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Quantitative fire risk assessment to optimise investments into fire safety

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Workshop «An engineering perspective on risk assessment:
from theory to practice»

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Content

Objectives:

- Present cases where QRA has provided a significant benefit
- Use of different risk acceptance criteria
- Present convenient risk modelling techniques

Applications of QRA in practice:

1. Handling of dangerous goods for air cargo
2. Fire risk assessment at Zurich Airport's control tower

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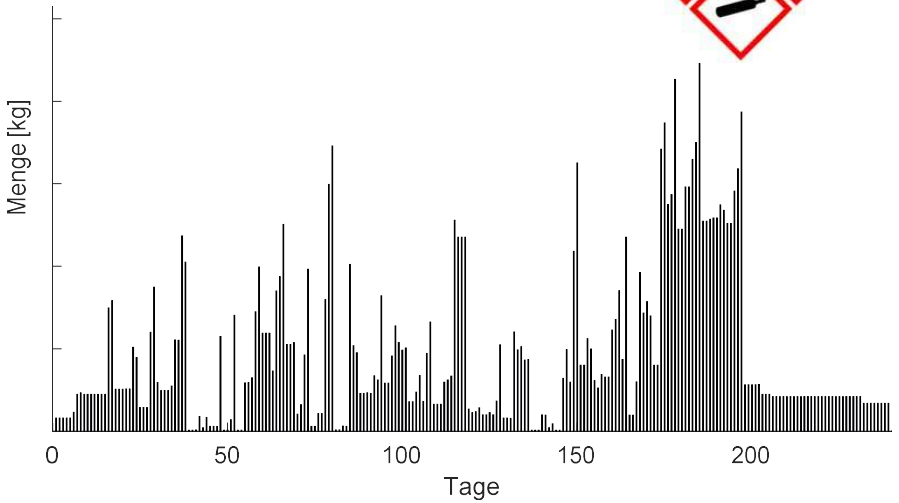
Handling of dangerous goods for air cargo

Air cargo handling

- Short temporary storage of goods (< 8 hours)
- Sometimes storage over night / weekend (> 8 hours)

Dangerous goods (DG) involved:

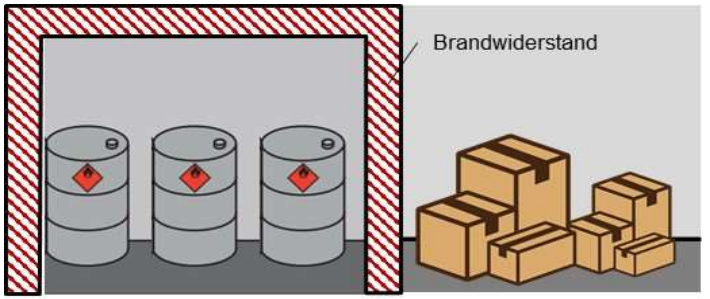
- Ca. 1.6% of the total volume
- High variability of the volume
- Dangerous goods complies with high packaging requirements according to IATA / ICAO
- No production, no refilling, no opening of the containment



Strict application of the prescriptive fire safety codes

Main requirements of Swiss Fire Safety codes (VKF):

- For flammable liquids stored for more than 8 hours
- Fire compartments (passive fire protection)
- … or reduced fire resistance of the fire compartment when using foam sprinkler
- No consideration of air cargo, e.g. high variability of volume, high packaging requirements, etc.



Consequences for the handling processes / building owner:

- Fire compartments make handling more difficult and unsafe
- Cargo processes (grouping of DG and non DG / labelling, etc.) are more difficult
- High investment costs (e.g. full protection of the whole area when using foam sprinklers)

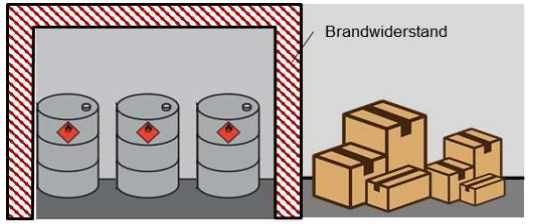
Alternative design solution

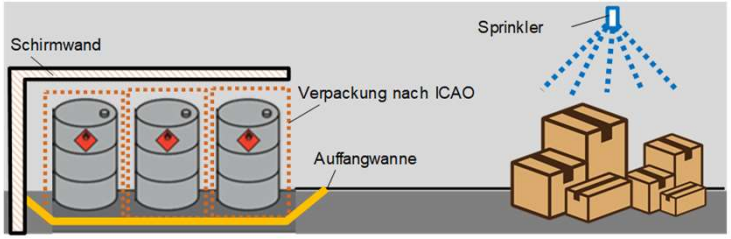
Swiss Fire Safety Codes allows to deviate from prescriptive fire safety requirements if:

- fire risk deviates clearly from «the standard case»
- safety objectives can be reached equivalently compared to the standard case

