Detailed Risk Analysis

by

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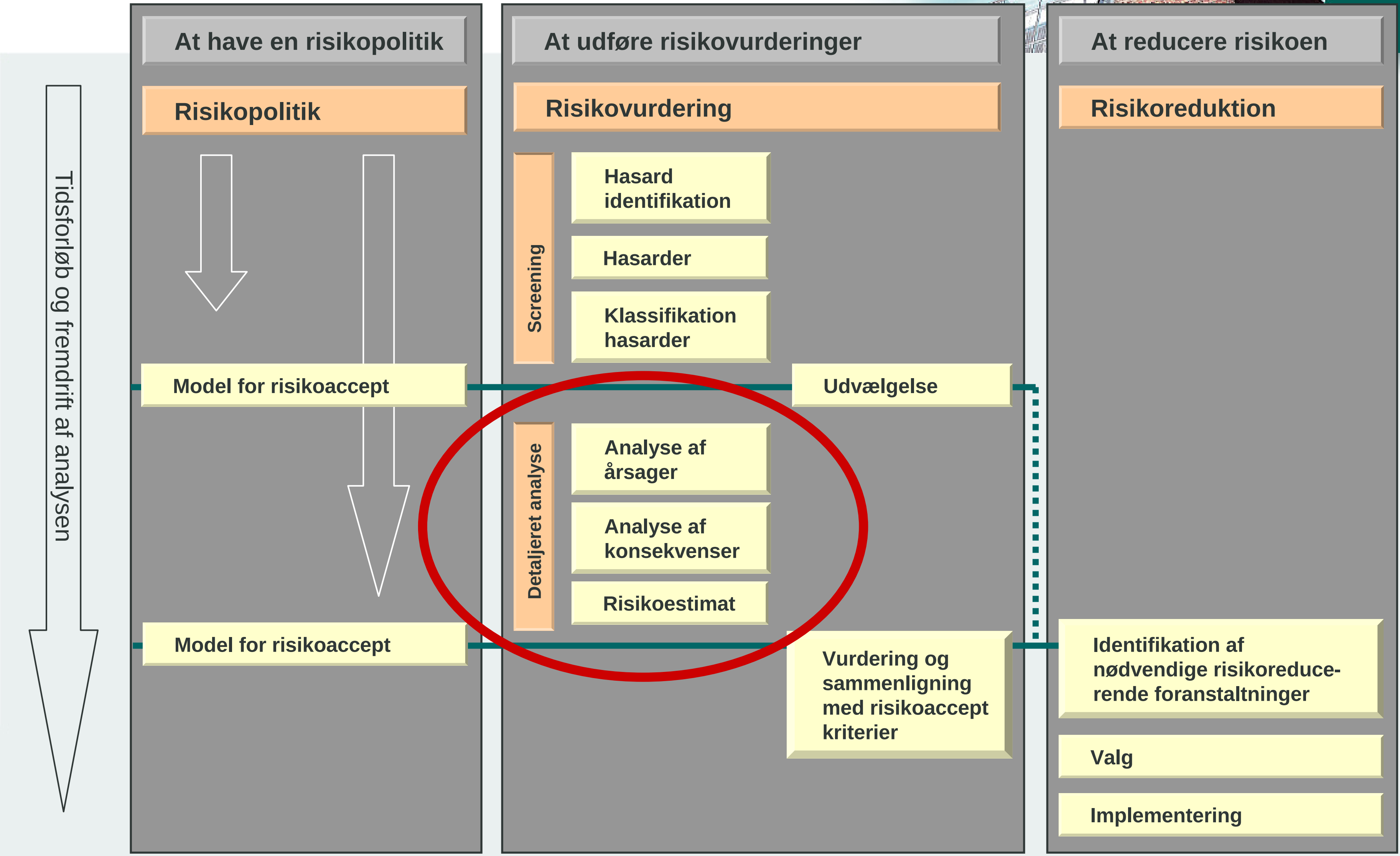
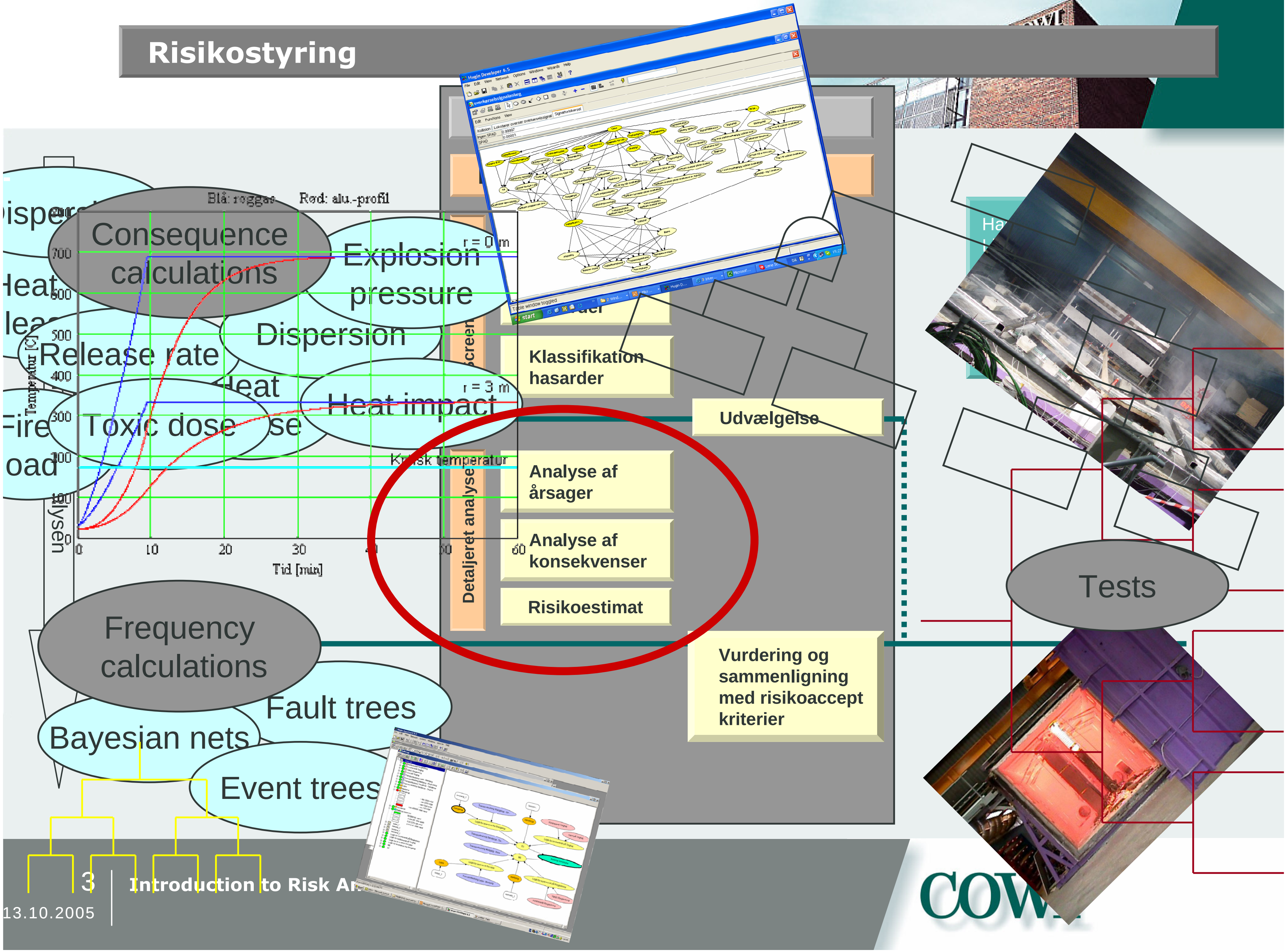
Risikostyring



