The Quantitative Risk Analysis of a Water Pipe Bridge on Earthquake Disasters – Case study of SinDian Water Pipe Bridge

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Outline of Presentation

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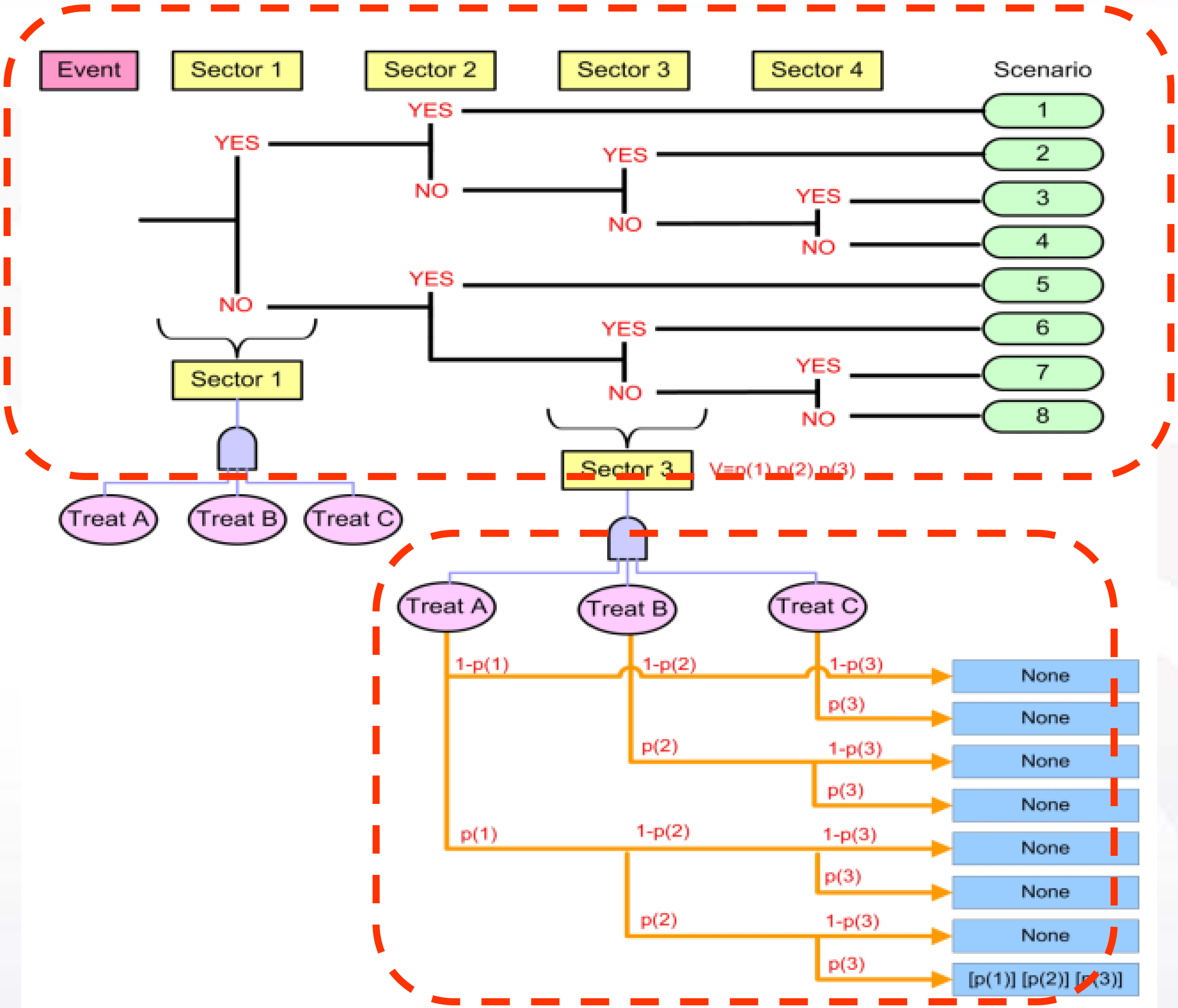
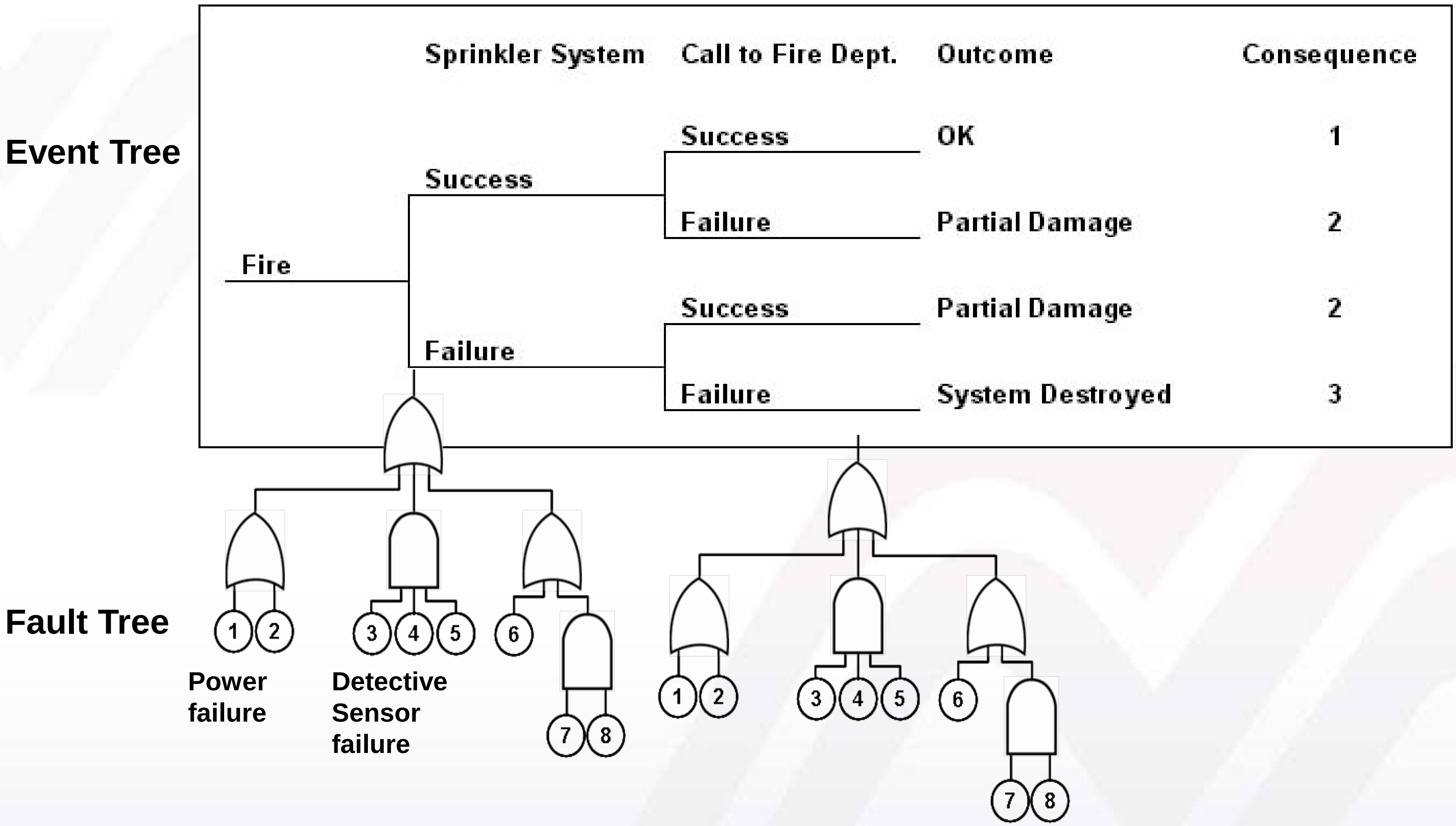
Quantitative Risk Analysis



