Dam safety risk analysis using bayesian networks

by Marc Smith P.E. Ph.D.

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**Introduction**

Dam failures: not common important consequences

Always a residual risk → must be **MANAGED** by dam owner

Two of the main characteristics of risk

**COMPLEXITY** and

**UNCERTAINTY**
Problem description

Analyzed project (irrigation and flood protection)
Problem description

- overtopping
- internal erosion
- unreliable gate components
- insufficient spillway capacity
Interrelations between failure mechanisms

- reservoir level (+) → overtopping (+)
  → internal erosion (+)
- precipitations (+)
  → reservoir level (+)
- spillway operation (-)
- reliability of components (-) → spillway operation (-)
- wind speed (+) → spillway operation (-)
- waves (+) → overtopping (+)

Geotechnical, hydrological and structural risks have to be compared.
**Interrelations between failure mechanisms**

A. What are the most significant factors contributing to the overall risk?

B. What are the rehabilitation works to be realized in priority?

Complexity and uncertainty have to be taken into account.
Bayesian networks

Overall technical risk analyzed using bayesian networks

A is the cause of B and C

\[ P(C \mid A) = 0.9 \text{ etc.} \]

what is the most probable effect of A?

inferences are based on Bayes' theorem and realized using a specialized software
**Probability tables**

Probabilities are determined using:

1. Statistical techniques
2. Models

\[ P(\text{failure of lifting mechanism}) \]
Probability tables

Probabilities are determined using:

3. Expert knowledge about the dam and its behaviour

Carried soil particles: $P(CSP)$ is high
Optimal risk-reduction measures

A. What are the most significant factors contributing to the overall risk?

The variables $V_a$ ($WS, GC, EW$) having the most negative impact on $P(F)$ are related to overtopping.

The most critical variable is the operation of the gantry crane:

$P(F) \quad P(F \mid V_a) = \max(-)$

$impact (-) \uparrow \quad P(GC) \uparrow$
In technical and monetary terms, the optimal risk-reduction measure is the construction of a filtering berm:

\[
\text{priority\_index} = \frac{\text{impact}(+) \cos t}{\cos t} = \text{max.}
\]
Optimal risk-reduction measures

This analysis should be considered as an aid to decision regarding the technical and monetary aspects of the problem.

Social, environmental and legal aspects are also important.

*Ex. a minimal spilling capacity could be prescribed by law*

Must consider the potential negative impacts of the proposed rehabilitation measures to assess their overall net outcome.

*Ex. an increased spilling capacity provides more safety for the structures but could endanger the population living downstream*
Conclusions

The presented concepts allowed the determination of the overall risk by considering the complexity (interrelations) and uncertainty.

\[ P(F) \] was considered as common denominator to compare the geotechnical, hydrological and structural risks.

\[ P(F) \] can be used to judge the potential relative effectiveness of risk-reduction measures.

It was therefore possible to determine:

*What could go wrong?*

*What should be done about it?* among the main responsibilities of a dam owner.