The alternative design solution:

- Life safety objectives complies with the prescriptive requirements
- Prevention of fire spread (economic consequences):
  - Separation of DG and non DG (> 3 m)
  - or non-flammable separation
  - Water sprinkler for non-DG
  - Drip trays to reduce spread of flammable liquids
  - Removal of ignition sources





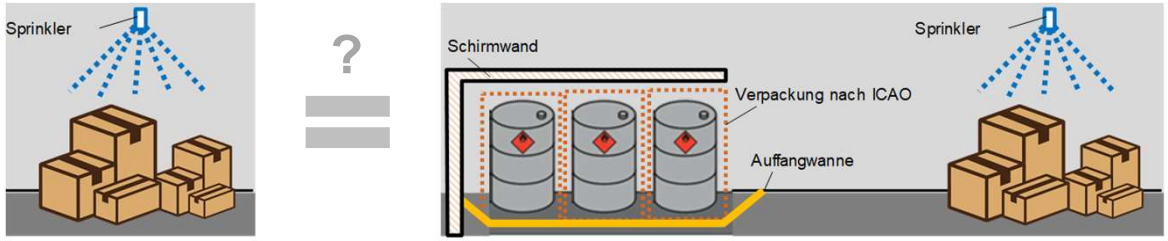
Proof of equivalence to the standard case

What is the standard case?

- Storage for a chemical industry (production and use are in the focus)
- Storage for non-DG (handling operations are in the focus)

How to proof equivalence to the standard case?

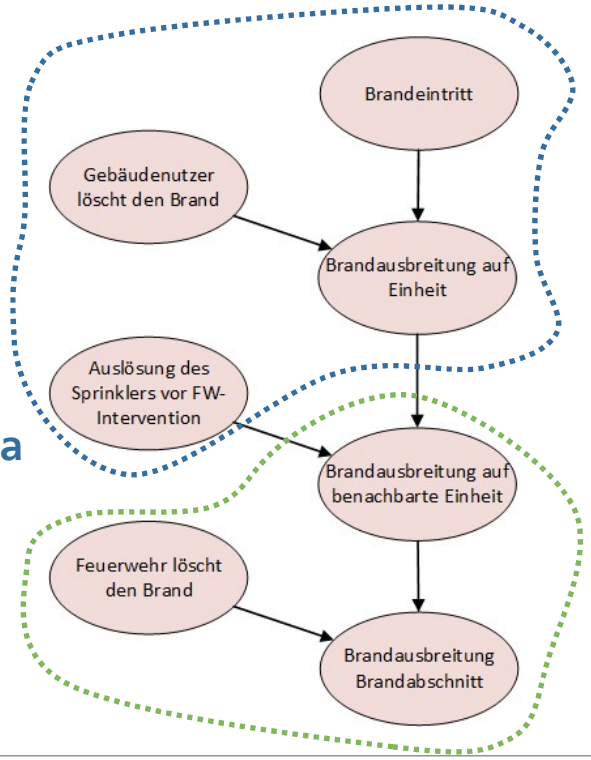
- Risk-based approach
- Quantification of the expected loss in monetary terms and comparing the alternative design solution with the standard case



Risk modelling

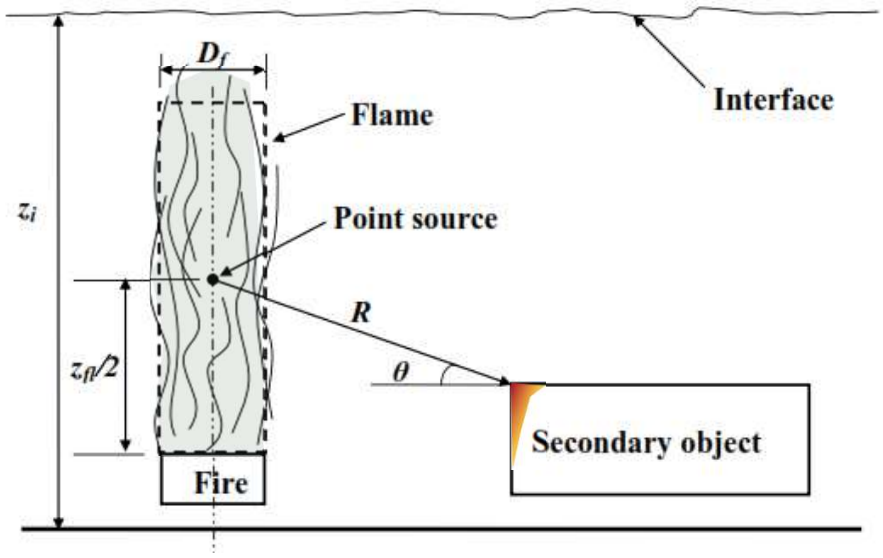
Modelling strategy

- Representation of all major risk influencing factors
- Fire development as chain of (fire spread) events influenced by suppression actions
- Every event has an occurrence probability
- Probabilities are assessed based on statistical data or by probabilistic physical modelling