Risikostyring



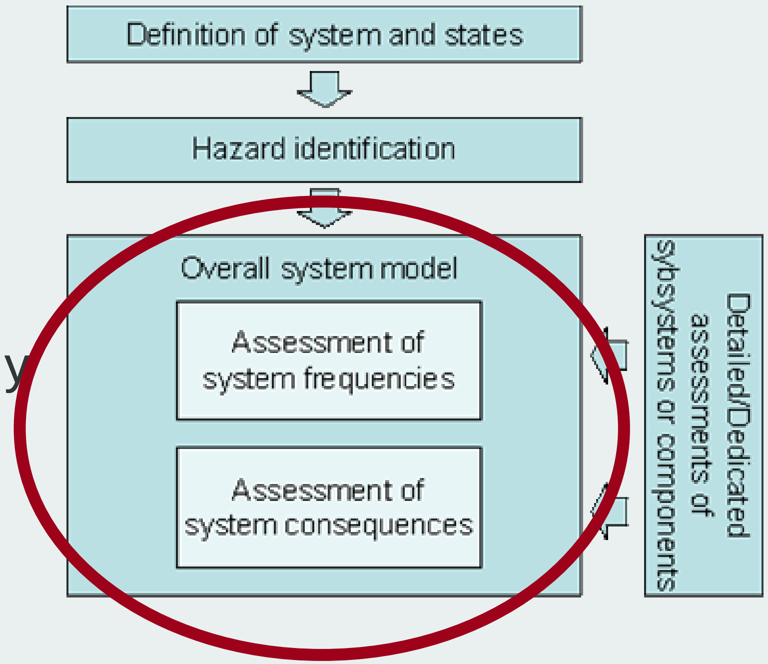
Detailed Risk Analysis

- The components in the detailed risk analysis are in general terms:
  - Causal analysis
  - Consequence analysis
  - Risk estimation

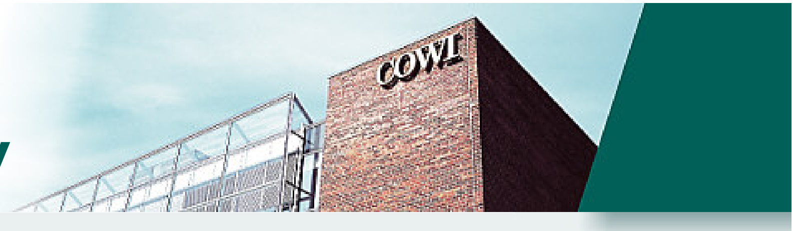
  } Can be combined in one analysis (causal analysis and consequence analysis)
- When is detailed risk analysis necessary?
  - Particular hazards cause concern and are not fully clarified in screening
  - Choice between alternatives for which it is not obvious which one to choose
- It is important to keep the focus of the analysis on the needed end result and make the necessary level of detailing for decision making

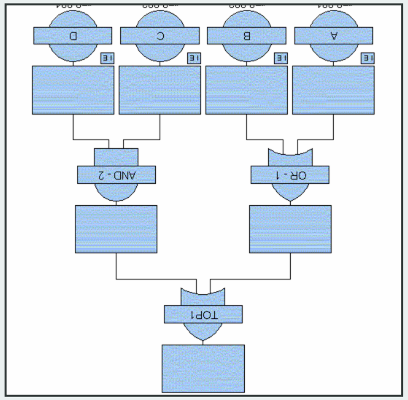
Quantitative Techniques for Detailed Risk Analysis

- Event Tree Analysis
- Fault Tree Analysis
- Cause-Consequence Diagrams
- Safety Barrier Diagrams (semi-quantitative)
- Failure Modes, Effects and Criticality Analysis
- Bayesian Probabilistic Networks
- Influence Diagrams



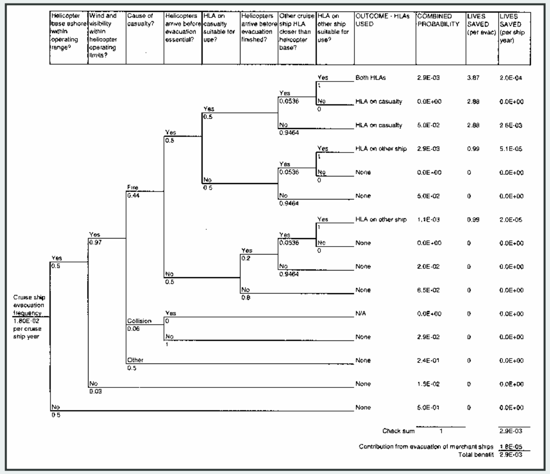
Detailed Risk Analysis - Traditionally





Fault tree analysis

Calculation of
the probability of
the initiating fault



Event tree analysis

Detailed analysis of the consequences

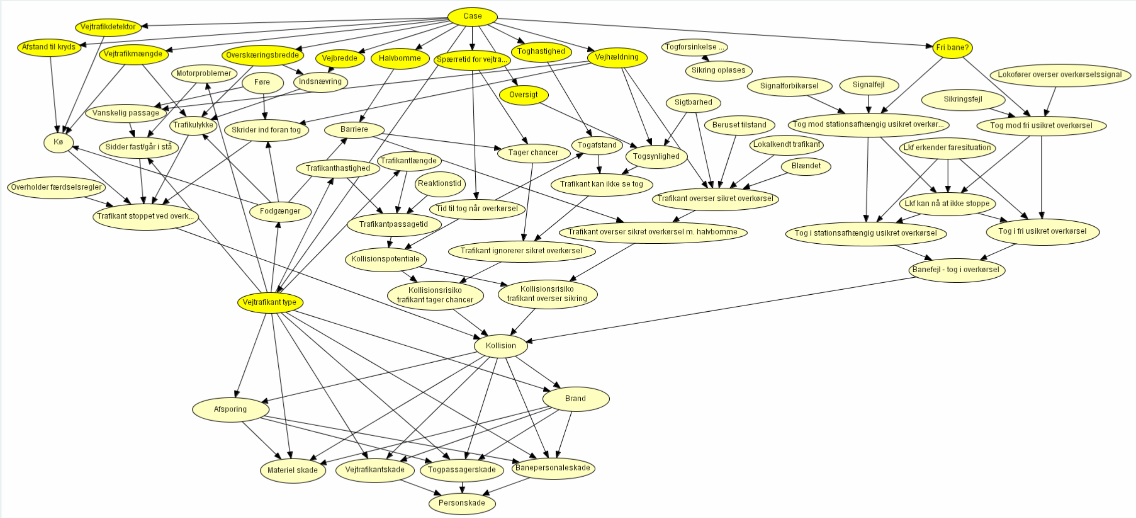
initiating fault — hazard development — hazard development — hazard development — Unwanted consequence

TIME

Detailed Risk Analysis

Bayesian network analysis

Calculation of the probability of unwanted consequences



COWI

Level crossing

As observed by the train driver

As observed by the road user

Automatic warning system with half barriers

Decision Parameters

- Toghastighed
- Oversigtsforhold langs banen
- "GIV AGT"-mærke
- Vejhældning umiddelbare før og efter overkørslen
- Afstand til større vejkryds
- Vejtrafikmængden
- Overkørselsbredden
- Vejbredden før og efter overkørslen
- Vejtrafikanttypen
- Lukketid for vejtrafik (kun sikrede overkørsler)
- Typen af sikringsanlæg (kun sikrede overkørsler)
- Vejtrafikdetektor (kun sikrede overkørsler)
- Afhængigheden af stationssignaler (kun sikrede overkørsler)