Event tree :
Establish logic model that identifies and quantifies the possible outcomes following an initiating event.

Fault trees:
Graphically represent the interaction of failures and other events within a system.

Example


Event Tree
Sprinkler System
Call to Fire Dept.
Outcome
Consequence
Fire
Success
Failure
Success
Failure
Success
Failure
OK
1
Partial Damage
2
Partial Damage
2
System Destroyed
3
Fault Tree
1
2
3
4
5
6
7
8
Power failure
Detective Sensor failure
1
2
3
4
5
6
7
8

Introduction

NCDR

www.ncdr.nat.gov.tw

- **SinDian Water Pipe Bridge**
  - **Steel arch bridge with length of 290m**
  - **Super structure consists of 3-span steel arches, each is 70m long.**
  - **Arches are 10.6m high, and there are also 11 shafts supporting the main water pipe.**

Introduction

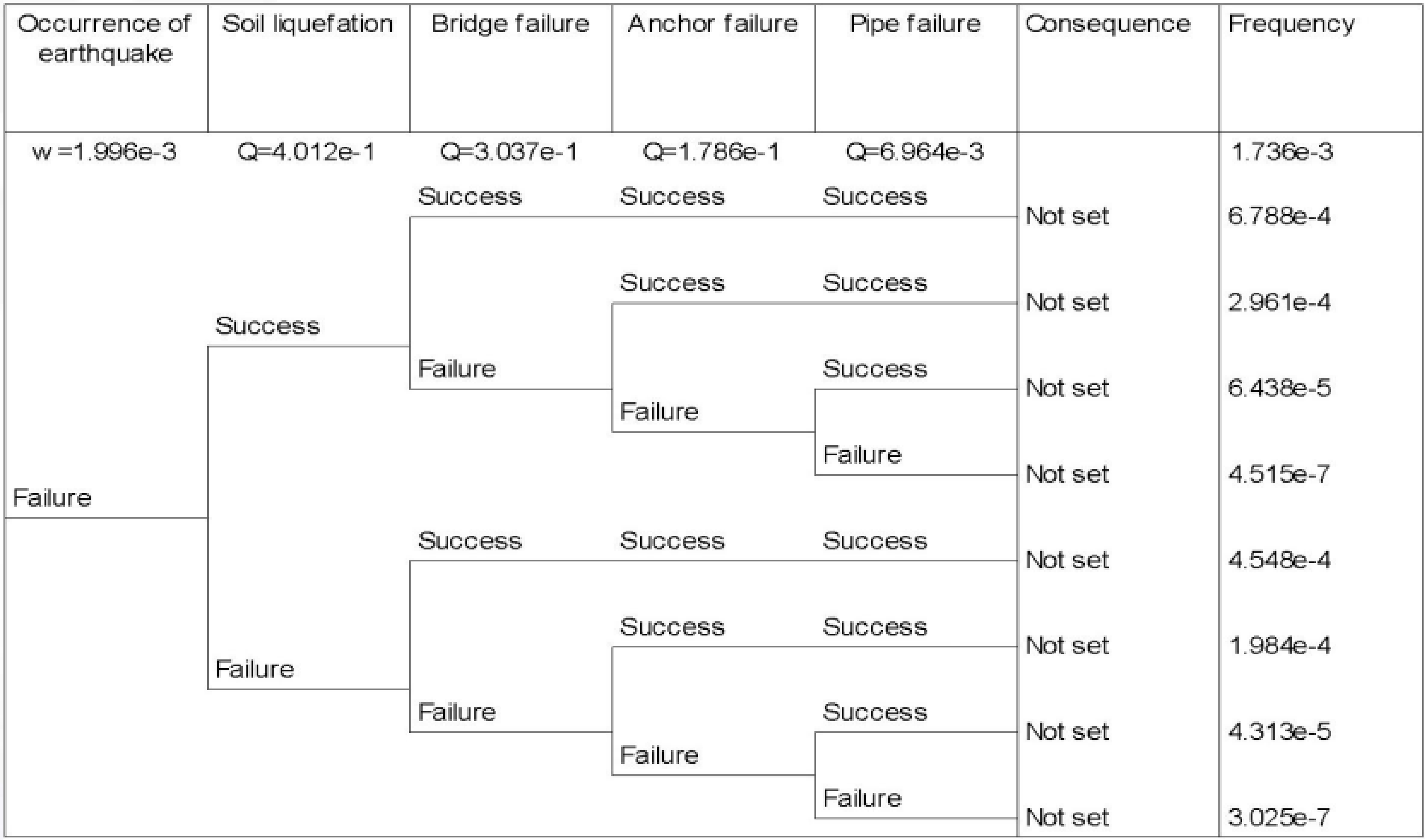
- **SinDian Water Pipe Bridge**
  - **Lower structure consists of a 12m-high single reinforced concrete pier with pile foundation.**
  - **Inner diameter of the water-transporting pipe is 2400mm, with 20mm thickness.**