Probabilistic physical modelling

– Fire spread to neighbouring objects…



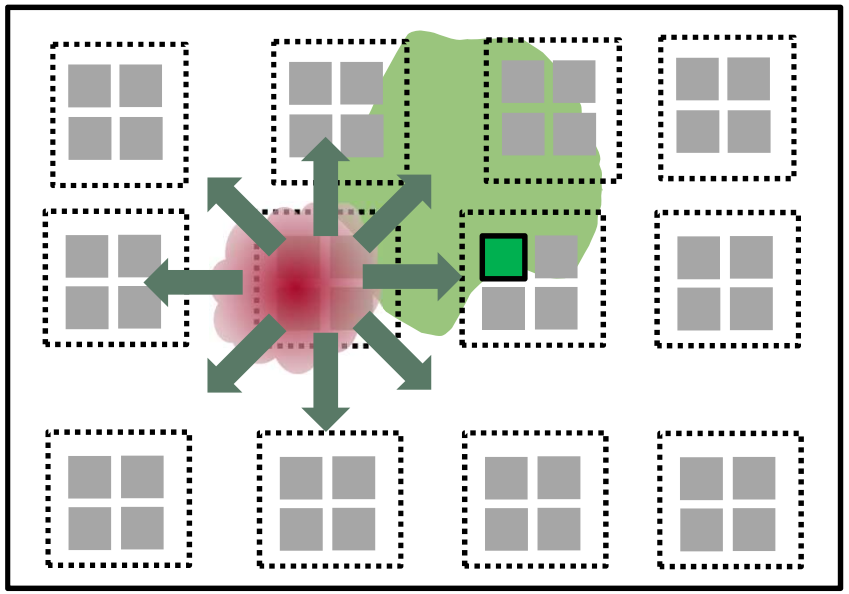
– Point source model to determine the fire ignition time of the secondary object
– Estimation of fire spread velocity from staple to staple

Probabilistic physical modelling

Fire spread to neighbouring objects and leakage of containment

- Evaluation weather DG participate to the fire or not (location fire / DG, probability of presence)
- Estimation of the pool size when a fire is spreads to DG

⇨ **Development of the fire size over time**



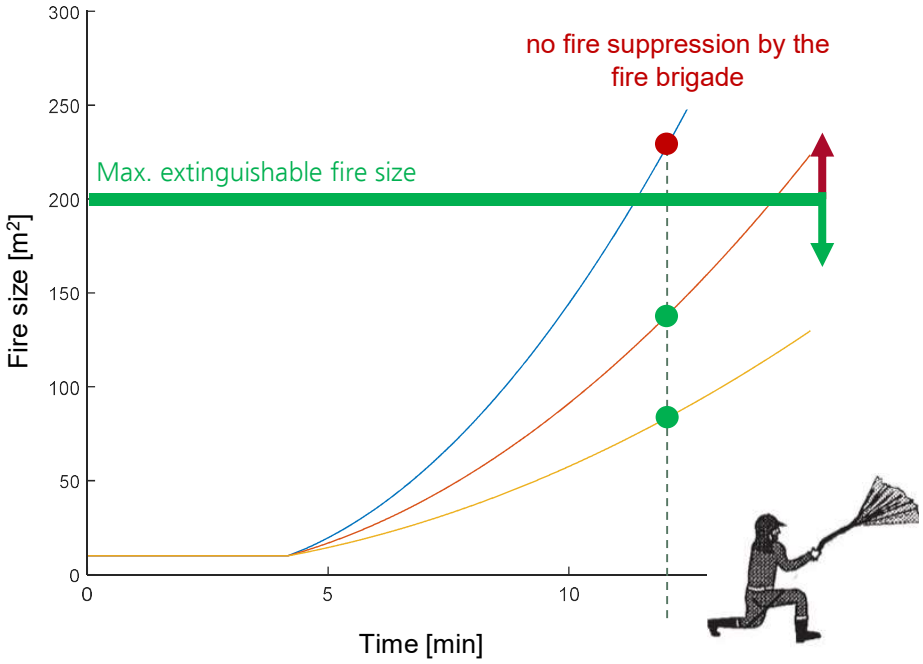
Probabilistic physical modelling

Fire brigade intervention

- Time of intervention
- Maximal fire size that is extinguishable by the fire brigade

Probabilistic parameters:

- Heat release rate
- Fire spread velocity
- Volume of flammable liquids
- Fire brigade intervention time (including detection, alarm and response time)
- Maximal extinguishable fire size
- Location of the fire



