework for decision making under uncertainty and provide suitable methodologies to compare different decision alternatives within the context of water quality failure

- Develop computational tools to assess the benefits and cost-saving potential of routinely carrying out uncertainty analysis

Decision Framework



Decision Framework



Key Research Questions

1. How to represent the Risk of failure for each alternative by including Model Uncertainty?

2. How to define the appropriate objective function reflecting the uncertainty?

3. Which method to choose for decision analysis?