Quantitative Risk Analysis of Water Pipe Bridge

- **The Establishment of Event Tree**
  - **Event Tree is established in the first place including occurring of earthquakes, and then the occurrence probability of events will be calculated throughout.**
  - **Event Tree is started from the occurrence of earthquake, and end in the failure of water-transporting pipe**
  - **“ whether or not the soil liquefaction happens ? ”**
  - **“ whether or not the bridge is damaged ?”**
  - **“ whether or not the anchor is damaged ?”**
  - **“ whether or not water pipe is damaged ?”**

Quantitative Risk Analysis of Water Pipe Bridge

- **Event Tree**



Quantitative Risk Analysis of Water Pipe Bridge

- **Establishment of Fault Trees**
  - **Fault Tree will be analyzed from 2 sectors:**
    - **Material itself (material failure)**
    - **Damage caused by external force**

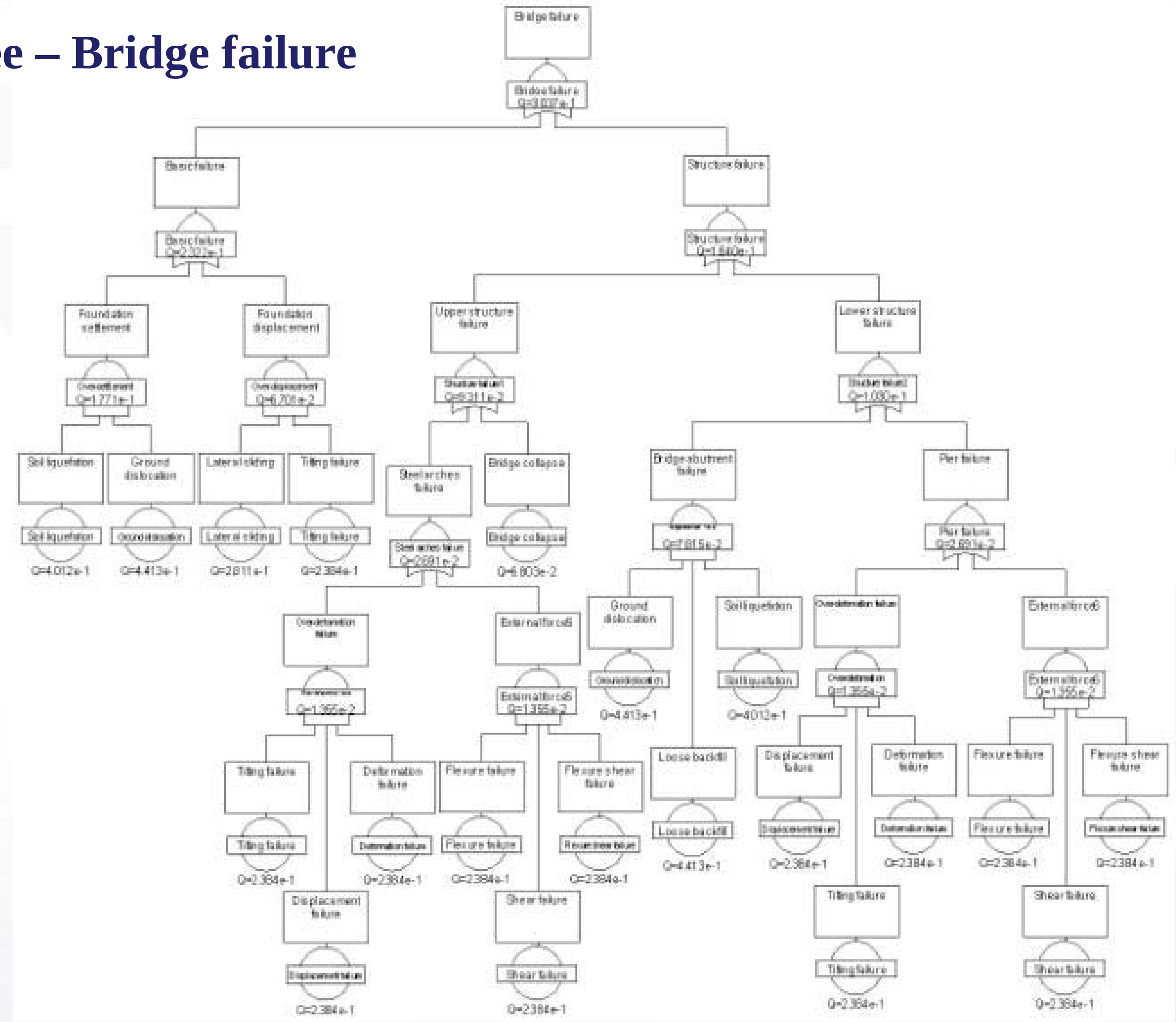
  to find out whether the failed event is caused by a single basic fault or several basic faults collectively.

