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MIRMAP – Modelling Instantaneous Risk for Major Accident Prevention

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MIRMAP (2013-2017)

- Modelling Instantaneous Risk for Major Accident Prevention
  - Finansiert av:

    The Research Council of Norway

    GASSCO

    Statoil
  - Budget ca 10 mill kr
  - Research partners

    NTNU Institutt for marin teknikk

    SAFETEC

    NTNU Samfunnsforskning AS

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Objectives

As expressed in the project plan:

- "The objective of this project is to explore and define the concept of *instantaneous major hazard risk* and how this can be analysed in *living risk analysis*, as a basis for providing better decision support in an operational setting."

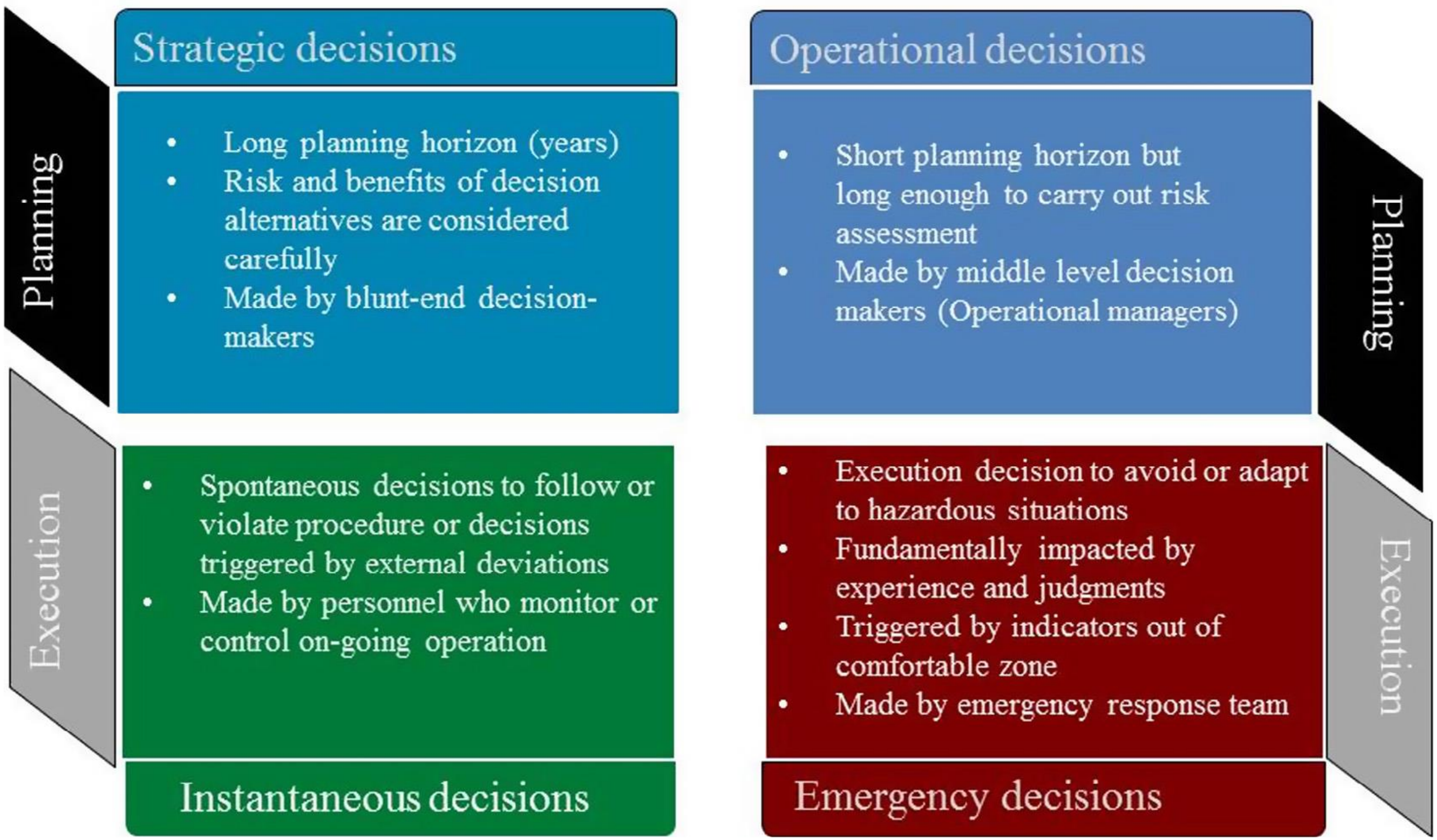
- Focus on providing better decision support to operational planning and decision-making
  - Work-order preparation and planning, work permit preparation and planning
  - Not execution («sharp end»)
  - Major acidents, not occupational

Decisions

- Long-term decisions (strategic planning)
  - The plant lifetime should be extended for another ten years – do I have to upgrade my safety systems?
  - My maintenance costs are a heavy burden – can I reduce the cost and still maintain acceptable safety?
  - What explosion overpressure do I need to design for to achieve acceptable safety?

- Day-to-day planning of activities (operational planning)
  - Is it safe to perform all of these activities at the same time?
  - The most experienced operator on the shift is off sick – do I have to postpone some activities?
  - This is a complicated operation with potentially high risk, but it needs to be done – is it safe to do now?

Decisions


Planning
Strategic decisions
Long planning horizon (years)
Risk and benefits of decision alternatives are considered carefully
Made by blunt-end decision-makers
Operational decisions
Short planning horizon but long enough to carry out risk assessment
Made by middle level decision makers (Operational managers)
Planning
Execution
Spontaneous decisions to follow or violate procedure or decisions triggered by external deviations
Made by personnel who monitor or control on-going operation
Instantaneous decisions
Execution decision to avoid or adapt to hazardous situations
Fundamentally impacted by experience and judgments
Triggered by indicators out of comfortable zone
Made by emergency response team
Emergency decisions
Execution

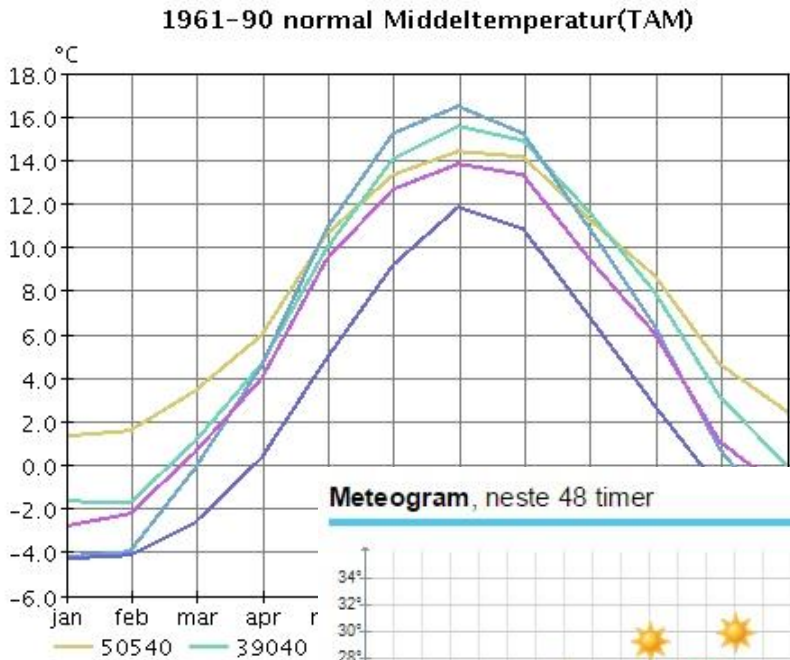
A problem with QRAs?