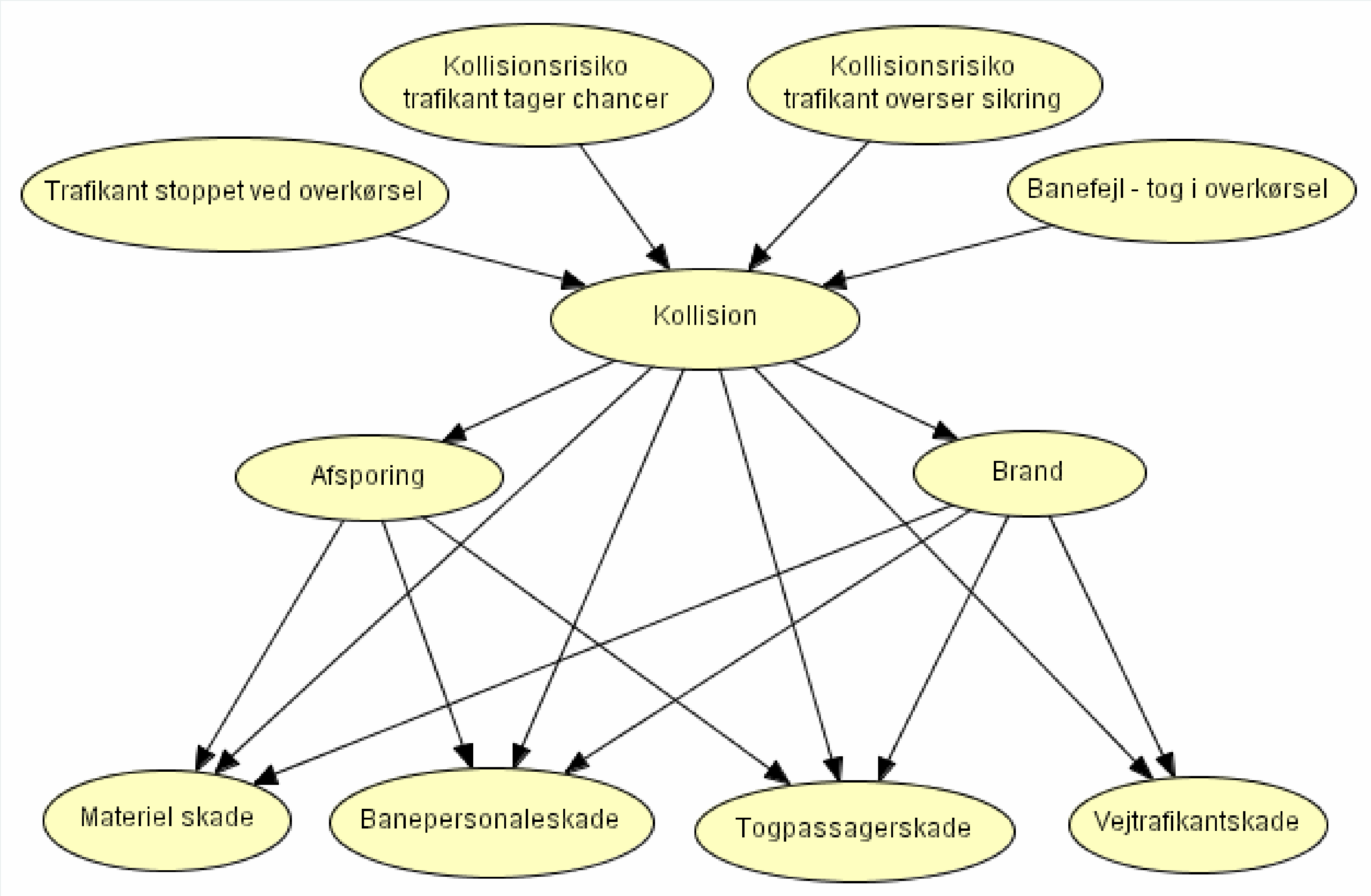
Cost-Benefit Calculations for Upgrade Decision

Ved vurdering af den samfundsmæssige nytte indgår følgende forhold:

- **Uheld i overkørsler**. Et forbedret sikringsanlæg i en overkørsel vil betyde en reduktion i antallet af uheld, dvs. en reduktion i det forventede antal personskader og omfanget af materielle skader
- **Transporttid for togpassagerer**. Såfremt en ny sikkerhedsforanstaltning tillader en øget toghastighed, betyder det en kortere transporttid
- **Ventetid for vejtrafikanter**. Den alternative sikring af overkørslerne medfører en ændring i ventetiden for vejtrafikanterne. På grund af afstandsforholdene kan det for nogle alternativer betyde en betydelig forøgelse af ventetiden. Dette kan også friste nogle trafikanter til at begå usikre handlinger, der har indflydelse på hyppigheden af uheld
- **Etableringsomkostninger** er omkostninger til etablering af nye sikringsanlæg, dvs. BUES-1/2-bomanlæg, niveaufri skæringer samt omkostninger til etablering og/eller ændring af vejanlæg eller vejforhold
- **Vedligeholdelsesomkostninger**. Disse omkostninger varierer for de forskellige alternativer.