The Establishment of Fault Trees

Failure event	Detail	Factor
Bridge failure	foundation failure	soil liquefaction and ground dislocation; soil liquefaction and ground dislocation;
	Structural failure	Upper structure: 1. over-deformation failure (displacement, tilting and deformation failure) failure by external force (flexure, shear and flexure shear failure). 2. failure by external force (flexure, shear and flexure shear failure).
		Lower structure: 1. Bridge abutment failure includes ground dislocation, loose backfill, and soil liquefaction. 2. Pier failure includes over-deformation failure (displacement, tilting and deformation failure) and failure by external force (flexure, shear and flexure shear failure).
Anchor failure	U-shaped ring failure	shear failure and over-deformation
	Bolt failure	1.failure caused by external force is shear and pull-out failure. 2.material quality such as corrosion, temperature difference, ageing, inferior material etc
	Coating degradation	peel off, swollen, crack, color fading and rust
pipe failure	Joint failure	1.mainly caused by inferior material 2.failure caused by external force consists of tension failure, bearing failure, water pressure failure and flexure failure.
	Pipe body failure	1.mainly caused by material defects such as splits, temperature difference, hardening and inferior material quality. 2.failure caused by external force consists of cracks, twisting/deformation, cut-off and water pressure failure.
	Fittings failure	pipe-fixing facility, cracks on manhole or loosened anchor bolts

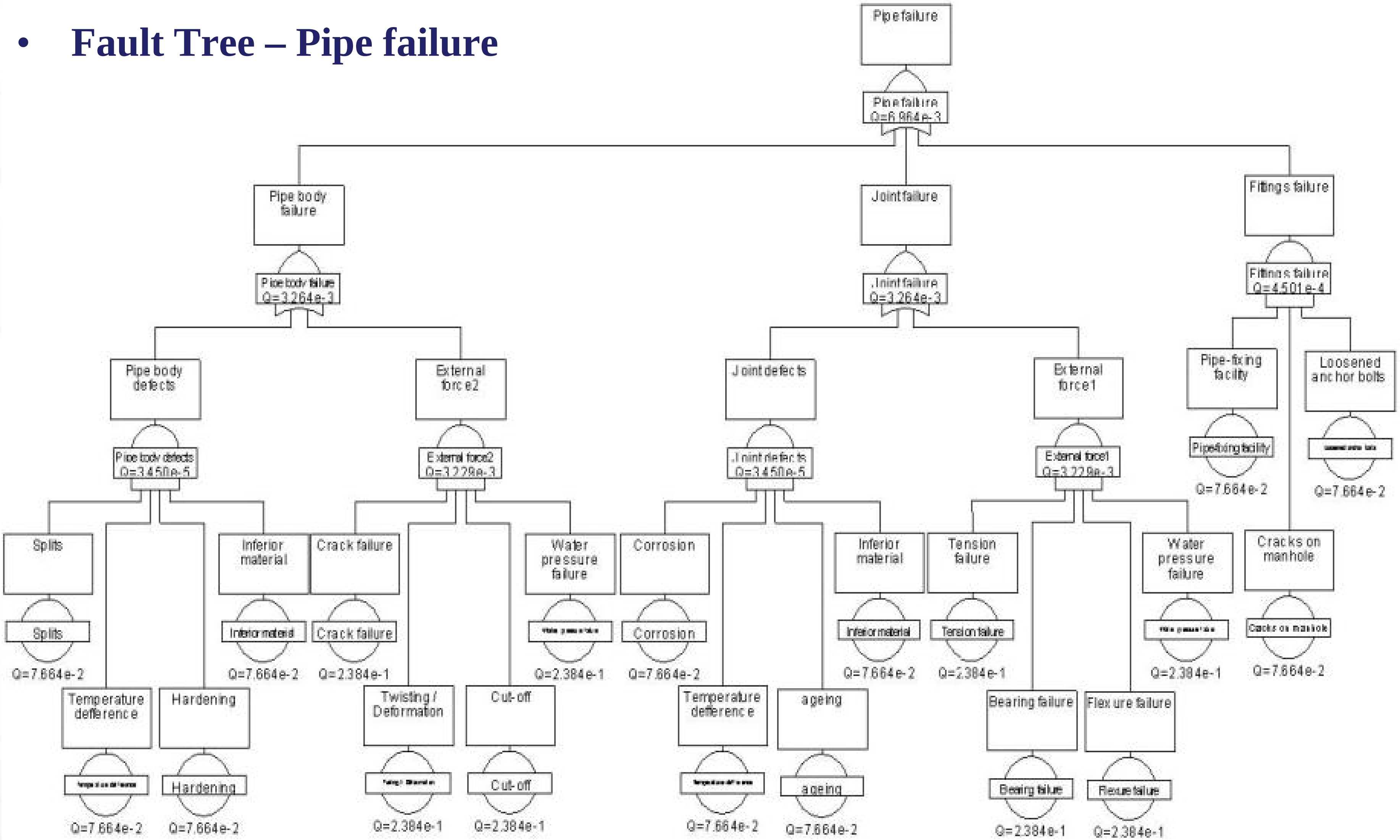
Quantitative Risk Analysis of Water Pipe Bridge

