Expert judgements in probabilistic risk analysis – issues in nuclear power plant applications

Jan-Erik Holmberg Risk Pilot AB

COST Programme “Building Expertise for Innovation - Conference on Innovation Decision Support Using Structured Expert Judgement”, 25-27 April ,2017, Aalto University, Espoo, Finland

RISK PILOT©
YOUR RISK NAVIGATOR

Contents

- Use of expert judgements in probabilistic risk analysis (PRA)
- Issues
- Conclusions

Background

- Objective, statistical data do not exist for many input data needed in risk analysis
- Examples
  - Human reliability analysis
  - Phenomenological uncertainties related to severe accidents
- Expert judgements are needed and applied
- Plenty of literature exists of methods, but are they practical and applicable for industrial risk analyses?

Some commonly appearing definitions in risk analysis

- Expert judgement
- Expert judgement elicitation
- Engineering judgement
- Screening values
- Generic data

- Domain expert
  - Knows the subject (scientific/technical discipline)
  - Provides ”judgements”

- Method expert
  - Risk analysis, probability calculus, expert judgement method expert
  - Elicits ”judgements” (facilitator)

RISK PILOT©
YOUR RISK NAVIGATOR

Risk analysis context

- Risk analysis
  - Qualitative analysis
  - Quantitative analysis

RISK PILOT©
YOUR RISK NAVIGATOR

Use of experts in **qualitative** risk analysis

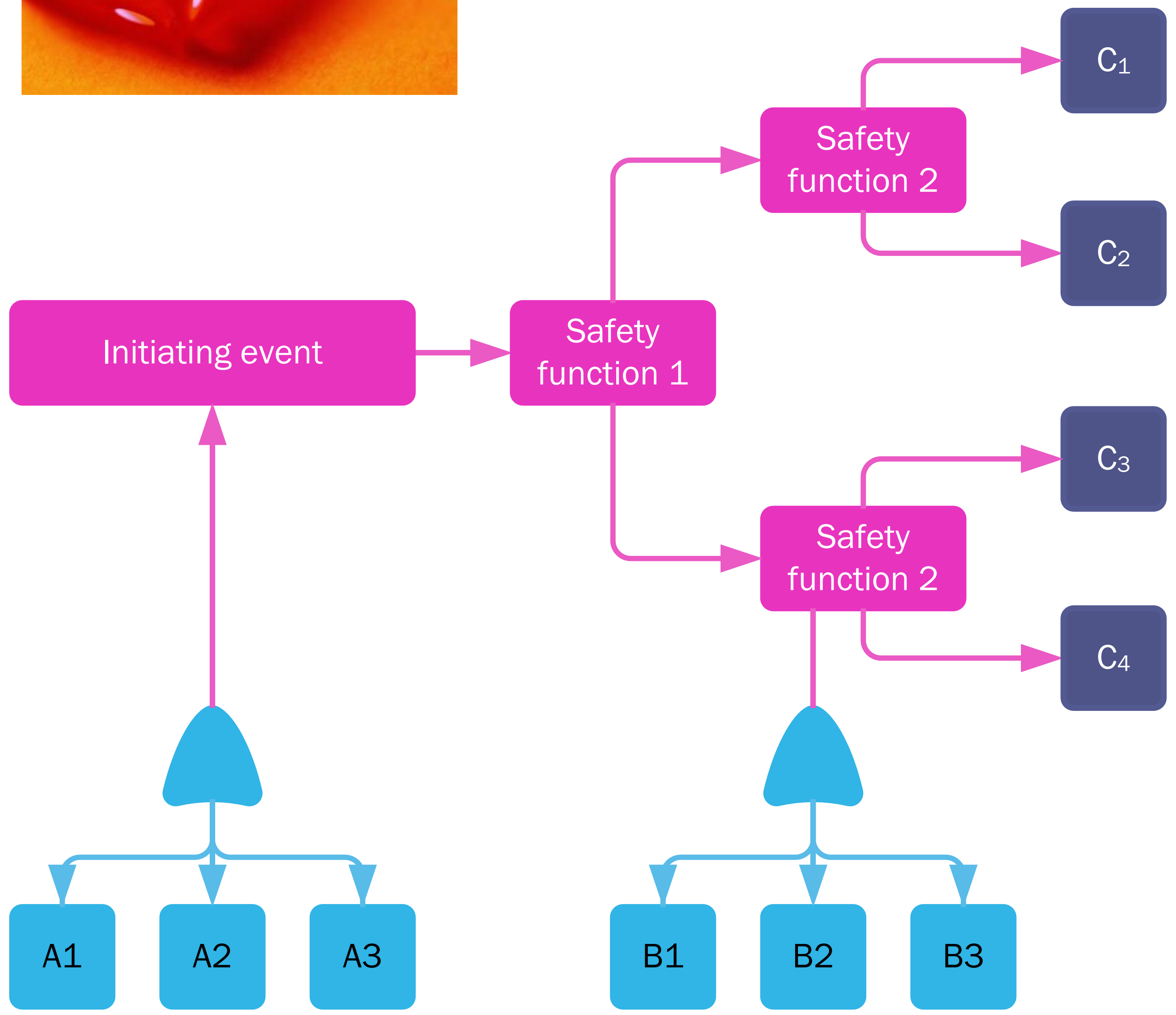
- Qualitative risk analysis methods like FMEA, HAZOP rely on expert judgements
- Domain experts are asked
  - to identify failure modes, causes and impacts
  - to give qualitative estimate of the likelihood and severity of failures
    - “low” – “medium” – “high”