Bayesian Networks

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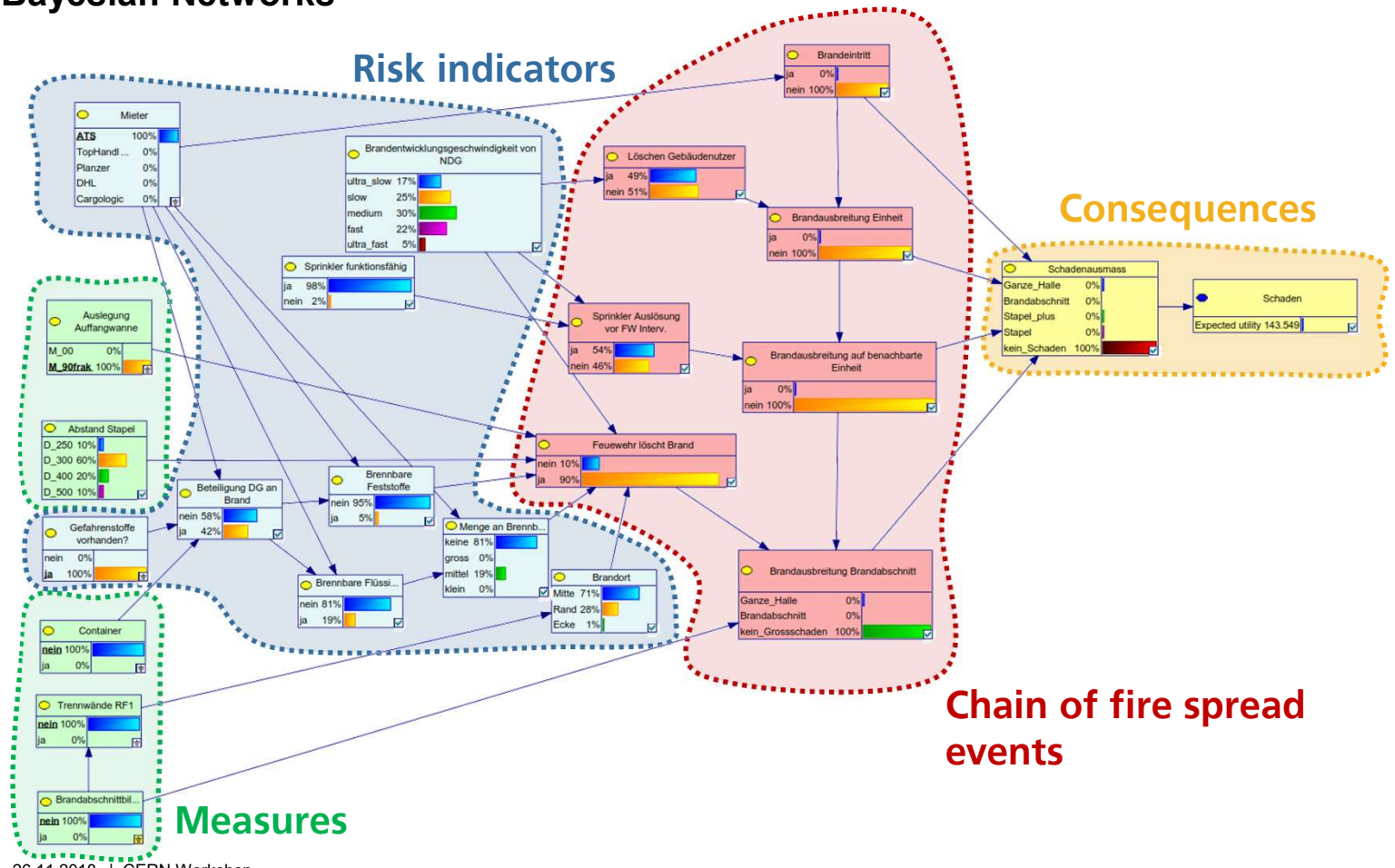
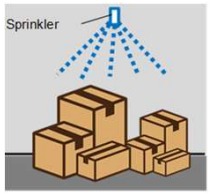
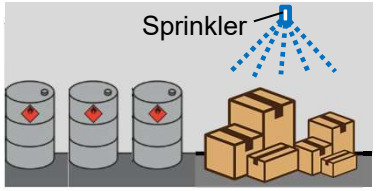


