NAIVE FAULT TREES

DR. MOHAMMAD RAJABALI NEJAD
ASSISTANT PROFESSOR
FACULTY OF ENGINEERING TECHNOLOGY, UNIVERSITY OF TWENTE
ABOUT THE PRESENTER

- Assistant Professor: University of Twente, System Safety
- Associate Editor: J. of Intelligent Automation and Software Engineering
- Advisory Board: J. of Advances in Systems and Measurements

- Postdoc, University of Montreal, Canada, “Reliability of Infrastructures”
- PhD, TUDelft, “Reliability Methods for Finite Elements Models”
- MSC, IUST, Tehran, “Safety of Civil Structures”

- Worked in various projects
OVERVIEW

- Fault Trees (FT)
- FT Analysis
- FT in early design
  - Pros/ cons
- Naïve Fault Trees
- Example application
- Conclusions
FAULT TREES (1)

- Formalized approach
  - symbols, identifiers, labels
- Analytical approach
  - to analyze/evaluate flow of states/events
- Graphical representation
  - for events contributing to a final outcome
- Top-down approach
  - a predefined top event
For modelling system performances
- safety, reliability, maintainability, etc.

- Qualitative/quantitative
  - estimated probability

- FT enjoys logic
  - And/OR

- FT and FMEA
  - top <=> bottomn
FAULT TREES (3)

- FT and ET
  - Cause-consequence Analysis (CCA)
- FT and MC
  - Dynamic FT
- FT and BDD
  - Effective calculations
- FT and RBD
  - More realistic predictions
- Etc.
FT CHALLENGES

- In early design phases
  - Quantitative analysis can be difficult
  - Understanding of numbers
  - Objectivity of values
  - Unlikely to capture all failure modes
  - Quantification of human errors
  - Data quality
FOR THE CHALLENGES, WE NEED...

- There are only two things you need to be successful in life:

  *Ignorance and confidence*
WHAT WE NEED TO DO/HAVE?

- We should
  - acknowledge lack of knowledge
  - avoid pretending to know exact uncertainty
  - use flexible communication means

- A tool that
  - Embraces uncertainty
  - Embeds flexibility
EMBRACING UNCERTAINTY

- Early design decisions with
  - imprecise data
  - a flexible framework
  - different stakeholders
  - individual/plural information

- See Rajabalinejad (2012), Int. Journal of Industrial and Systems Engineering
MEASURE OF OCCURRENCE

- Mathematics for
  - weighted opinions
  - measure of occurrence
  - naive fault trees
  - reliability of estimates
EXAMPLE APPLICATION

- The case study
Figure 2. The cross section of the flood wall at 17th street canal and its foundation (Team 2006).
FAULT TREE FOR THE FLOOD WALL
FAILURE SCENARIOS

- Sliding
  - partial/ complete
  - main failure mode
- Overflowing
  - uncertain estimation
  - needs for resiliency
- Piping
  - depends on foundation materials
  - low probability
# QUANTITATIVE VS QUALITATIVE ANALYSIS

<table>
<thead>
<tr>
<th>Qualitative</th>
<th>Quantitative*</th>
</tr>
</thead>
<tbody>
<tr>
<td>No-Occurrence</td>
<td>The event is not expected to happen in 10,000 years</td>
</tr>
<tr>
<td>Seldom Occurrence</td>
<td>The event may happen 1 time in 10,000 years</td>
</tr>
<tr>
<td>Less-frequent Occurrence</td>
<td>The event may happen 1 time in 1000 years</td>
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<tr>
<td>Frequent Occurrence</td>
<td>The event may happen 1 time in 100 years</td>
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<tr>
<td>Often Occurrence</td>
<td>The event may happen 1 time in 10 years</td>
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<tr>
<td>Continuous Occurrence</td>
<td>The event may happen once in a year</td>
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</tbody>
</table>
## FAILURE AT SERVICE LEVEL

<table>
<thead>
<tr>
<th>Failure at normal service condition</th>
<th>Failure mode</th>
<th>Intermediate even</th>
<th>Scenario 1</th>
<th>Qualitative*</th>
<th>Numeric data*</th>
<th>Simulation outcome</th>
<th>Qualitative outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sliding</td>
<td>in pool side</td>
<td>Seldom</td>
<td></td>
<td>0.0001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sliding</td>
<td>in protected side</td>
<td>Seldom</td>
<td></td>
<td>0.0001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sliding</td>
<td>of whole dike</td>
<td>Seldom</td>
<td></td>
<td>0.0001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piping</td>
<td></td>
<td>No</td>
<td></td>
<td>0.00005</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Failure of the I-wall</td>
<td></td>
<td>No</td>
<td></td>
<td>0.00005</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

*Qualitative and numeric data values are for demonstration purposes only.*

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UNIVERSITY OF TWENTE.
# FAILURE AT EXTREME LEVEL

<table>
<thead>
<tr>
<th>Failure mode</th>
<th>Intermediate even</th>
<th>Scenario 1</th>
<th>Qualitative*</th>
<th>Numeric data*</th>
<th>Simulation outcome</th>
<th>Qualitative outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sliding</td>
<td>in pool side</td>
<td>Less-freq.</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>in protected side</td>
<td>Less-freq.</td>
<td>0.001</td>
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<tr>
<td></td>
<td>of whole dike</td>
<td>Less-freq. to freq.</td>
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<tr>
<td>Erosion of inner slope</td>
<td></td>
<td>Less-freq.</td>
<td>0.001</td>
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</tr>
<tr>
<td>Erosion of the support</td>
<td>Erosion of I wall</td>
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<td>0.0001</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>piping</td>
<td>seldom</td>
<td>0.0001</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Failure mode</td>
<td>Intermediate event</td>
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<tr>
<td>Sliding of whole dike</td>
<td>Less-freq. to freq.</td>
<td>0.005</td>
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<tr>
<td>Erosion of inner slope</td>
<td>Less-freq.</td>
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<td>Top Event</td>
<td>Failure of the flood-wall</td>
<td>≈0.005</td>
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* This data is imprecise and subject to an expert opinion.
CONCLUSIONS

- FT demands for quantitative values in early design resulting in
  - mix highly accurate/ inaccurate data
  - imbalance analysis, quality concerns for results

- Paper suggests
  - embedding flexibility in communication
  - pluralistic basis for integration of data
  - using fault trees for early design phases
PLEASE CONSIDER CONTRIBUTING TO

Special track
ESITIS 2017: Evolution of Safety in Transportation and Industrial Systems

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M.Rajabalinejad@utwente.nl

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