RISK PILOT©
YOUR RISK NAVIGATOR

Use of experts in **quantitative** risk analysis

- Probability estimates for the basic events of the model
  - If statistical data do not exist, then experts can provide
    - directly probability values
    - qualitative values which are translated into probabilities
    - answers guided by expert elicitation methods

- Structures of the reliability models (e.g. event trees, fault trees) are based on knowledge about scenarios and system behaviour
- Simulation models
  - development of the model to correspond with the reality
  - interpretation of the results to support the development of the reliability models



RISK PILOT©
YOUR RISK NAVIGATOR

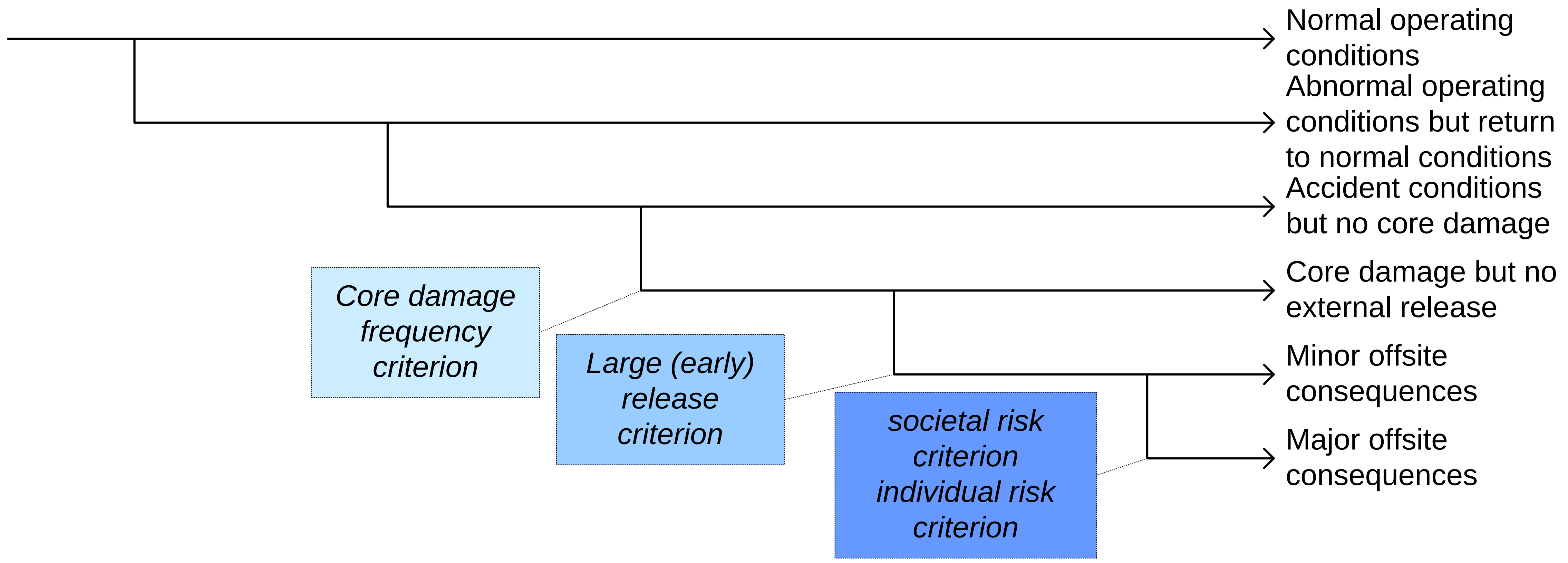
PRA for nuclear power plants

- Regulatory requirement for all nuclear power plants
  - licensing of new plants
  - operational safety management of existing plants (living PRA)

- Principal structure rather standardised
  - Levels 1-2-3
  - Event tree-fault tree modelling approach