- QRAs and the methodology was originally developed to support strategic decisions
  - Largely successful in reaching this target
- Like all engineering models, QRAs are simplifications of the real world
  - Take into account (only) the factors that are important for the result
  - Explicitly model (only) factors that we can influence
  - Explicit: Layout and equipment
  - Implicit: Activities and organization
- What happens when we need to support other types of decisions, with other factors that can be influenced?

A long-term (strategic) decision:
The weather is awful – maybe I should move?

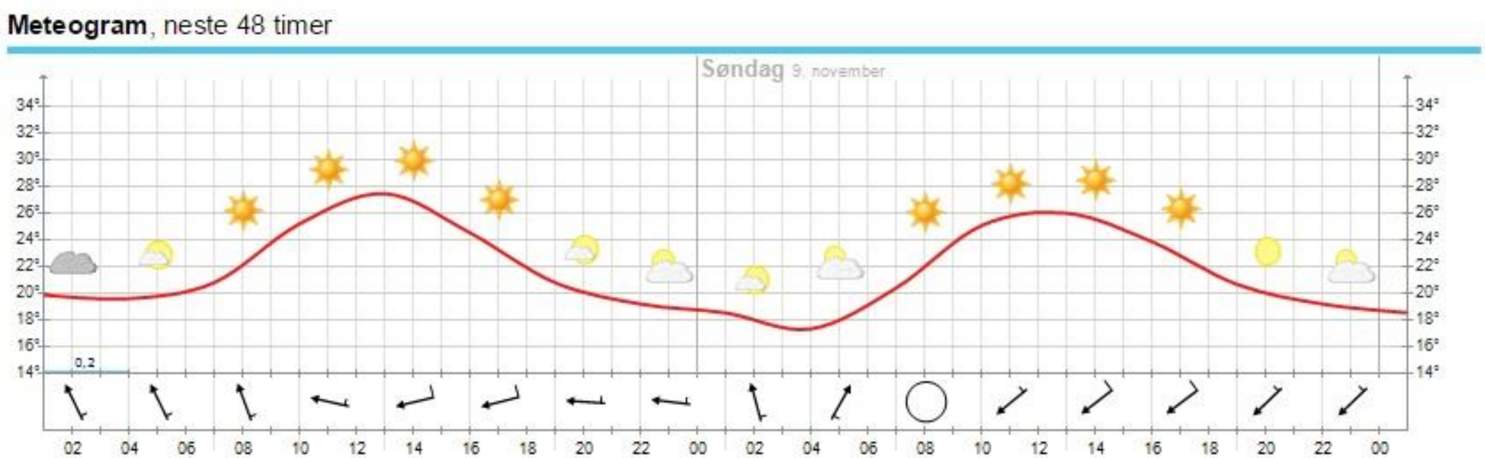
A short-term (operational) decision:
What should I do this weekend?

Decision basis



Climate statistics?

Or weather forecast?



Our hypothesis: «Risk climate» and «risk forecast» is not the same – and we need both for different decisions

Design vs Operation

- Design
  - Develop a solution that in the long term gives the lowest risk on average over the life-time of the system that we are designing
  - Can change technical solutions and average level of operations to achieve the goal

- Operation
  - Avoid accidents today
  - Technical systems are largely fixed, can more or less only change operational and organizational factors

Operational planning in oil&gas

- Key objectives with regard to safety:
  - Each activity must be performed safely
  - The total set of activities must be performed safely together
- Constraints:
  - Technical solutions that are present
  - Possible degradations in barriers – technical, operational and organizational
  - Availability of resources – people, equipment, time,…
  - External conditions
- Put simply the objective is:
  - "We want to get through (also) this day without anyone being killed or injured!"

Important aspects

- Focus modelling on aspects that change during operation
  - From system-based to activity-based modelling
  - Activities influencing barriers
- Averaging of risk over long time periods needs to be removed
  - Update parameters as often as necessary
- Provide support to the types of decisions taken during operations
  - Need to understand these decisions well

QRA vs Operational Risk Analysis

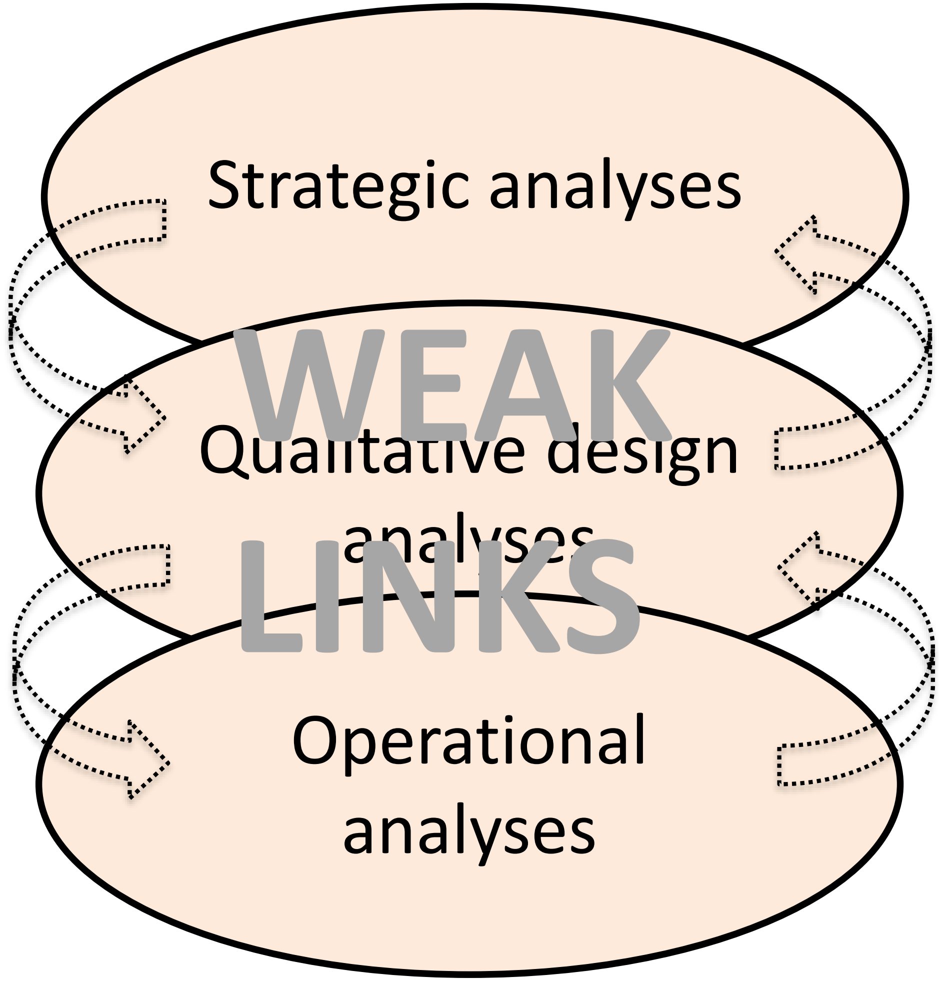
- QRA
  - Based primarily on modeling the technical systems, with activities reflected in a limited way
  - Calculates average long-term risk
  - Advantage: Quantitative, which gives a decision basis which is easier to use for ranking and decision about acceptable risk
- Operational Risk Analysis
  - Typical example is SJA
  - Activity-based analysis with technical systems and design as a «constraint» or context
  - Qualitative, not always good at focusing in major accidents