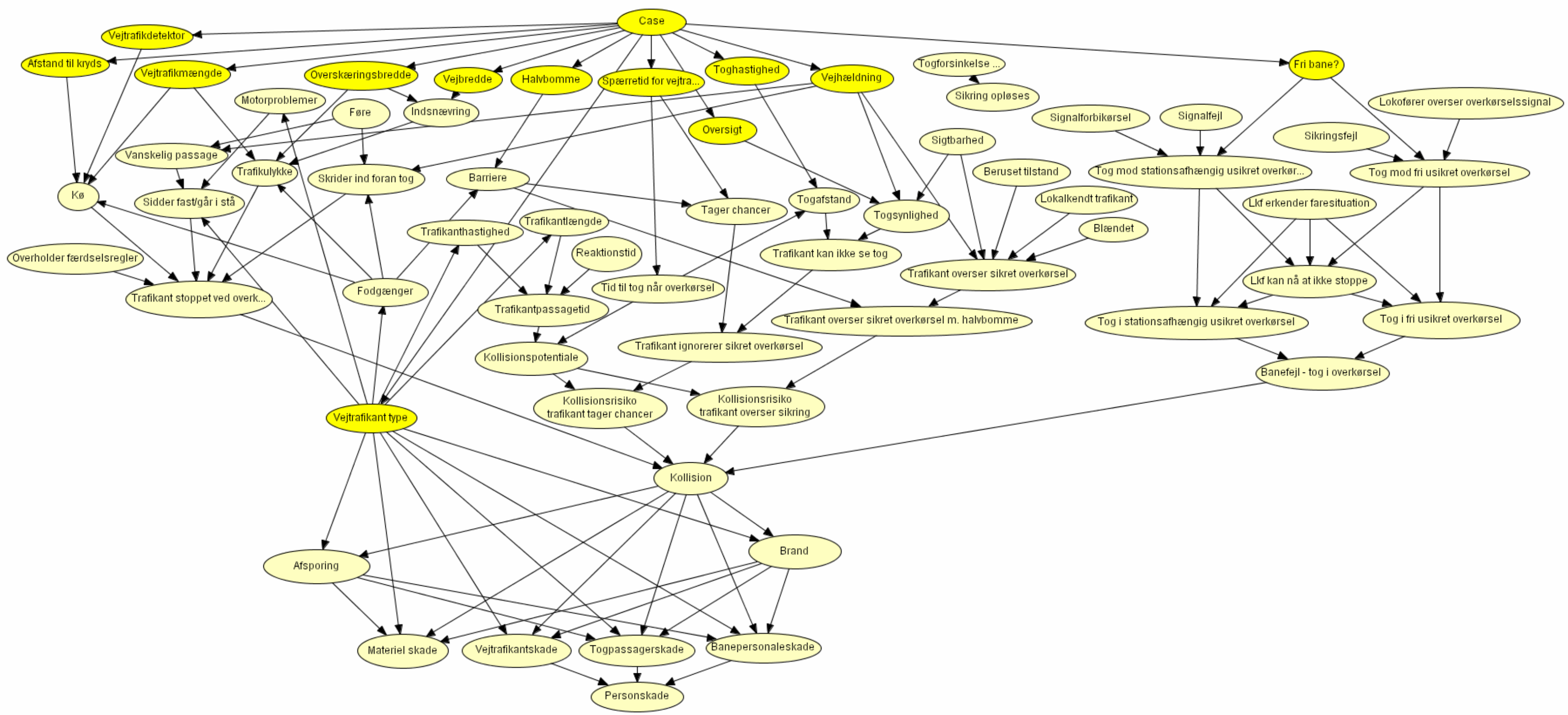
Level Crossing – Basic Risk Model

Risk analysis for railway crossing conditioned on meeting situation



Level Crossing – Risk Analysis

Risk analysis for railway crossing conditioned on meeting situation



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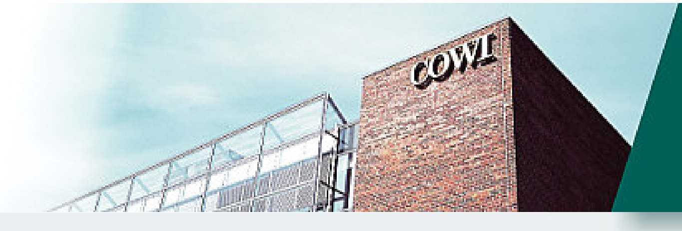
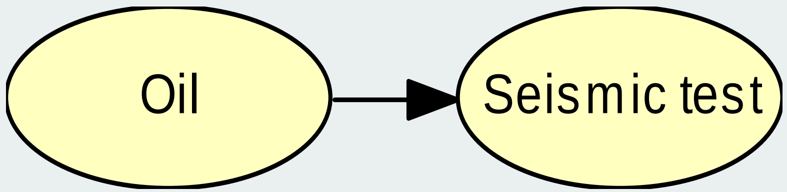


- What is a Bayesian Network?
- What is a fault tree?
- What is an event tree?
- Why use Bayesian Networks?

Bayesian networks are

- A class of probabilistic models

- Based on
  - Classical probability theory
  - Graph theory
  - Decision theory

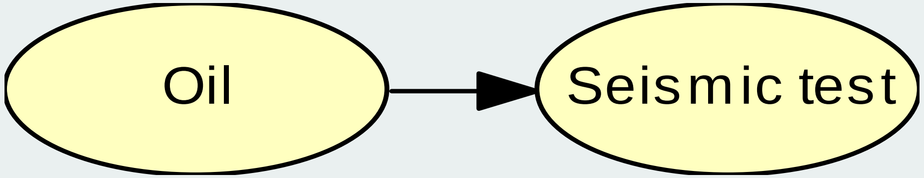


States	P[O]
Dry	0.5
Medium	0.3
Wet	0.2

- Elements
  - Nodes / Variables
  - Links
  - Probability tables (conditional)

P(S|O)	Dry	Medium	Wet
Positive	0.1	0.3	0.5
Diffuse	0.3	0.4	0.4
Negative	0.6	0.3	0.1

Simultaneous and marginal probability tables



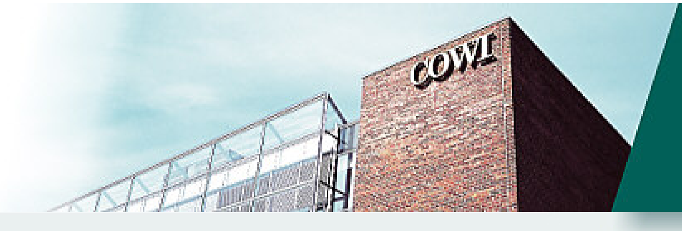
P(S|O)	Dry	Medium	Wet
Positive	0.1	0.3	0.5
Diffuse	0.3	0.4	0.4
Negative	0.6	0.3	0.1

States	P[Oil]
Dry	0.5
Medium	0.3
Wet	0.2

$$P(s_i, o_j) = P(s_i | o_j) P(o_j)$$

P(S,O)	Dry	Medium	Wet	P(S)
Positive	0.05	0.09	0.1	0.24
Diffuse	0.15	0.12	0.08	0.35
Negative	0.3	0.09	0.02	0.41
P(O)	0.5	0.3	0.2	1

Propagation of evidence



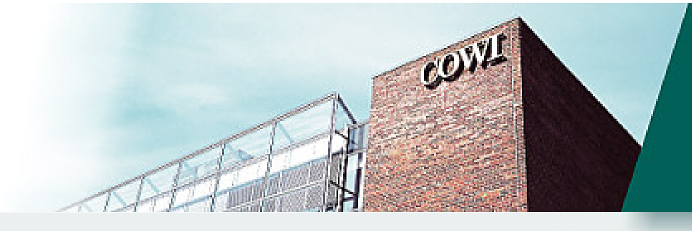
- Evidence = Observation of a variable
  - Positive
  - Negative
  - Likelihood

- Propagation= updating of the other variables

- Bayes rule: Example:

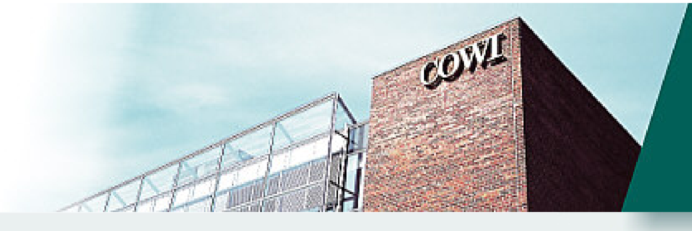
$$P(O \mid S) = \frac{P(S \mid O)\, P(O)}{P(S)} \qquad P(o_1 \mid s_1) = \frac{P(s_1 \mid o_1)\, P(o_1)}{\sum_j P(s_1, o_j)} = \frac{0.1\ \ 0.5}{0.24} = 0.208$$

- Evidence can be entered on several variables at a time



Bayesian networks, background

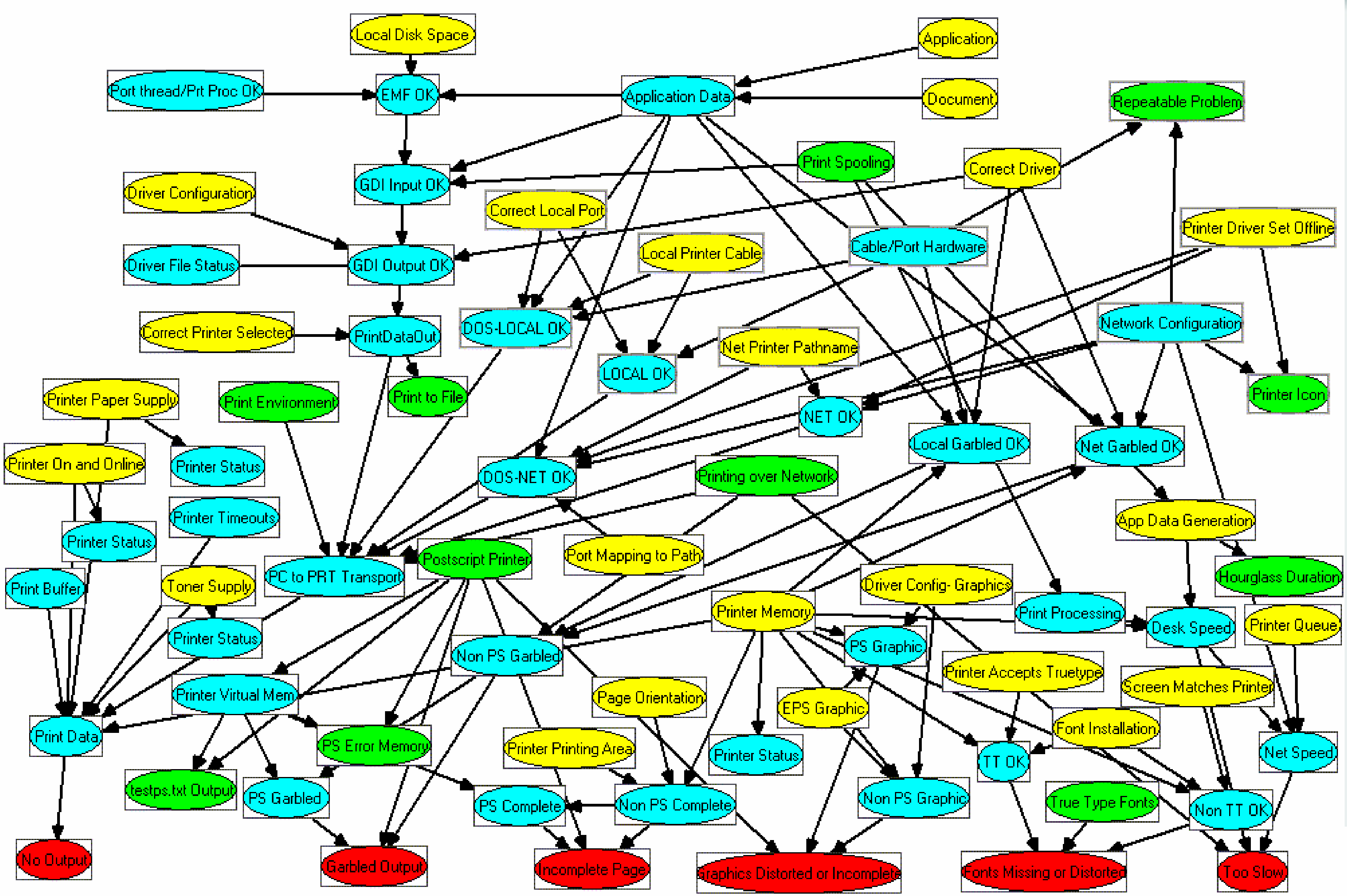
- Originally developed within artificial intelligence
  - Extension of logic
  - Started in the late 1980s
- Technology transfer to apply Bayesian networks in the field of risk and reliability analysis etc.
- The research field is populated by computer scientists and statisticians
  - Strong research group in Aalborg, at Microsoft, ...