- **Fault Tree – Bridge failure**



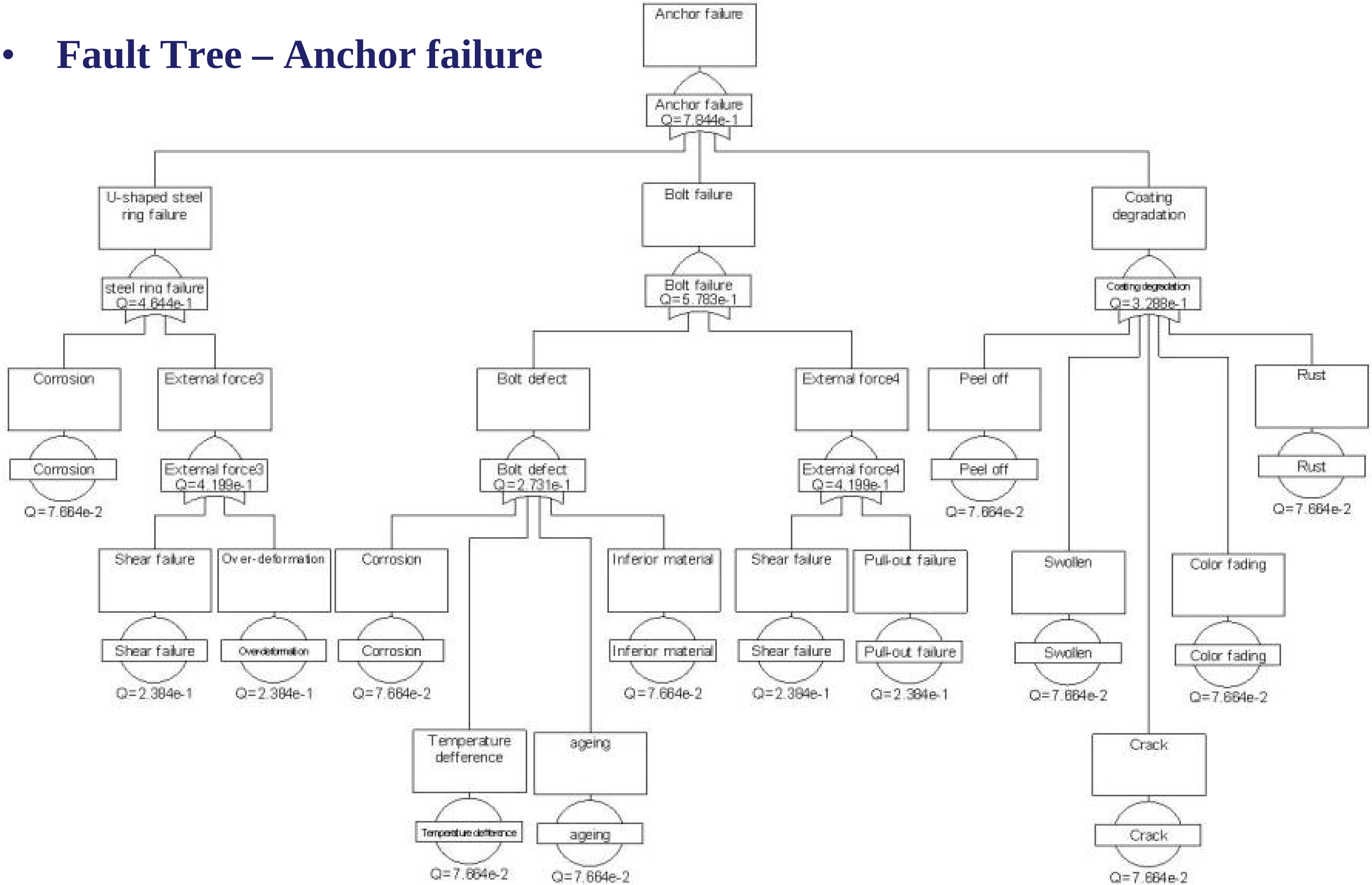
Quantitative Risk Analysis of Water Pipe Bridge