Risk evaluation

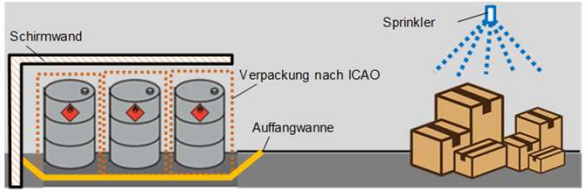
Standard case without DG

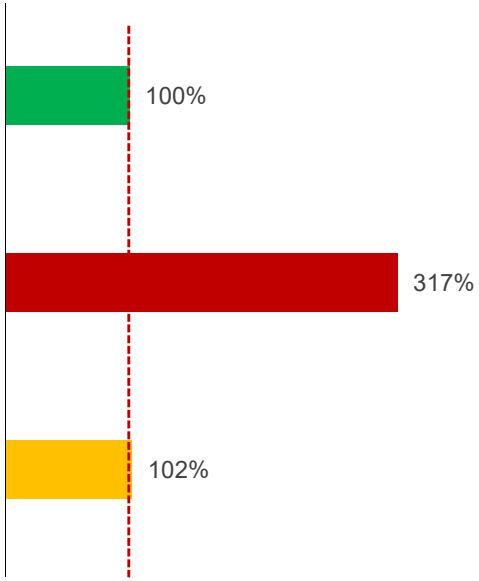


Reference case with DG and without additional fire safety measures



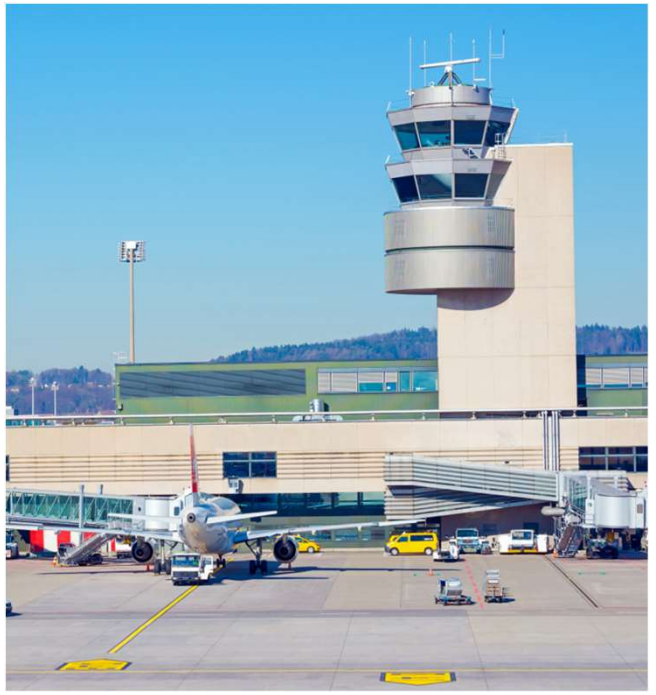
Reference case with DG and with additional fire safety measures





Equivalence could not be reached… but additional measures to reduce the risk to the standard case (e.g. -2%) are disproportionate.

Fire risk assessment at Zurich Airport’s control tower



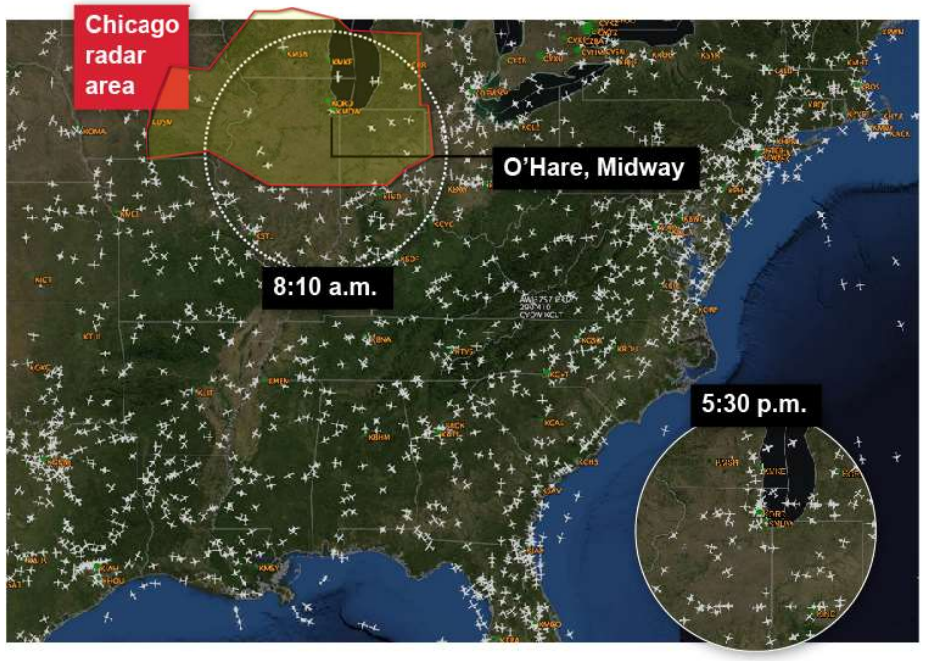
Airport control tower fires

Air traffic control tower fires

- Unlikely (ca. 3-4 cases in the last 15-20 years) and with minor consequences

… but Chicago Aurora Fire (2014)