Applications

- Medical diagnosis
  - Modelling of relationship between symptom, test results and disease
- Hardware troubleshooting
  - printers
- Decision problems within animal breeding
- Telecom
- Pattern recognition (image analysis)
- Offshore
- Etc.

Print trouble-shooter (Windows '95)

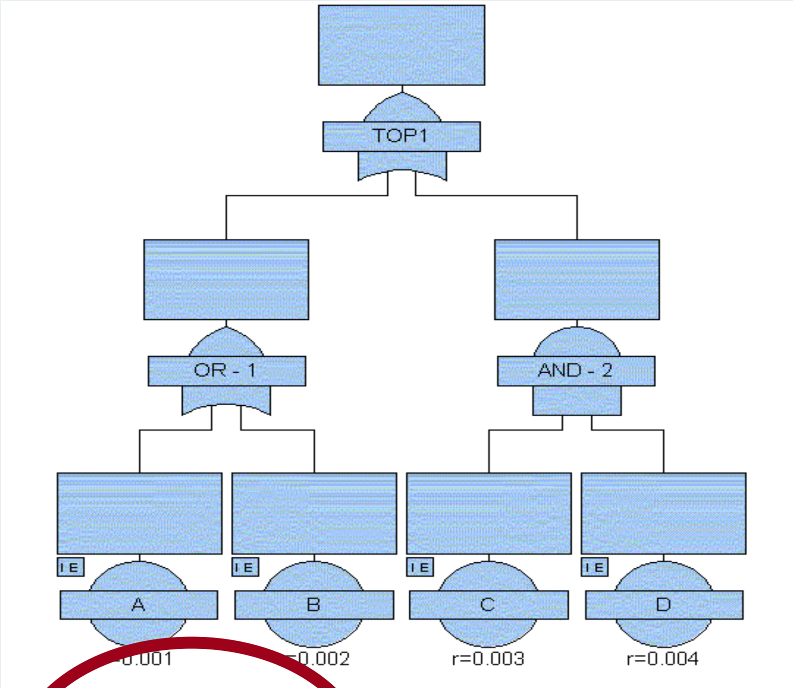


Estimation of conditional probabilities for BPNs

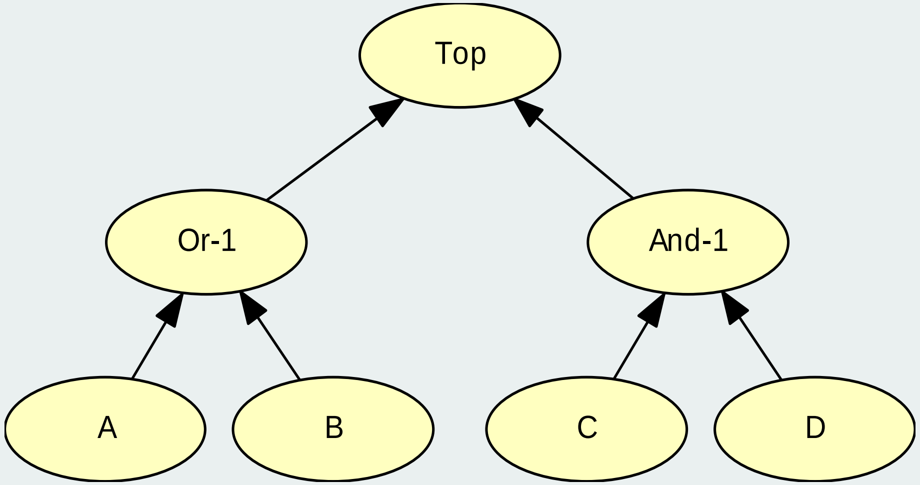
- The conditional probabilities have in a conservative manner been estimated based on:
  - calculation
    - failure for structural components are evaluated using methods of structural reliability theory
    - mechanical failures are to some extent evaluated using fault tree analysis
  - experience data
  - failure rate data
  - extrapolation of failure rate data relevant for similar situations
  - engineering judgement
  - independent expert reviews
    - workshop sessions
    - individually