Types of risk analyses – oil&gas

Quantitative risk analysis (QRA)

Qualitative analysis mainly (FMECA, HAZOP etc)

Qualitative analysis mainly (Risk matrix, SJA)



«Climate statistics»

«Weather forecast»

What we have tried in MIRMAP

- Develop a method that can exploit the strengths of both QRA and operational risk analysis

- Some important elements of this:
  - Activity-based risk analysis taking into account the configuration and the condition of the technical systems
  - Quantitative, to enable ranking of activities
  - Using relevant models and information from QRA to the extent necessary and useful

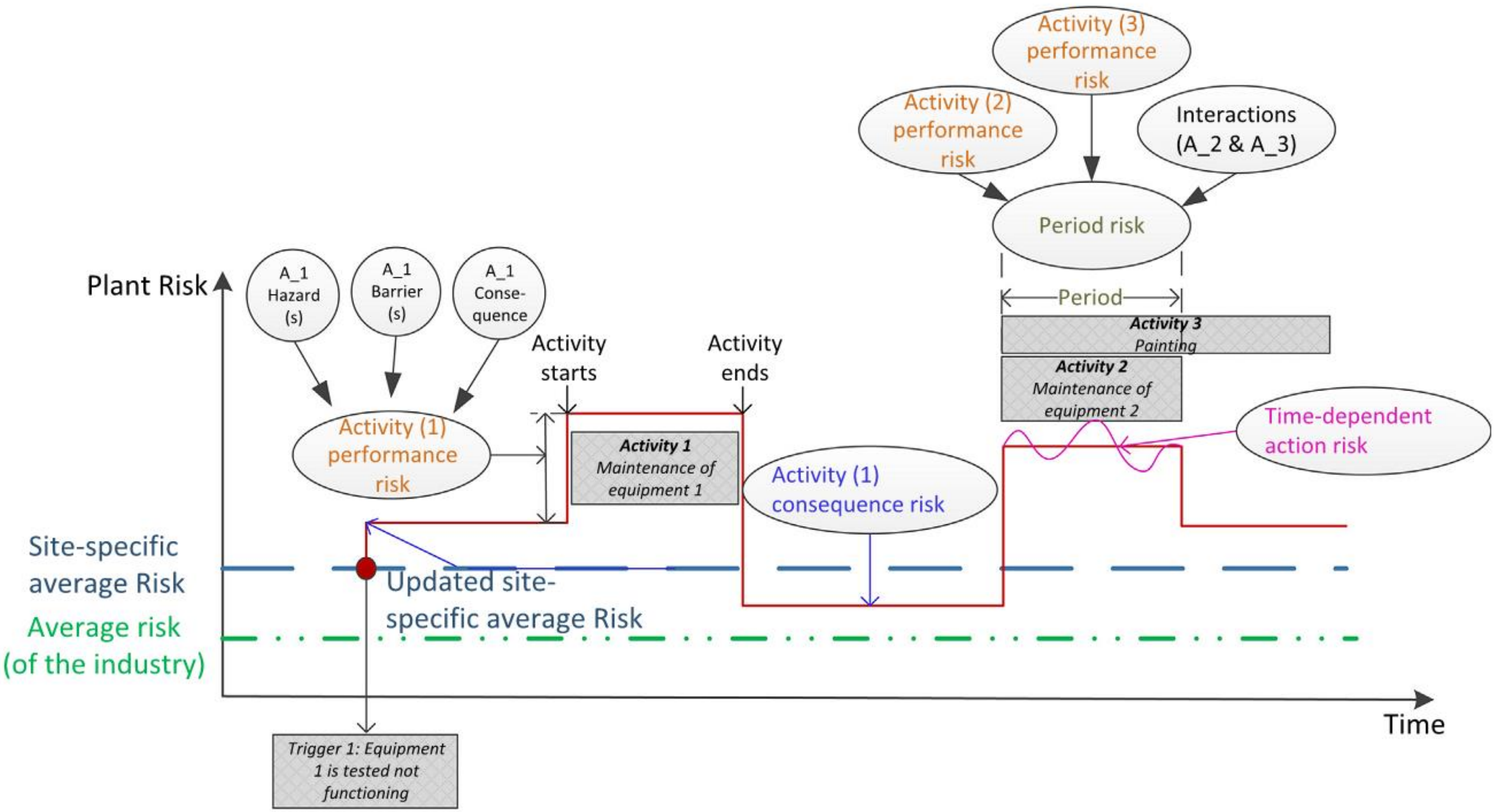
Challenges

- To have a good understanding of risk
  - Short-term and long-term effects of decision alternatives
  - Individual activities
  - Totality of activities
- To incorporate the (many) constraints in the decision basis

$\Rightarrow$ To make consistent decisions
  - Safe…
  - …but not overly conservative

Risk «types»

Risk type		Description
Average risk		Risk for an industry, a nation or an even wider scope averaging over a large group of plants, activities, areas and personnel
Site-specific average risk		Risk for a specific plant, averaged over a year and taking into account specific characteristics of the particular plant
Activity risk	Activity consequence risk	An expression of the effect that completing an activity will have on the risk level after the activity has been completed (risk after the activity)
	Activity performance risk	An expression of risk level associated with performing a specific activity (risk during the activity)
Period risk		An expression of risk for a plant or facility over a (normally short) period of time
Time-dependent action risk		An expression of short-term risk variation while performing one or several activities