- Arson at radar and network facilities
- Most of airplanes had to be diverted
- 18 days business interruption



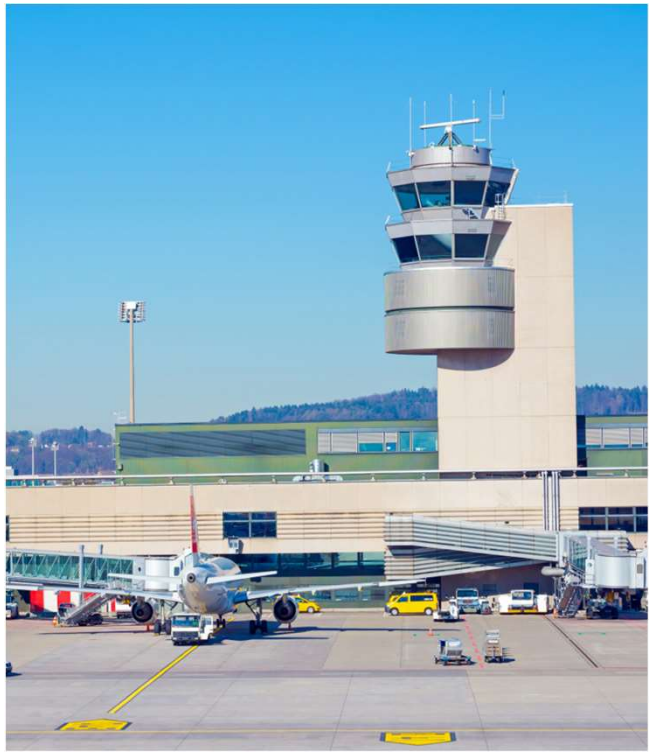
Zurich Airport control tower

Skyguide (Swiss air navigation service provider)

- Landing and take-off guidance for Zurich Airport
- Number of flights: 740 per day
- Passengers: 80’0000 per day
- Cargo: 1’300 t per day
- The building meets the fire safety regulations of the Swiss Association of Cantonal Fire Insurances

In case of a shutdown

- Skyguide is able to land flights safely
- Normal flight operations cannot be maintained
- Focus of the study: Economic losses for Skyguide and business area Zurich



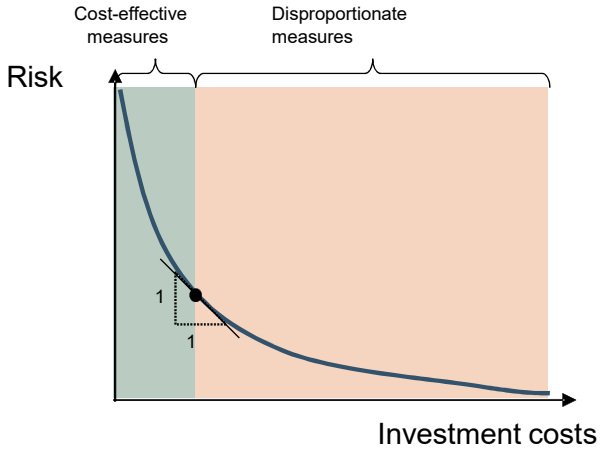
Decision problem

A new tower will be build in 15 years… until then,
what to do with the present one?

- Try to reduce risk to zero? ⇨ Redundant Tower ⇨ High costs
- Do nothing? ⇨ unacceptable high risk are possible
- Or something in between?

Measures are required,
whose costs are reasonable in relation
to the achieved risk reduction

$$\frac{Risk\ reduction}{Investment\ costs} \geq 1$$



Risk screening

Main focus:

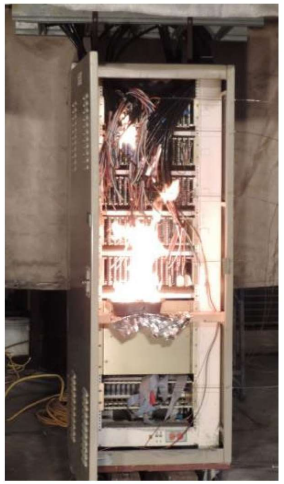
– IT-System located in two server rooms

Experts interviews

– Aim: Estimate the danger of fire ignition of technical equipment and its potential consequences

Risk indicators:

– Number of components per rack
– Age and planed service life ⇨ Fire ignition rate
– Separation to neighbouring rack (barrier) ⇨ Fire spread
– Estimate of duration of reactivation
– Redundancies of the components and its location ⇨ Consequences