- **Fault Tree – Pipe failure**



Quantitative Risk Analysis of Water Pipe Bridge

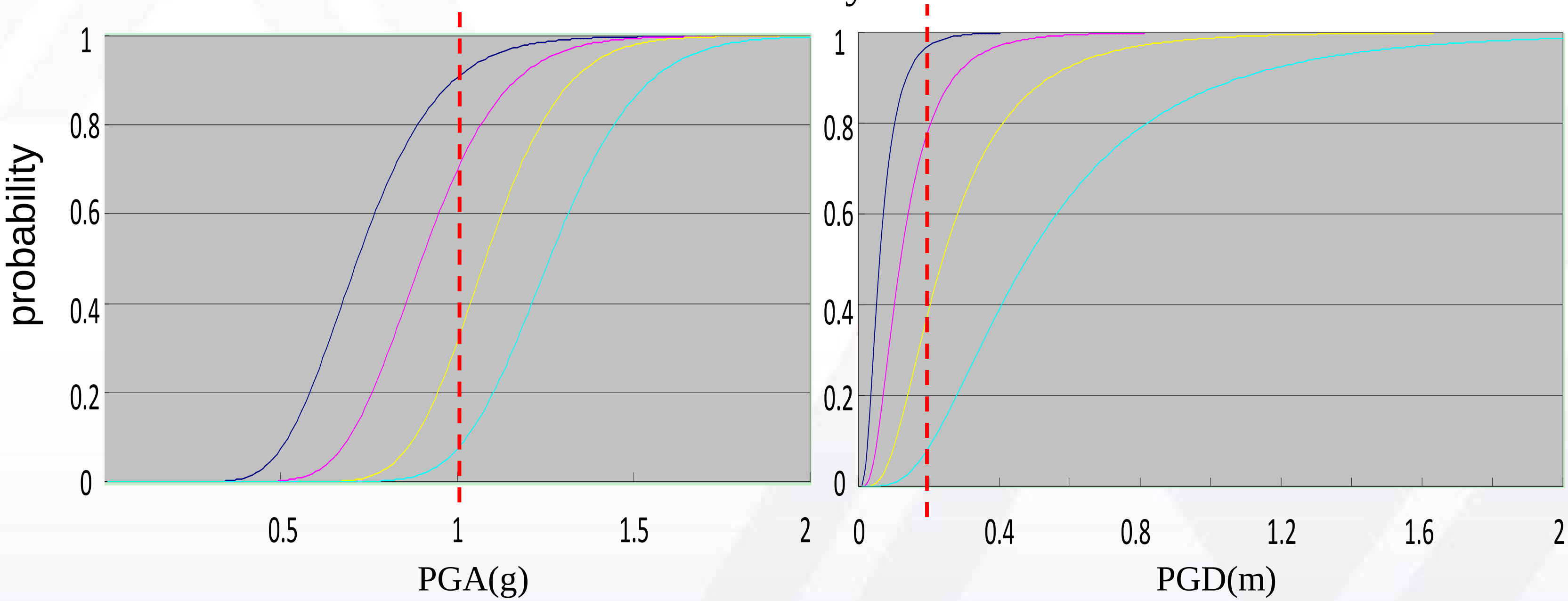
- **Fault Tree – Anchor failure**



Quantitative Risk Analysis of Water Pipe Bridge

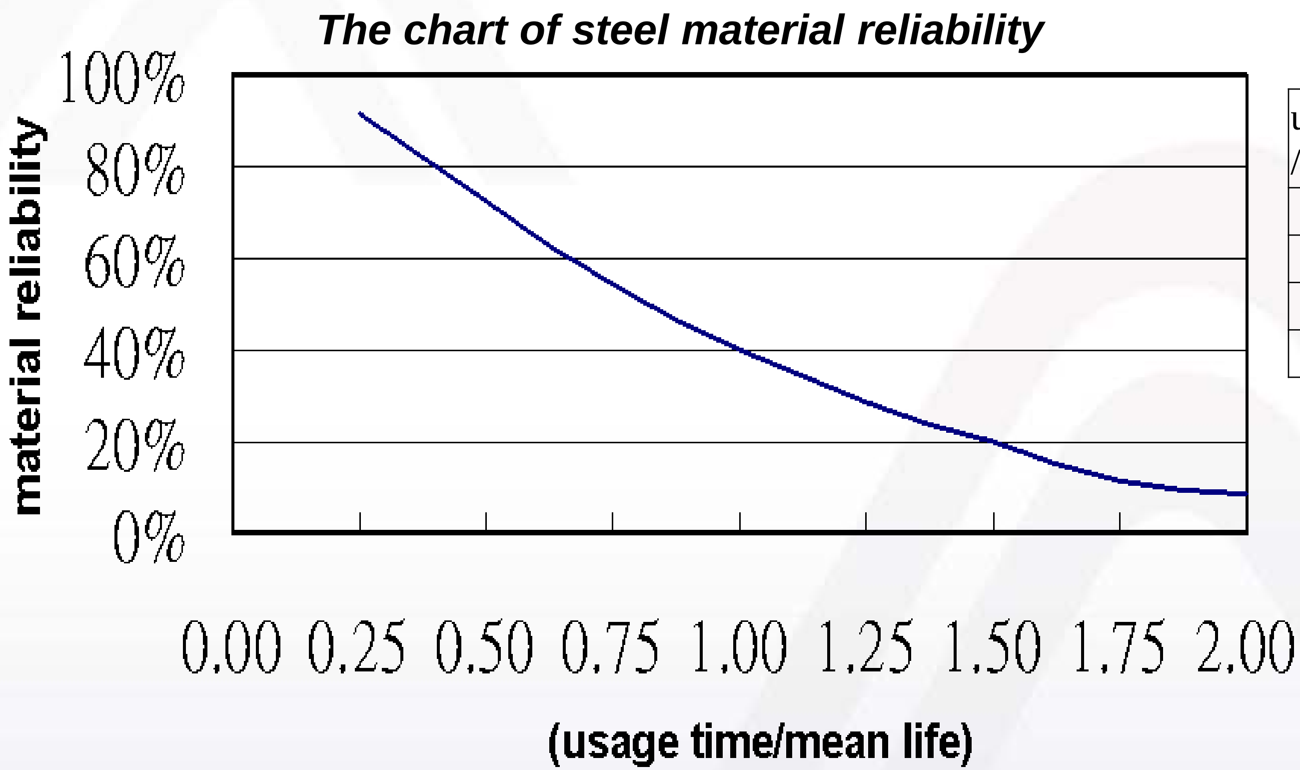
- **Parametric Quantification Method**
  - **Failure probability of bridge structures is analyzed from vulnerability aspect**