Activity (3) performance risk
Activity (2) performance risk
Interactions (A_2 & A_3)
Period risk
Period
Activity 3
Painting
Activity 2
Maintenance of equipment 2
Plant Risk
A_1 Hazard (s)
A_1 Barrier (s)
A_1 Conse-quence
Activity starts
Activity ends
Activity (1) performance risk
Activity 1
Maintenance of equipment 1
Activity (1) consequence risk
Time-dependent action risk
Site-specific average Risk
Updated site-specific average Risk
Average risk (of the industry)
Time
Trigger 1: Equipment 1 is tested not functioning

Risk Classification

	Strategic decisions	Operational decisions	
Planning	• Average risk • Site-specific average risk	• Activity risk • Activity performance risk • Activity consequence risk • Period risk	Planning
Execution	• Time-dependent action risk	• Time-dependent action risk	Execution
	Instantaneous decisions	Emergency decisions	

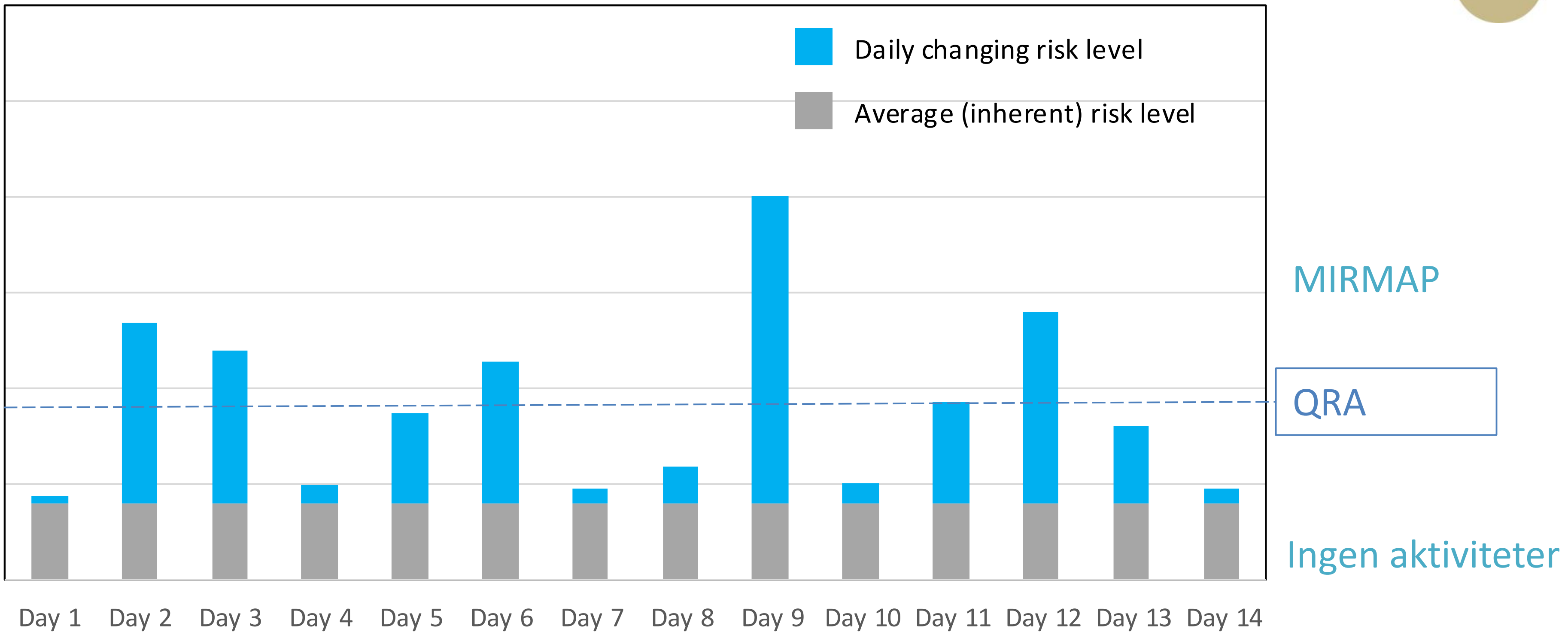
Measuring risk

- The key is avoiding accidents – more focus on probability (or uncertainty) than risk
  - Statistically expected consequences are not relevant in the same way as in strategic decisions
- Relative risk
  - Ranking of activities, absolute values are not focused on

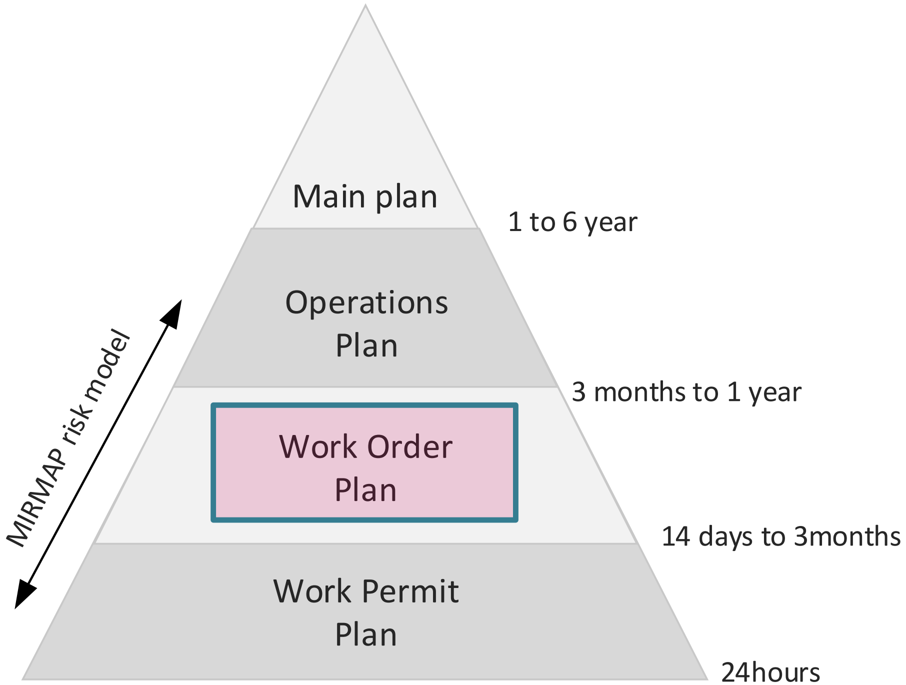
Lack of knowledge

- A key difference between strategic risk analysis and operational risk analysis is the use of probabilistic information vs facts (or at least with reduced uncertainty)
  - Strategic, long-term: Use average probability of failure of barriers, average number of operations, average number of people in area, etc
  - Operational: We can to a much larger degree know if barriers are working or not, what operations are taking place, who will be present, etc
- Uncertainty is expressed in terms of lack of knowledge

