

Tree based Methods to model scenarios of dam failure

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Principles et steps of a Risk Analysis Study



Tree based Methods in Risk Analysis

• 3 methods to model scenarios and to connect failure modes

- ETA: Event Tree Analysis Method
- FTA: Fault Tree Analysis Method
- BTA: Bow Tie Analysis Method

Methods with common points

- Need to perform a failure modes method before, as PRA or FMEA/FMECA methods
- ETA/FTA/BTA consist to connect "elements" (failures, events, causes, consequences ...) in a tree based method to model a scenario





Event Tree Analysis - Principles

☑ Inductive process of chaining failure modes

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- Assume an initial failure mode: the *Initial Event*
- **ETA** implemented after implemented Functional Analysis and FMEA
- A scenario is determined by considering a chain of failure modes issued from FMEA method





Event Tree Analysis - Principles



Example: Operation of closing gates of a dam





Example : Scenario of increase of pore pressure in the core or in the foundation - Clogging of the filter

Initial Event		Drain and Filter component: To Drain the leakage coming from the core		Core, Downstream Shoulder, Foundation: Resist mecanical stress
			Safety barrier: monitoring system	Sliding of the core or of the downstream shoulder or of the foundation
		Clogging of the Downstream Drain and Filter system		ce failure
Hudroulio		ailure		
Action		Success F		





> To model complex scenarios with many failure modes

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Assessment of the probabilities with ETA

• Principles:

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 Agregation of the elementary probabilities and evaluation of the global probability for the scenario/ETA



 $P_{1} = P(IE)$ $P_{2} = P(A | IE)$ $P_{3} = P(B | A \text{ and } IE)$ $P_{4} = P(C | B \text{ and } A \text{ and } IE)$ $P_{\text{scenario}} = P_{1} \times P_{2} \times P_{3} \times P_{4}$



Event Tree Analysis Method - Synthesis

- Method to model, from an Initial Event, the sequence of failure modes that may lead to a potential accident
- To provide Event Tree Analysis Method, it requires a good analysis quality for Functional Analysis and FMEA
- Method ensuring completeness of scenarios and their failure modes
- Method well suited to an quantitative/probabilistic risk analysis
- The method can be complex to implement if there are many scenarios ... and so many Event Trees





Fault Tree Analysis Method - Principles

- Deductive approach of chaining failure modes
- Determine the *Final Event* (Potential Accident) with a Preliminary Risk Analysis (PRA)
- ☑ Determine the chain of failure modes leading to the Final Event (collapse / limit-state)
- ✓ The Fault Tree Analysis Method used after a Preliminary Risk Analysis to search for causes and the intermediate events
 - Using an expert group to build up the Fault Trees
 - Supported by feedback and expertise
 - Questions asked to the expert group:
 - What did it take for? Are there other causes?
 - Stopping the construction of the Fault Tree when the causes are no longer linked to the system







Fault Tree Analysis Method – Logical gates

	Symbol	Function	Description
		GATE "AND"	Output Event occurs if all Input Events occur together
-		GATE "OR"	Output Event occurs if only one Input Event occurs





Example

Fault Tree Analysis Method

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Fault Tree Analysis Method – Example







Assessment of the probabilities with FTA



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Main limits of the quantitative assessment of probabilities:
 → the exhaustiveness and independence of events



Fault Tree Analysis Method - Synthesis

- Simple to implement and intuitive: requires a simple Functional Analysis and an PRA to determine the *Final Event* of the Fault Tree
- Need the search for the *causes* of the *final event* with expertise
- Be understood easily by those who are not risk analysis specialists
- The search for *causes* does not guarantied the completeness of failures. So the Fault Tree Analysis Method must rely on a strong expertise
- Pay attention to the independence of the events in the FTA, not guaranteed by the method
- FTA poorly suits to quantitative/probabilistic analysis
 FTA suits to semi-quantitative analysis





Bow Tie Analysis Method - Principles

- ☑ Tree based method, widely used in French practices
- ☑ Combination of FTA et ETA, around a Central Feared Event (CFE)
- ☑ To model the scenarios around the CFE, by examining:
 - ☑ The causes with a FTA
 - ☑ The consequences with a ETA





Bow Tie Analysis Method - Principles







Bow Tie Analysis Method - Synthesis

- Combinations of events leading to an CFE by a FTA
- Requires a simple Functional Analysis and an PRA to determine the CFE of the Fault Tree
- The Dangerous Phenomenon resulting from CFE in Bow Tie Analyse are simple (most of the time):
 - The formation of a dam break flood wave
 - The formation of flood wave due to a failure gate











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Central Feared Event 01 Dam Failure







et réservoirs

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Scenario of spillway breach by uplift pressures



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Scenario of breach following slip-surface instability of an embankment dam



Scenario breach by pipe enlargement following concentrated leak in an embankment dam

COLLAPSE OF PIPE LEADING TO LOSS OF FREEBOARD