Vulnerability curve



Quantitative Risk Analysis of Water Pipe Bridge

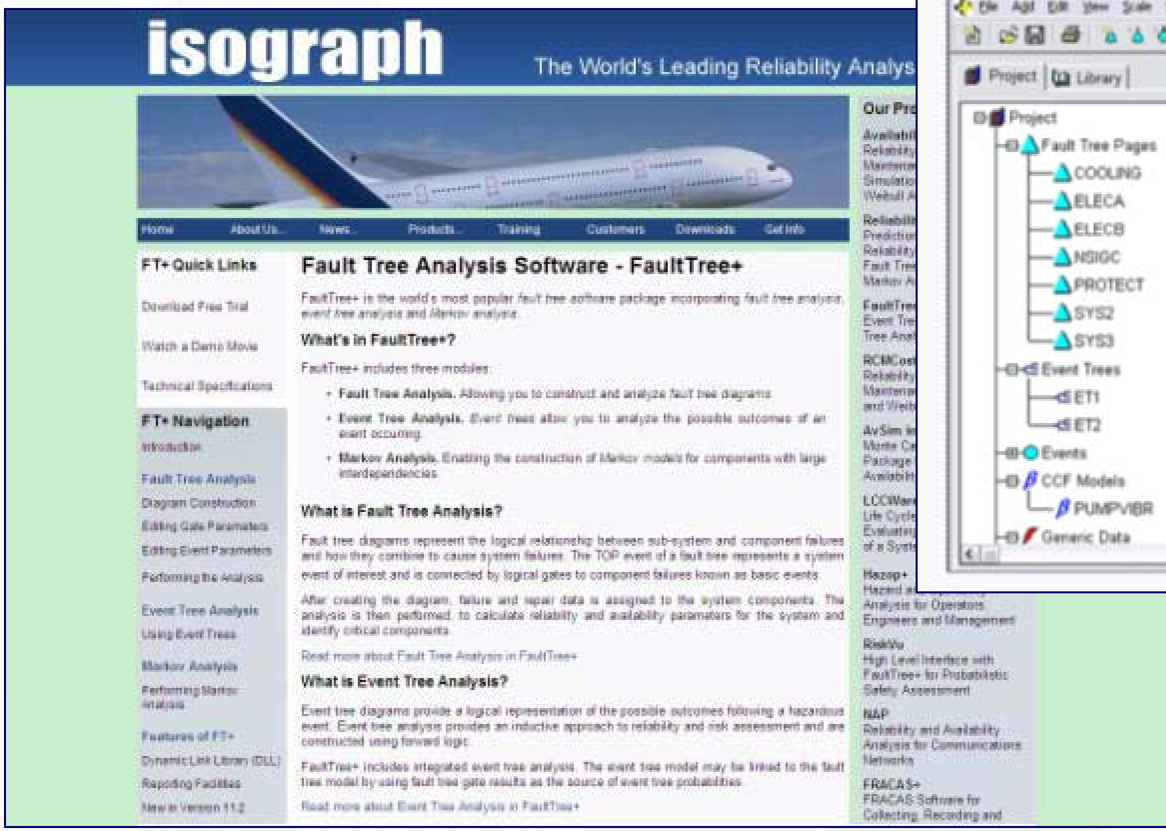
- **Parameters Quantification Method**
  - **Failure probability of steel material is analyzed from the aspect of material reliability**