What we were aiming to do



Operational planning



Activity-based approach

The lower-level of the risk model are activities

A1: Activities

Risk Increasing Activities (Hazards)
E.g. Hot Work, Work on HC systems

CMMS

A2: Impairments/ Deviations

Risk Increasing Conditions (Barriers)
E.g. Impairment of gas detection/fire detection, removal of PFP

Svekk-elser

To represent the complete risk picture we also include

B: Technical Degredation

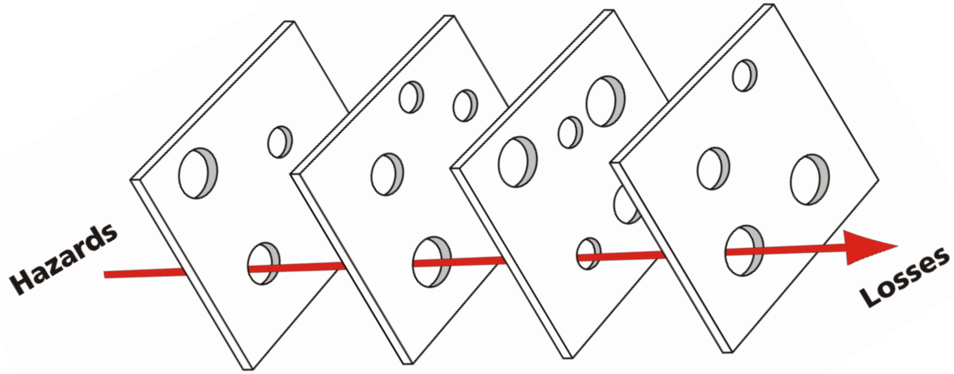
Teknisk tilstand
E.g. Ageing, Fatigue

C: Design Deficiencies

Tekniske begrensninger
E.g. Firewater deficiency, Detector coverage limitations

QRA

Activities (A1) and barrier impairment (A2)



Prevent Release	Limit Release Size	Prevent Ignition	Prevent Escalation
BF1	**BF2**	**BF3**	**BF4**
PSDVs	Gas Detectors	Hot Work B	Fire Wall/Door
Leak (intervention)	Gas Detection logic solver	Ventilation	Scaffolding
Leak (isolation)	ESDVs	Activity generating sparks	Open Drain
Leak (normal ops)	ESD Logic solver	Hot Work A	Blast wall
Leak (reinstatement)	BDVs	Ignition Source Isolation	PFP
PSVs	Flare		Auto Fire Detection Logic
PSD Logic solver	Depressurization Logic solver		Fire Detectors
PSD Transmitters	Manual Call point Control Logic		Fire water
	Manual Call point		Auto release mechanisms
	ESD Pushbutton		
	Knockout Drum		