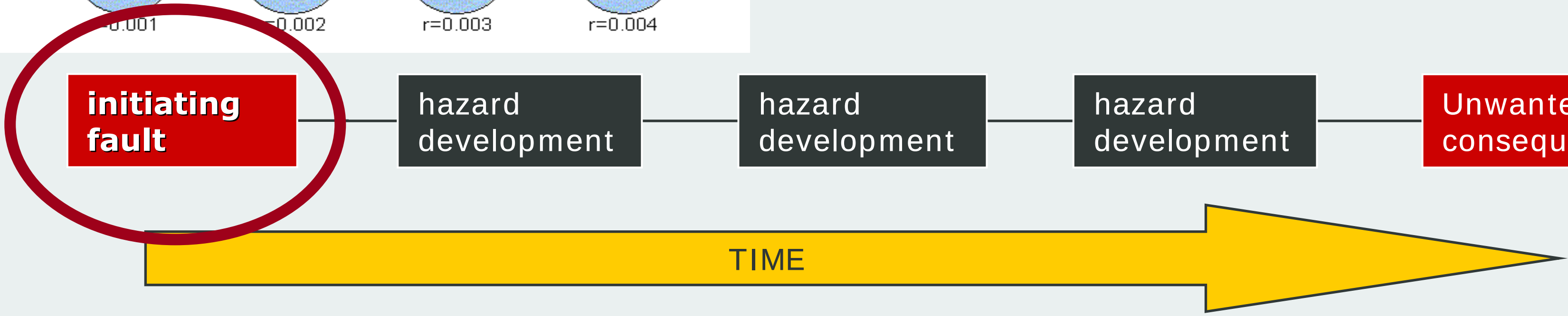
Fault trees

Fault tree



Bayesian network modelling fault tree

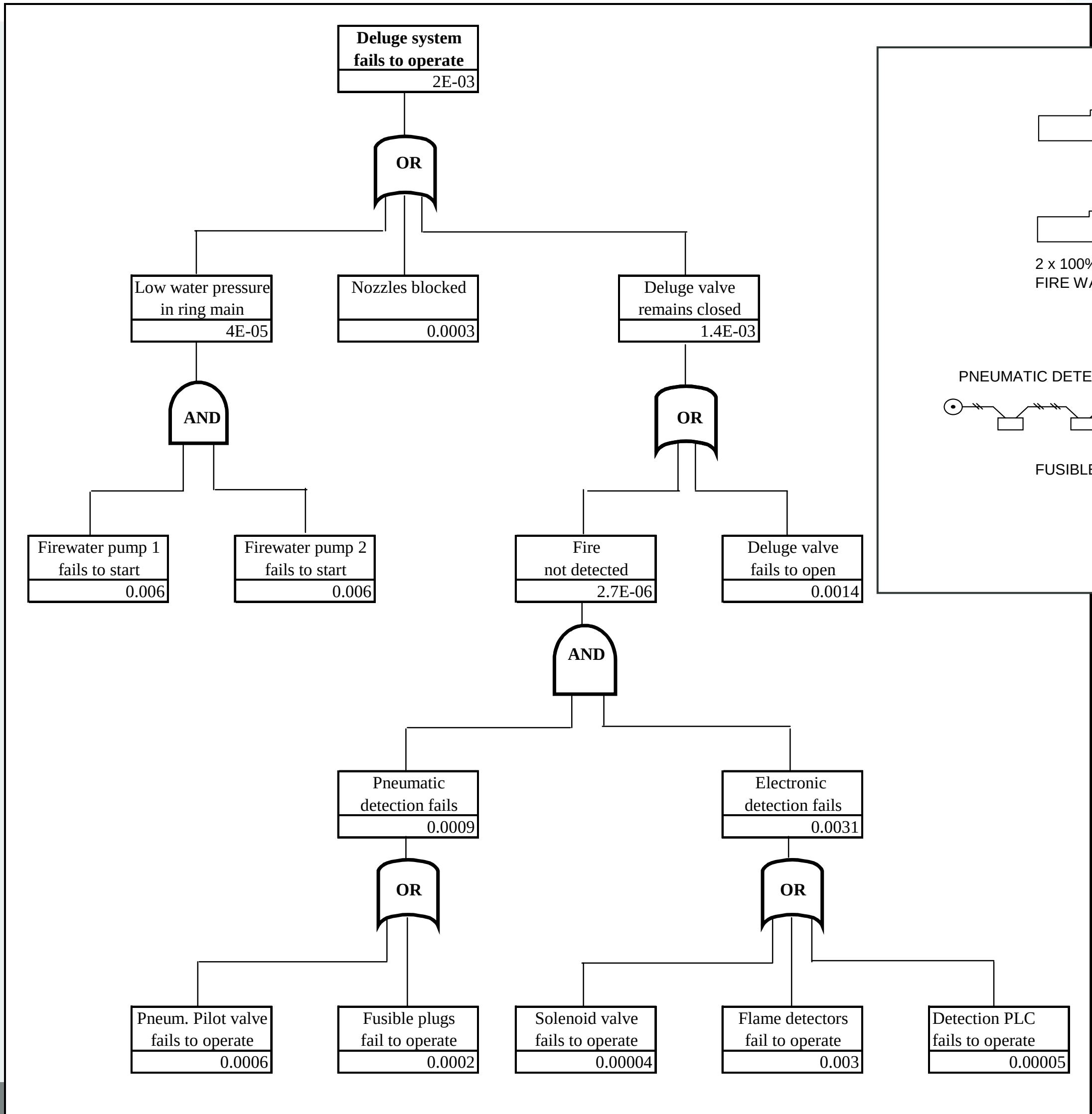


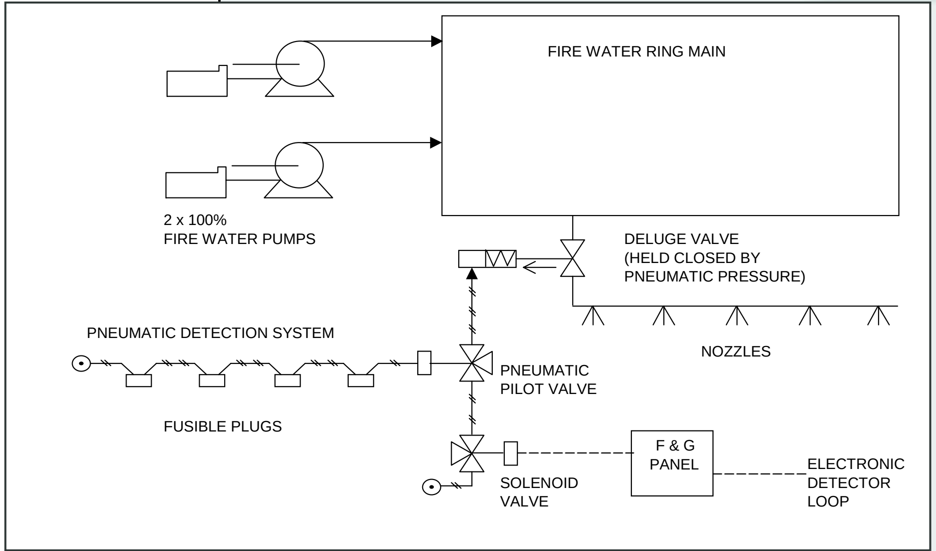


Fault tree

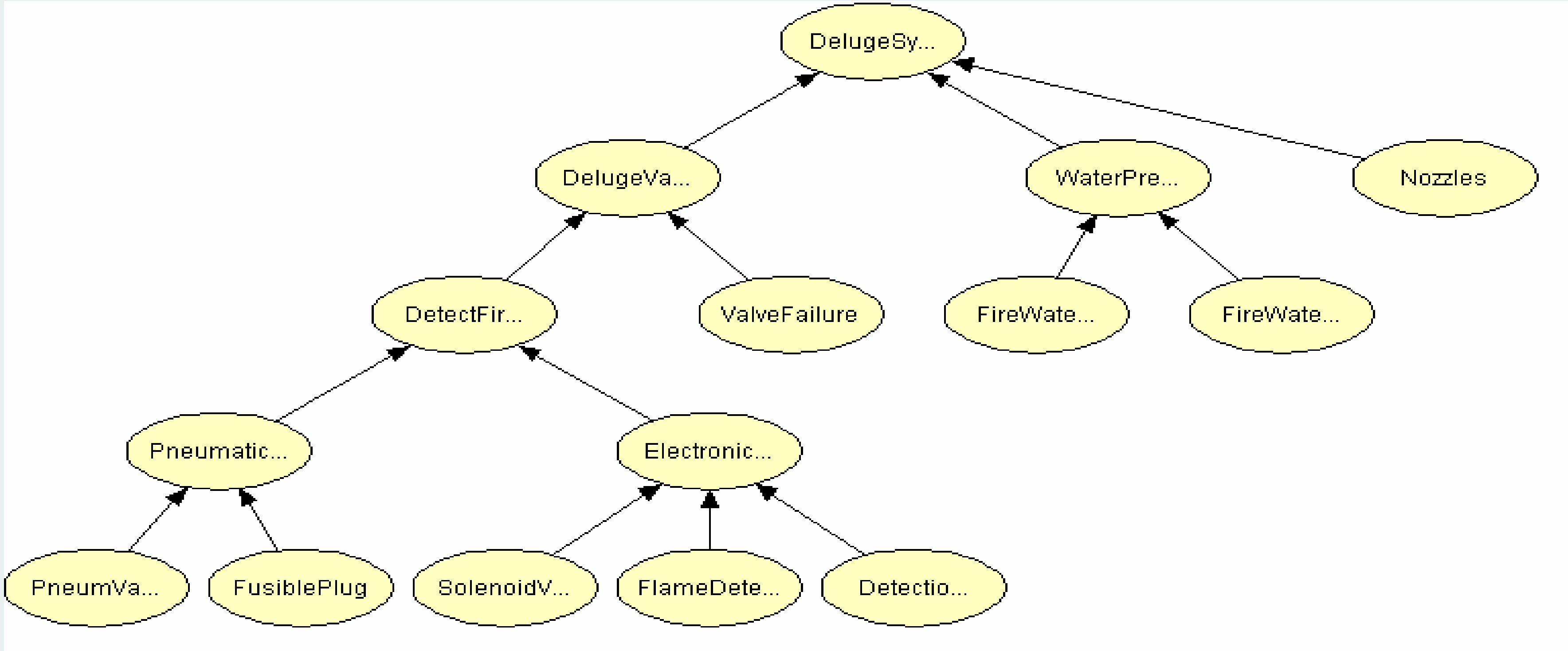
- Fault tree analysis is a "deductive" approach, which starts from an effect and aims at identifying its causes. Therefore a Fault Tree is used to develop the causes of an undesirable event. It starts with the event of interest, the top event, such as a hazardous event or equipment failure, and is developed from the top down.
- The Fault Tree is both a qualitative and a quantitative technique. Qualitatively it is used to identify the individual scenarios (so called paths or cut sets) that lead to the top (fault) event, while quantitatively it is used to estimate the probability (frequency) of that event.
- A component of a Fault Tree has one of two binary states, either in the correct state or in a fault state.
- A Fault Tree is basically the graphical representation of the Boolean (logical) equation which links the individual component states to the whole system state. Therefore, it encompasses all the possible states of the whole system (2N for N components). These states are split into two classes according to that the top event is achieved ("true") or not ("false").