- Due to large scope of the analyses, there are a lot open issues and varieties in the methods

Initiating event Level 1 PRA		Safety functions Level 1 PRA	Safety functions Level 2 PRA	Consequence Level 3 PRA	
DID level 1 Prevention of abnormal operation and failures	DID level 2 Control of abnormal operation and detection of failures	DID level 3 Control of accidents within the design basis	DID level 4 Severe accident management	DID level 5 Mitigation of the radiological consequences	Consequence



Examples of expert judgements in PRA
#1 Human reliability analysis

- Human error (e.g. omission of procedural step) probabilities (HEP) are often based on tabulated values, which can be modified with ”performance shaping factors” (PSF), such as quality of procedures, training, man-machine-interface, task complexity etc.

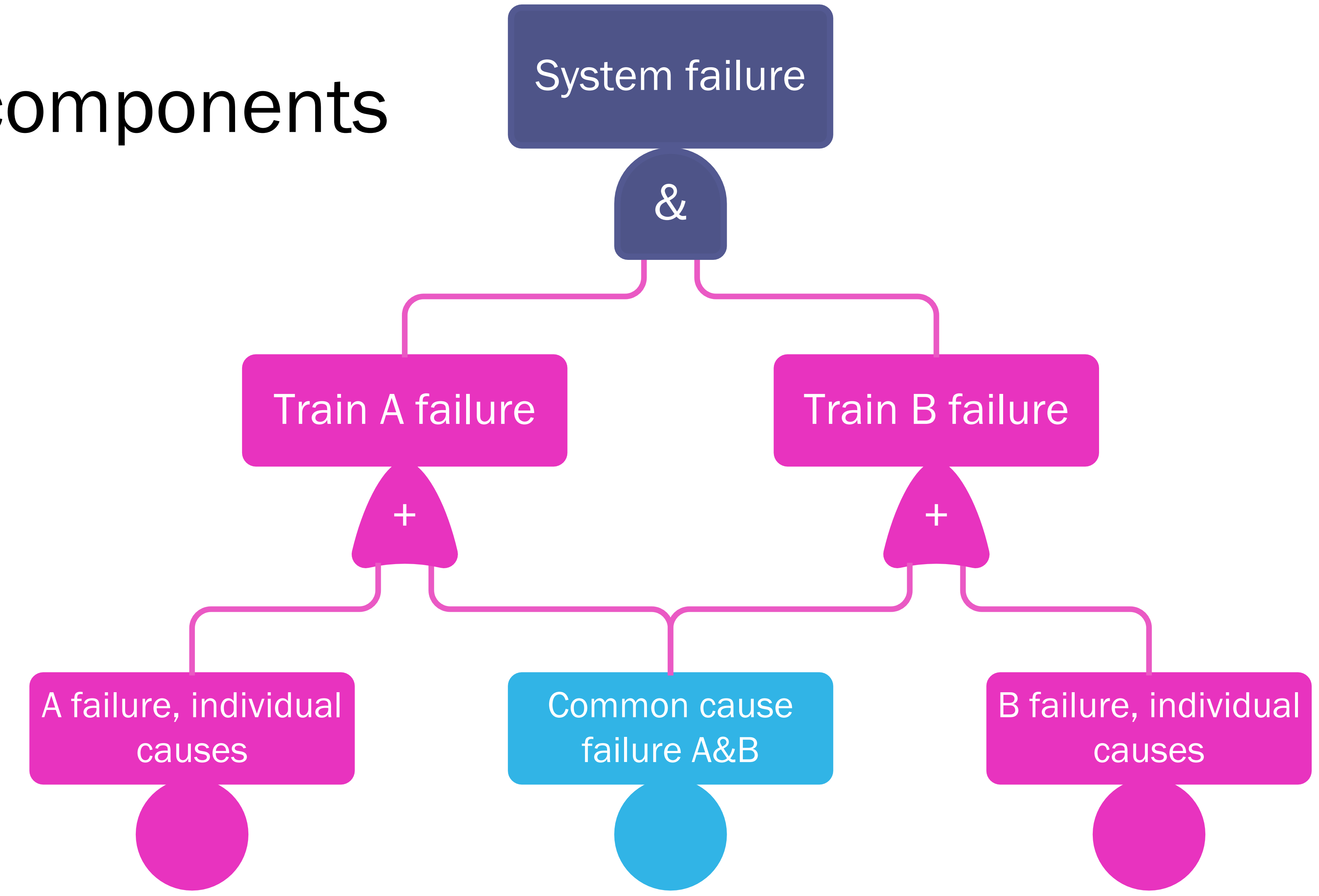
- Judgements
  - choice of method
  - definition of human failure events
  - qualitative task analysis
  - grading of performance factors
  - assessment of uncertainties