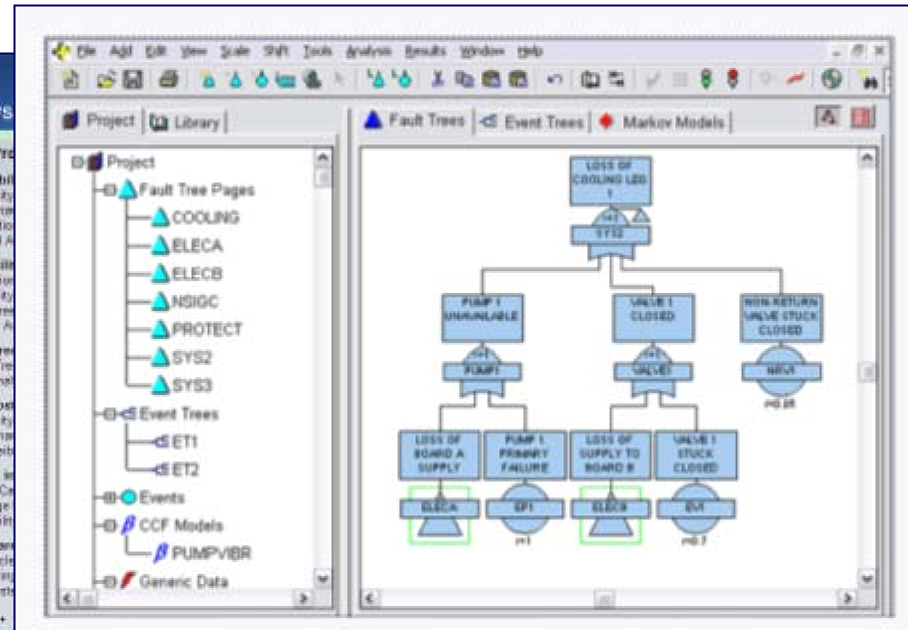


usage time /mean life	extinguishment rate
0.25	0.085
0.5	0.272
0.75	0.458
1	0.6

Quantitative Risk Analysis of Water Pipe Bridge

- **Calculated by FaultTree+ V11.20**





website: http://www.isograph-software.com/index.htm

Quantitative Risk Analysis Result

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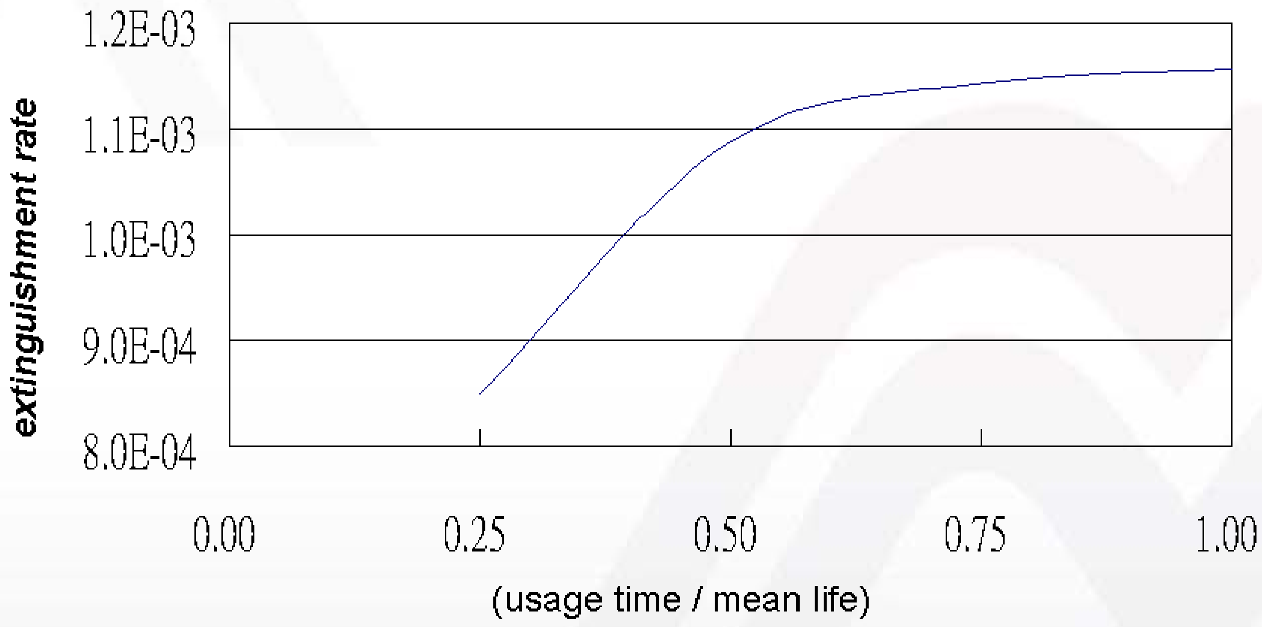
- **In Event Tree, the usage period normalization for steel material reliability ranges from 0.25, 0.5, 0.75 to 1.0, and the highest failure probability value of water-transporting function is 8.483e-4, 1.088e-3, 1.143e-3 and 1.156e-3. The trend of suspending rate of water-transporting function is shown as below.**



Quantitative Risk Analysis Result

NCDR

- **Higher failure probability indicates that the reliability and substantial strength of steel material is degrading over time, which increases the damage rate of water pipe. The increasing curve of failure probability over time tends to flatten when the usage period normalization is 0.5 or above.**

- **From Event Tree analysis result we found out that the controlling factors for usage period normalization which ranges from 0.25 to 1.00 are bridge and anchor failure, and from Fault Tree analysis for anchor failure it shows that when the usage period normalization is 0.5 or above, the controlling factor for bolt failure changes from failure caused by external force to bolt defects. These results can assist the management unit in planning inspection and maintenance priorities for different period.**

Conclusion

- **In this research we establish Event Tree and Fault Tree of water pipe bridge after earthquake and propose parametric quantification method for various basic failure events with SinDian water pipe bridge as the case study. The process is referable for related research.**

- **The evaluation and analysis results show that suspending probability of related failure events estimated through Vulnerability Curve for bridge and material reliability analysis could provide simple quantification data which can be used conveniently for preliminary evaluation.**

- **This method could consider the condition of various components under the sequence of circumstances within a disaster and establish distinctive Event Tree and Fault Tree according to each protection target. In the same time, the steel material reliability variation over time is also considered in the evaluation process to analyze risk management priorities of the protection target under different life cycle.**

Thanks for your attention !!