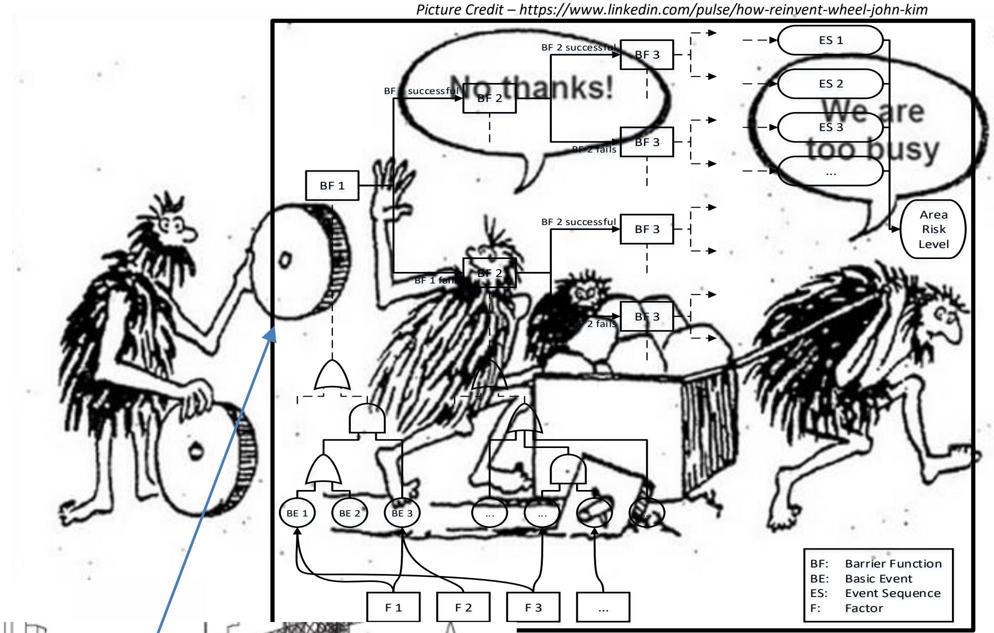
Analysis

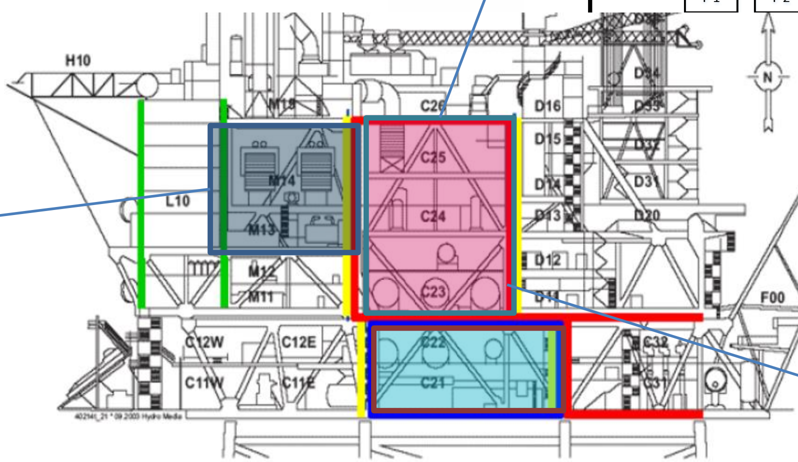
A. Event trees

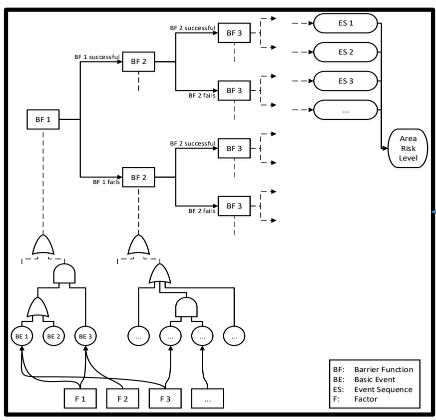
B. Fault trees

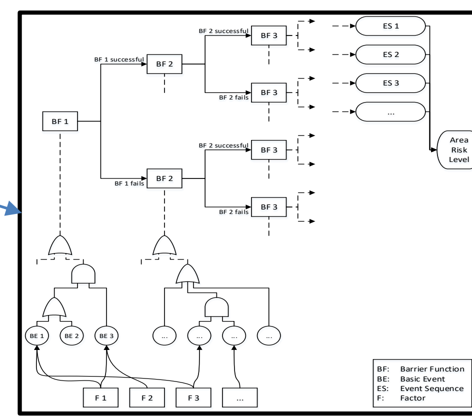
C. Influence diagrams

Picture Credit – https://www.linkedin.com/pulse/how-reinvent-wheel-john-kim

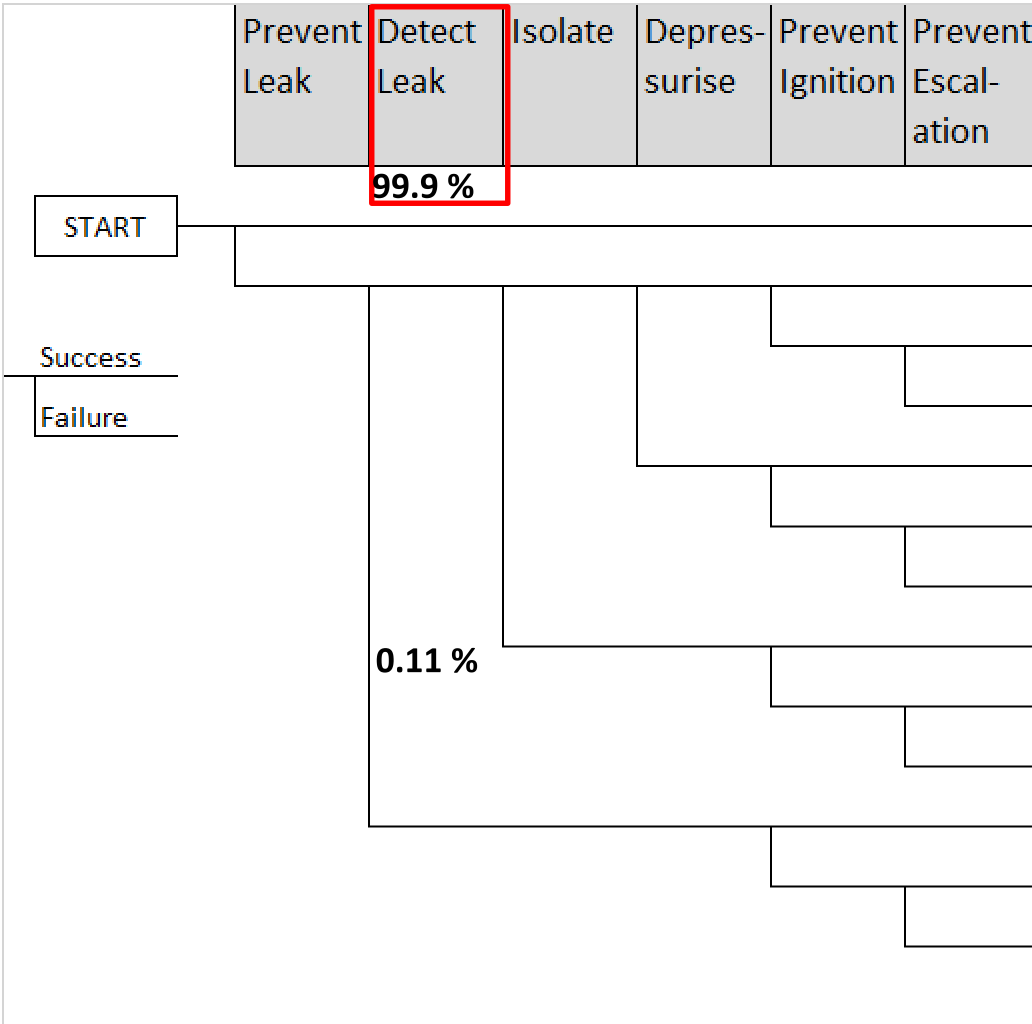








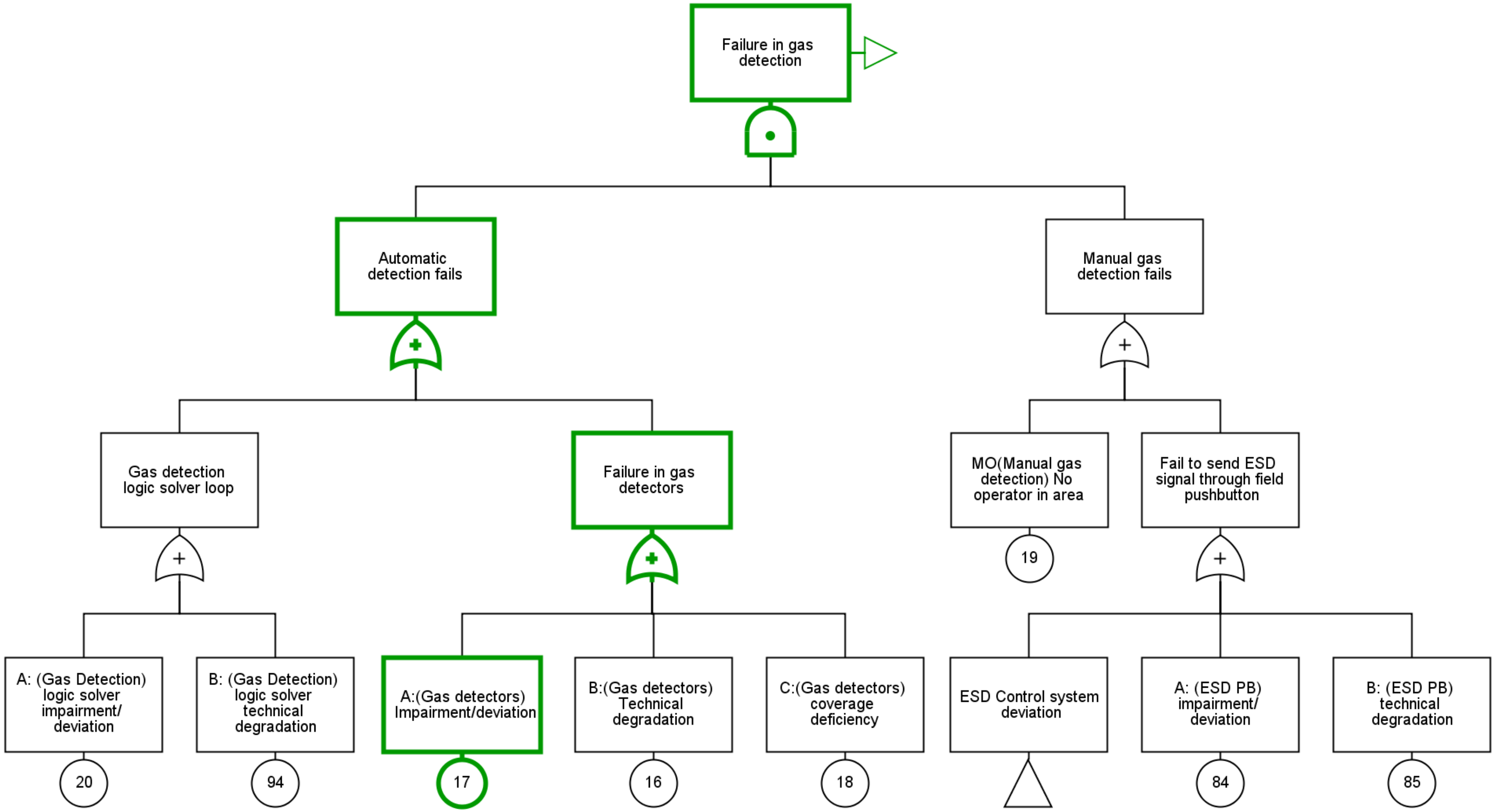
A. Event tree



Out-come	Out-come Prob.	Outcome Fatality Number	Expected Num. of Fatalities
C0	9.9E-01	0	0E+00
C1	5E-03	0	0E+00
C2	3E-05	0.04	1E-06
C3	4E-05	0.1	4E-06
C4	1E-03	0	0E+00
C5	3E-06	0.6	2E-06
C6	3E-05	0.8	3E-05
C7	8E-04	0	0E+00
C8	3E-06	1	3E-06
C9	3E-05	1.2	4E-05
C10	7E-06	0	0E+00
C11	3E-08	1.4	4E-08
C12	3E-07	1.6	4E-07

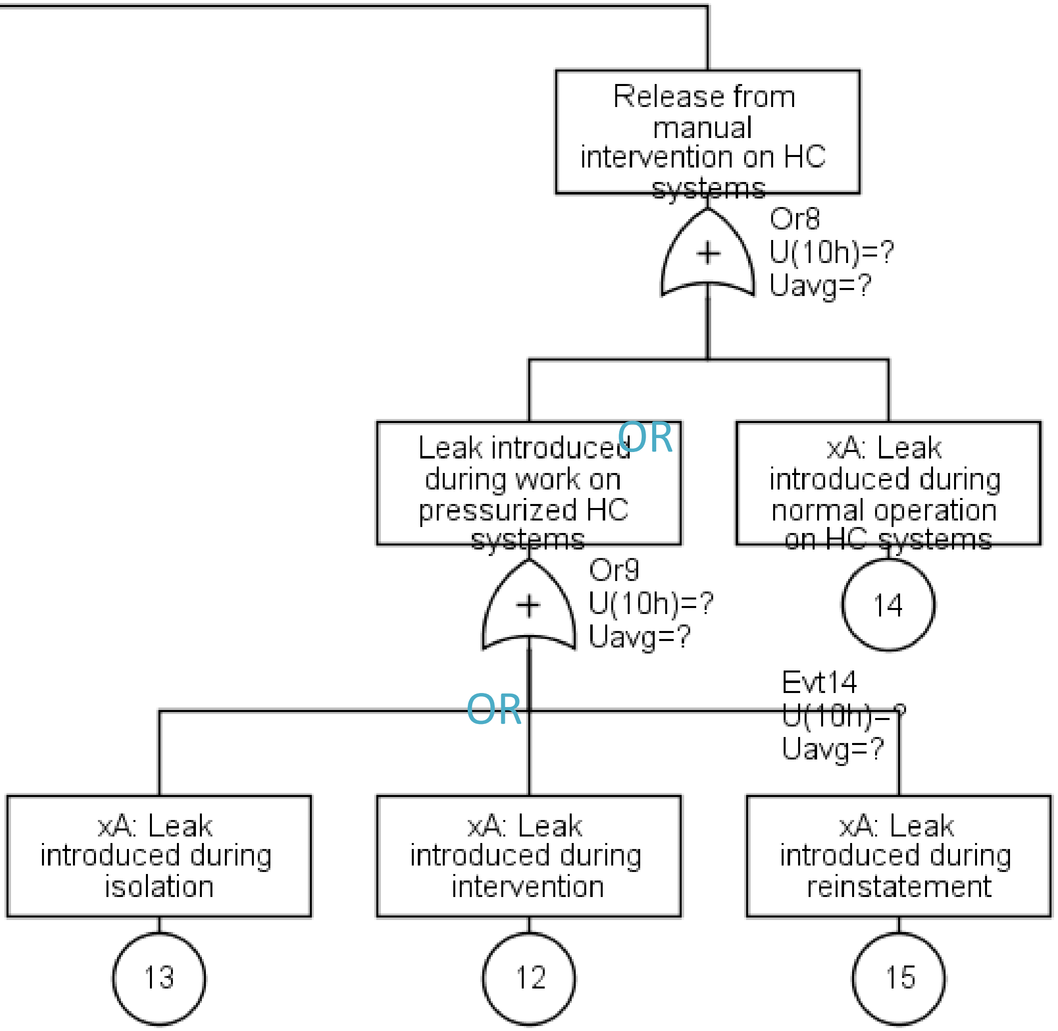
PLL: 7E-05

B. Fault tree



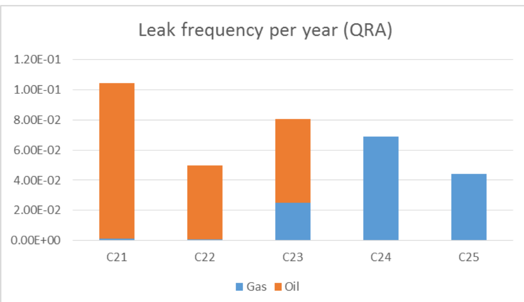
Failure in gas detection
Automatic detection fails
Manual gas detection fails
Gas detection logic solver loop
Failure in gas detectors
MO(Manual gas detection) No operator in area
Fail to send ESD signal through field pushbutton
19
A: (Gas Detection) logic solver impairment/ deviation
B: (Gas Detection) logic solver technical degradation
A:(Gas detectors) Impairment/deviation
B:(Gas detectors) Technical degradation
C:(Gas detectors) coverage deficiency
ESD Control system deviation
A: (ESD PB) impairment/ deviation
B: (ESD PB) technical degradation
20
94
17
16
18
84
85

Example – HC leakage



Example 1 – HC leak

Use input from QRA to quantify basic events



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Applied leak distribution

MIRMAP category	Events	Distr.
Isolation	19	10 %
Execution	44	23 %
Reinstatement	18	9 %
Normal operations	25	13 %
Overpressure	9	5 %
Technical degradation	46	24 %
Design	29	15 %
External	0	0 %
Total	**190**	100 %