$$HEP = \frac{NHEP \cdot PSF_{composite}}{NHEP \cdot \left(PSF_{composite} - 1\right) + 1}$$

RISK PILOT©
YOUR RISK NAVIGATOR

Examples of expert judgements in PRA
#2 Common cause failures

- Types of dependences considered in PRA
  - support system dependences and other functional dependences
  - spatial dependences (e.g. in case of fire)
  - common cause failures (CCF) between identical, redundant components
- CCF is modelled by a parametric model
  - CCF probabilities are fractions of single failure probabilities
  - due to scarce data, generic parameter are used
- Judgements
  - identification of CCF groups (which should be postulated?)
  - choice of CCF model
  - choice of CCF parameters (e.g. representativeness issues)
  - assessment uncertainties



RISK PILOT©
YOUR RISK NAVIGATOR

Issues with expert judgements in PRA
#1 PRA is used in regulatory context

- Quality requirements
  - justification of the method
  - justification of judgements
  - transparency and traceability of assessments
  - uncertainty assessment

- Documentation requirements

- Assessments are subject to peer review

Issues with expert judgements in PRA
#2 Large size of the model & complexity of the PRA projects

- Number of model elements is huge
  - hundreds of event sequences
  - thousands of various probability estimates and related parameters

- PRA projects are rather complex to manage
  - resources needed for a complete (level 1 and 2) PRA is extensive
  - in addition, keeping and using the model “living” requires several man-years per year
  - coordination of various analysis activities
  - review process is also required

- Laborious to keep various parts of PRA (sub-models and all reports) up-to-date and consistent with each other

Conclusions

- Expert judgements are needed and extensively applied

- Traceability of judgements important
- Peer review important

- Rather simple mathematical models and elicitation procedures preferable
- Judgements that can be flexibly updated/revised are preferable
- Industry consensus desired property

- Continuous need for method improvements satisfying the regulatory requirements and practical project constraints => application specific developments
- Less attention is paid to the overall management of various expert judgements used in PRA

Jan-Erik Holmberg

jan-erik.holmberg@riskpilot.fi
+358(0)40 827 6656

RISK PILOT©
YOUR RISK NAVIGATOR