Fault tree analysis for deluge system

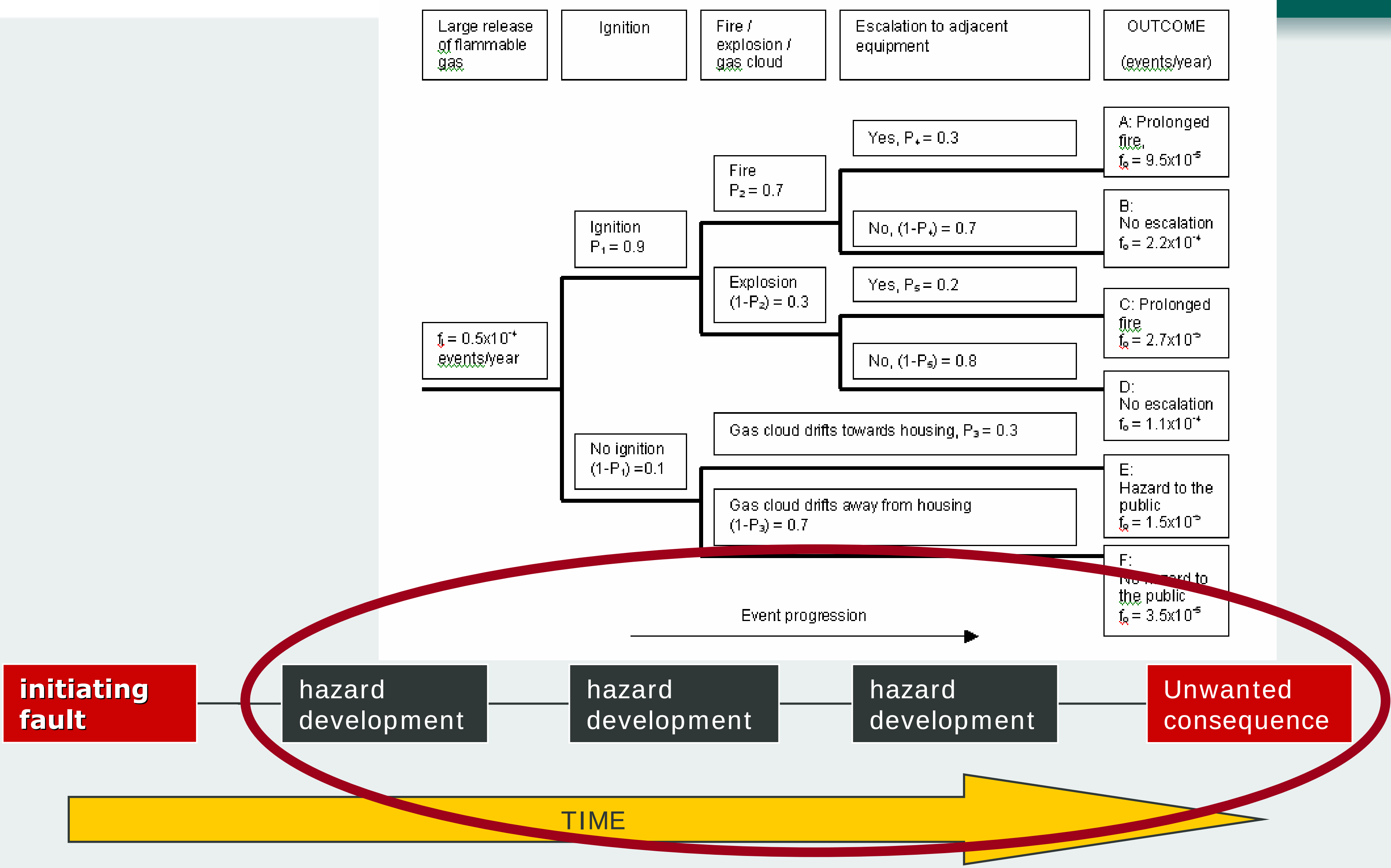




BPN for analysis of Deluge System



Event Tree



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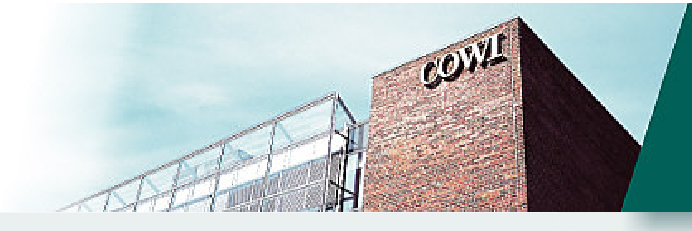
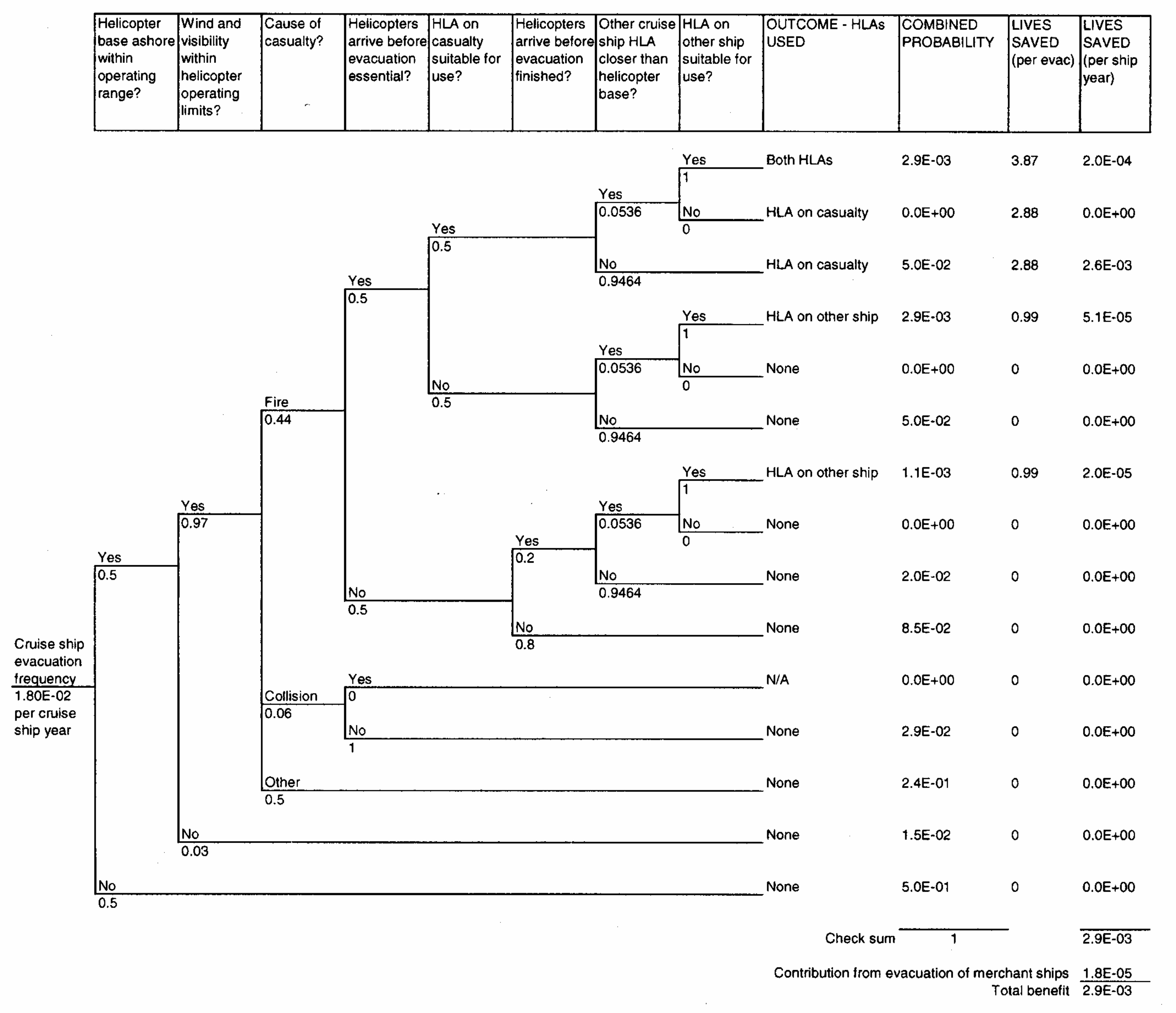