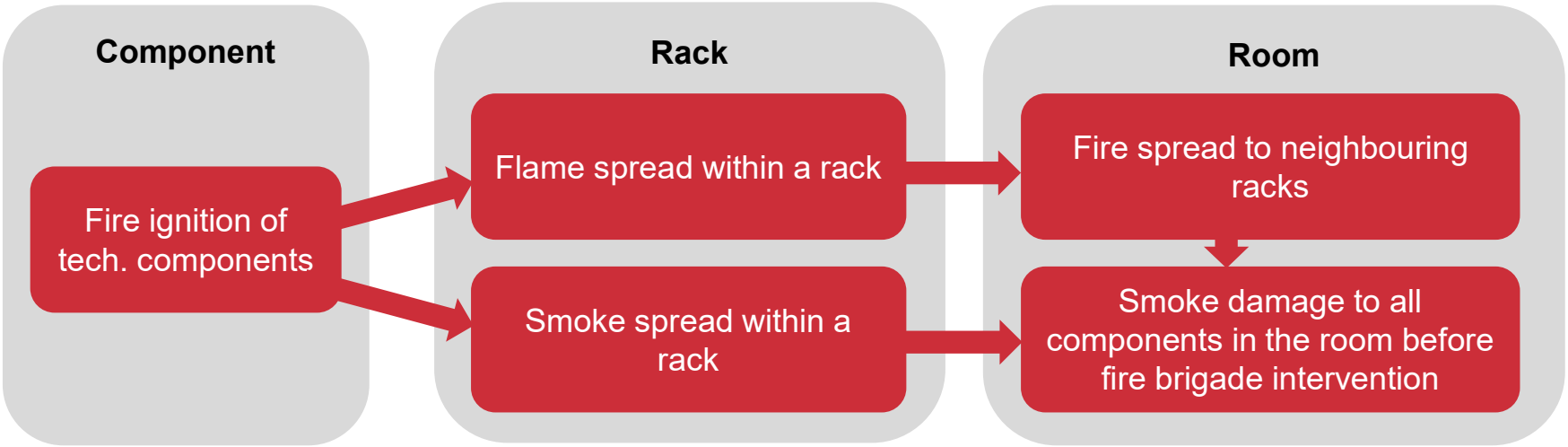


[NUREG/CR – 7197]

Risk modelling

Modelling fire and smoke spread and its consequences:

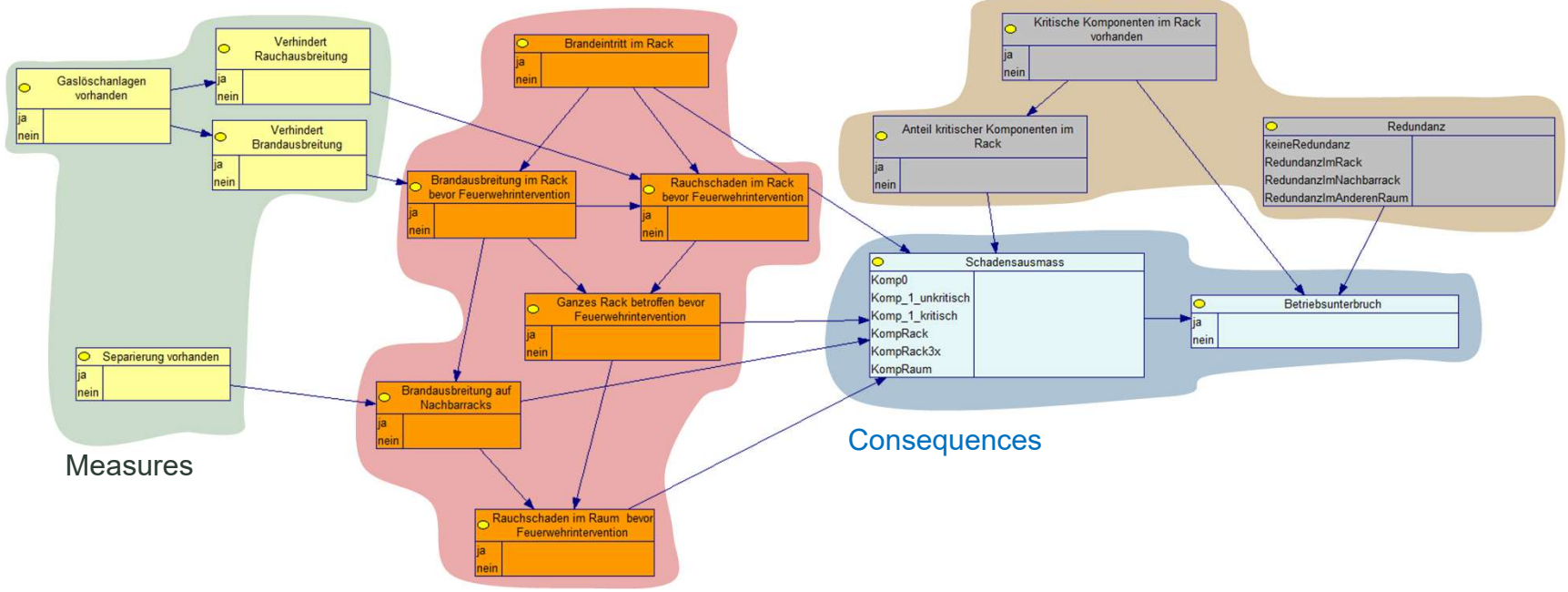
- Damage by exposing electrical devices to heat
- Deposition of smoke on electrical devices causing a short circuit