Event Tree

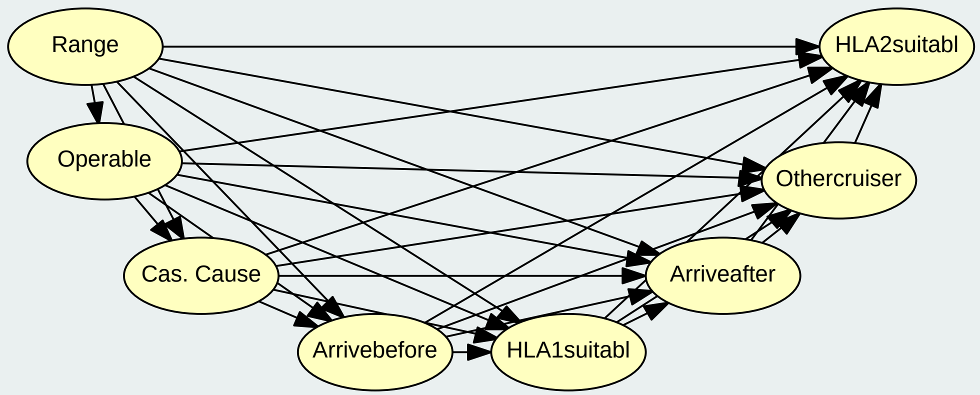
- An Event Tree is used to develop the consequences of an event.
- It starts with a particular “initial event” such as leak of flammable fluid and is developed from bottom up to the outcome of the event.
- The Event Tree is both a qualitative and quantitative technique.
- Qualitatively it is used to identify the individual outcomes of the initial event, whilst quantitatively it is applied, under some conditions and precautions, to estimate the frequency or probability of each outcome.
- Each branch of the Event Tree represents a particular scenario. When all the elements in the branches are independent from each other and not time-dependent, the Event Tree is a means of estimating the frequency of the outcome for that scenario.
- An Event Tree is very efficient to show the results of an analysis, but it is rather difficult to build it from scratch. This is due to the fact that it is almost impossible to modify a detail without redrawing the whole structure. The analyst must have in mind the whole Tree when he begins to draw it.

Event tree for helicopter landing area

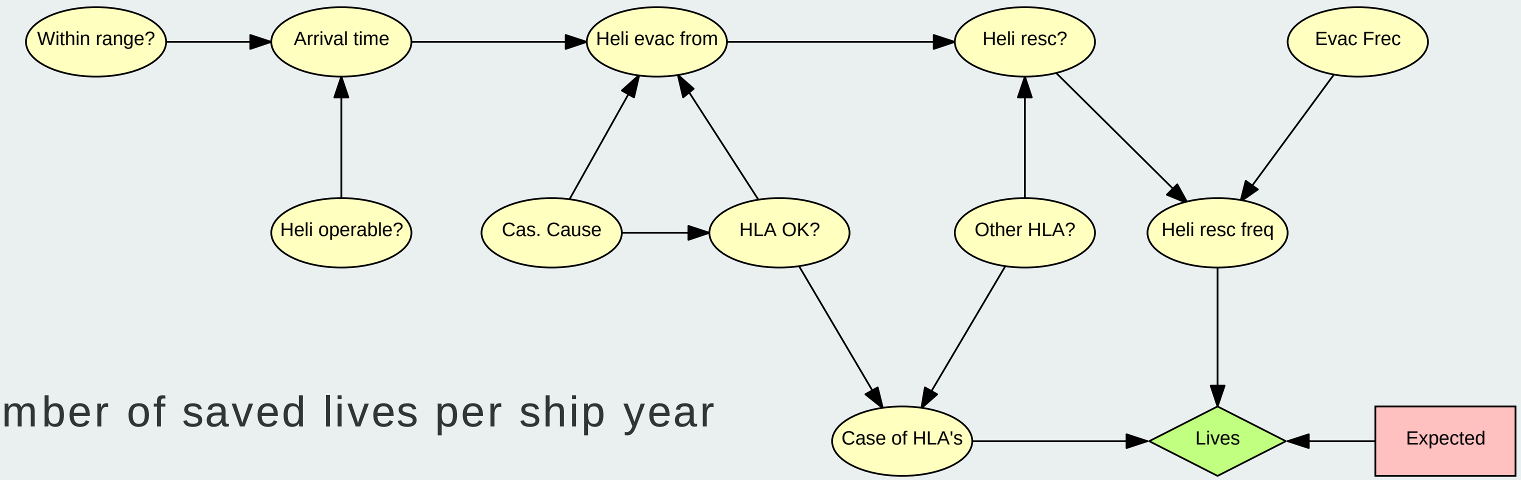


From event tree to Bayesian network

- Direct translation



- Use of independency information



Number of saved lives per ship year

Advantages of using Bayesian networks

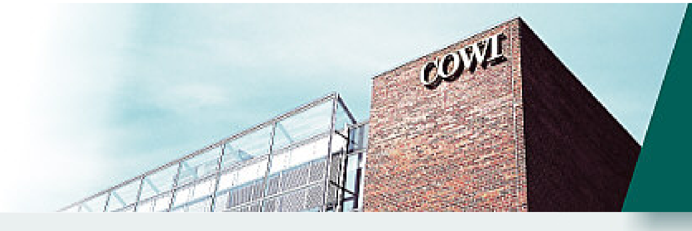
- Give intuitive overview: communication and validation
- Solid theoretical basis
  - Graph theory
  - Probability theory
- Handle uncertainty consistently
- Cover event trees and fault trees
- Combine input from other methods
  - Structural reliability, regression,…
  - Qualitative information
  - Engineering judgement
- Hugin has an interface to MS Excel, Java, C++

For risk analysis and decision support the BPNs provide a quantitative "tool box" which:

- Has a sound theoretical basis in probability and graph theory;
- Technically is stronger than traditional tools;
- Allow for seamless integration of Structural Reliability Analysis (SRA) and Quantitative Risk Analysis results;
- Can accommodate risks and uncertainties related to human and organisational factors; and
- May be applied for "diagnostic“ purposes identifying the most likely critical event scenarios.

BNP thus provide a technology to support decision-making.

The constituents of the BPN risk assessments are:



- Identification of consequences for the considered options;
- Identification of event scenarios contributing to these consequences;
- Formulation of a Bayesian probabilistic network (BPN) model reflecting causal relations between events and consequences;
- Assessment of the event uncertainties and assignment of associated discrete (conditional) probability tables;
- Calculation of the probabilities of identified consequences;
- Verification of the calculations by means of expert workshop sessions, sensitivity analyses, etc.

The graphical interface for BPN risk assessment

- The graphical character of the BPNs enhance the process by representing event scenarios visually observable in strictly logically - yet intuitively comprehensible - causal interrelations.
- The graphical user interface improves exchange of knowledge between experts and assessment teams.
- The graphical user interface greatly facilitates communication with non-professionals leading to an overall improved communication.