Risk modelling

Bayesian Networks

Fire in a rack

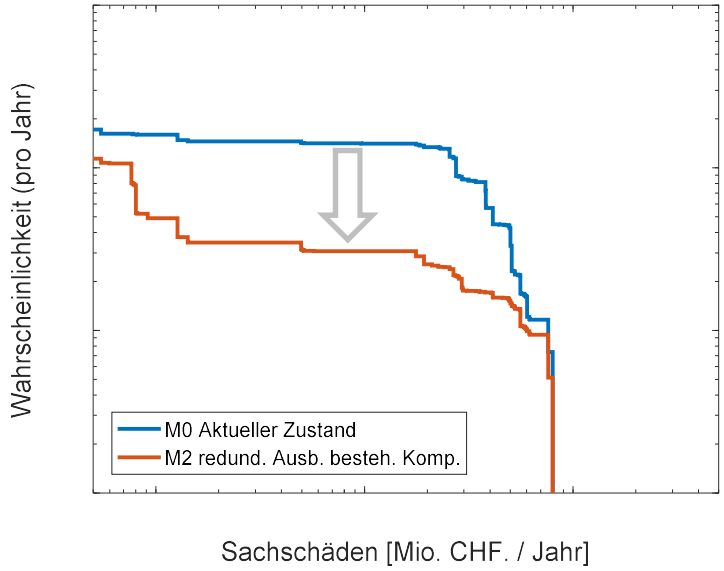


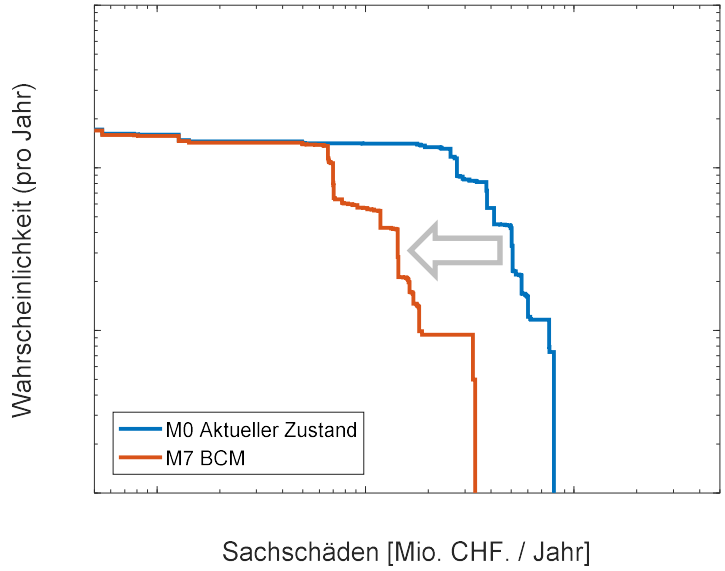
Evaluation of fire safety measures

Reducing the probablity of events and / or reducing the potential consequences

(e.g. by fire barriers or fire suppression measures)

(e.g. by improving Business Continuity Management)





Evaluation of fire safety measures

A measure is cost-effective if an investment results in at least the same monetary risk reduction

$$\frac{Risk\ reduction}{Investment\ costs} \geq 1$$

⇨ Allowing a prioritisation of measures…
⇨ and exclusion of non-efficient fire safety measures

Measures		ratio
M0	Actual State of the system	
M1	Measure 1	0.2
M2	Measure 2	16
M3	Measure 3	0.04
M4	Measure 4	3
M5	Measure 5	0.3
M6	Measure 6	0.4
M7	BCM (reduction of down time)	1
M8	Independent Emergency-Tower	1

max. investment costs for $\Delta R/\Delta I = 1$

→ 34'000 CHF

→ 48'000 CHF

Conclusions / recommendations for practical use of QRA

- QRA can solve problems which are difficult to handle when using a traditional approach (e.g. PBD based on worst-credible cases)
- The choice of an acceptance criterion should be made in accordance with legal requirements and with the stakeholder perspective.
- QRA can be used to obtain reliable, robust and resilient systems with a balanced ratio between investment costs and risks.
- Use a combination of different probabilistic methods such as Bayesian Networks, Event Trees, MC, FORM, Subset Simulation, PCE, etc.
- Try to be as «holistic» as possible: include all major risk influencing factors, especially the fire brigade intervention.
- «Better to be roughly right than precisely wrong.»