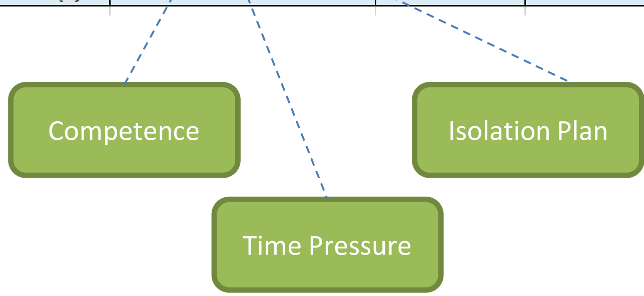
+

Number of WOs and WPs on HC systems or

Module	Period 2013-2015		Average per year	
	WPs	WOs	WPs	WOs
C21	211	88	70	29
C22	147	55	49	18
C23	185	74	62	25
C24	264	95	88	32
C25	349	189	116	63
Total	**1156**	**486**	**385**	**162**

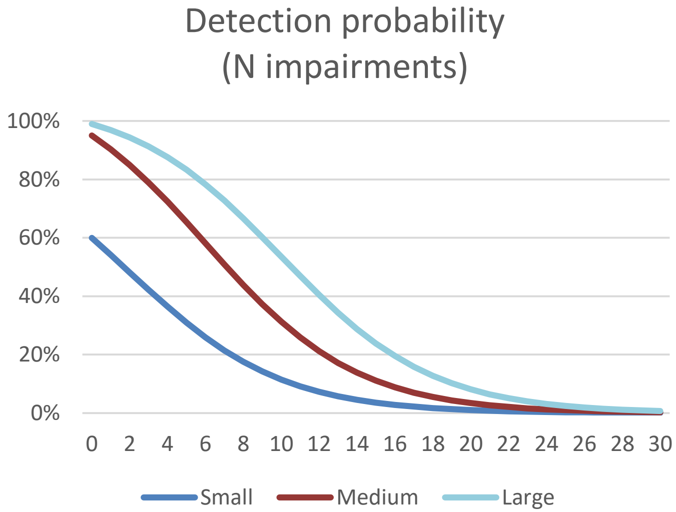
	Leak probabilities per WO			
Module	**Category**	**Small**	**Medium**	**Large**
Allocate to	Isolation	1.30E-04	5.34E-05	3.19E-05
relevant	Execution	3.00E-04	1.24E-04	7.39E-05
module(s)	Reinstatement	1.23E-04	5.06E-05	3.02E-05

	Leak probabilities per day			
Module	**MIRMAP category**	**Small**	**Medium**	**Large**
C21	Normal operations	2.30E-05	9.16E-06	5.49E-06
C21	Overpressure	8.28E-06	3.30E-06	1.98E-06
C21	Technical degradation	4.23E-05	1.69E-05	1.01E-05



Adjust values based on state of influencing factors

Example 2 – Gas detection

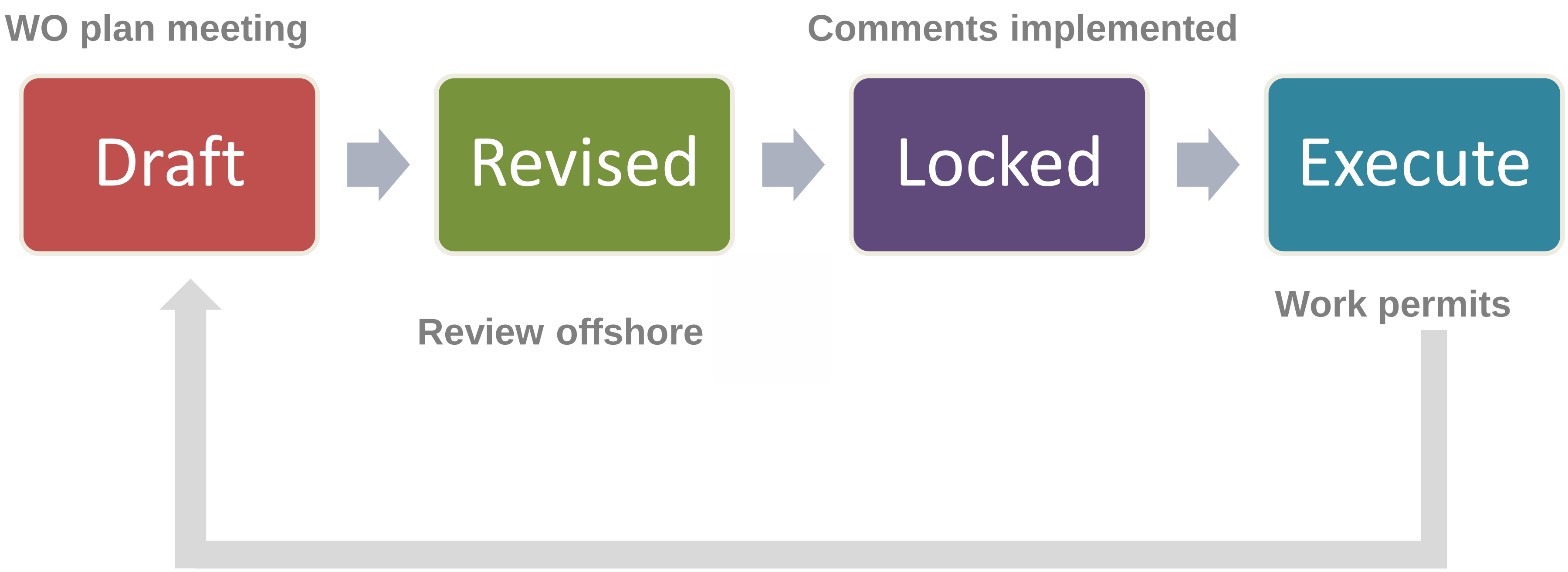


Sensitivities performed in QRA – effect of detectors not working

	Gas Detectors	UnknownUnknow	Unknown(1-2)	Unknown(3-5)	Unknown(6-10	Unknown(11-15	Unknown(16+)	FullyUnknown
1	**Number of units impaired**	Unknown	(1-2)	(3-5)	(6-10)	(11-15)	(16+)	Unknown
2	**Compensatory Measures**	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Fully
		70 %	15 %	39 %	70 %	90 %	100 %	70 %
		53 %	8 %	24 %	53 %	81 %	100 %	53 %
		33 %	3 %	12 %	33 %	65 %	100 %	33 %
		50 %	50 %	50 %	50 %	50 %	50 %	0 %
		35 %	**7 %**	**20 %**	**35 %**	**45 %**	**50 %**	**0 %**
		27 %	**4 %**	**12 %**	**27 %**	**41 %**	**50 %**	**0 %**
		17 %	**2 %**	**6 %**	**17 %**	**32 %**	**50 %**	**0 %**

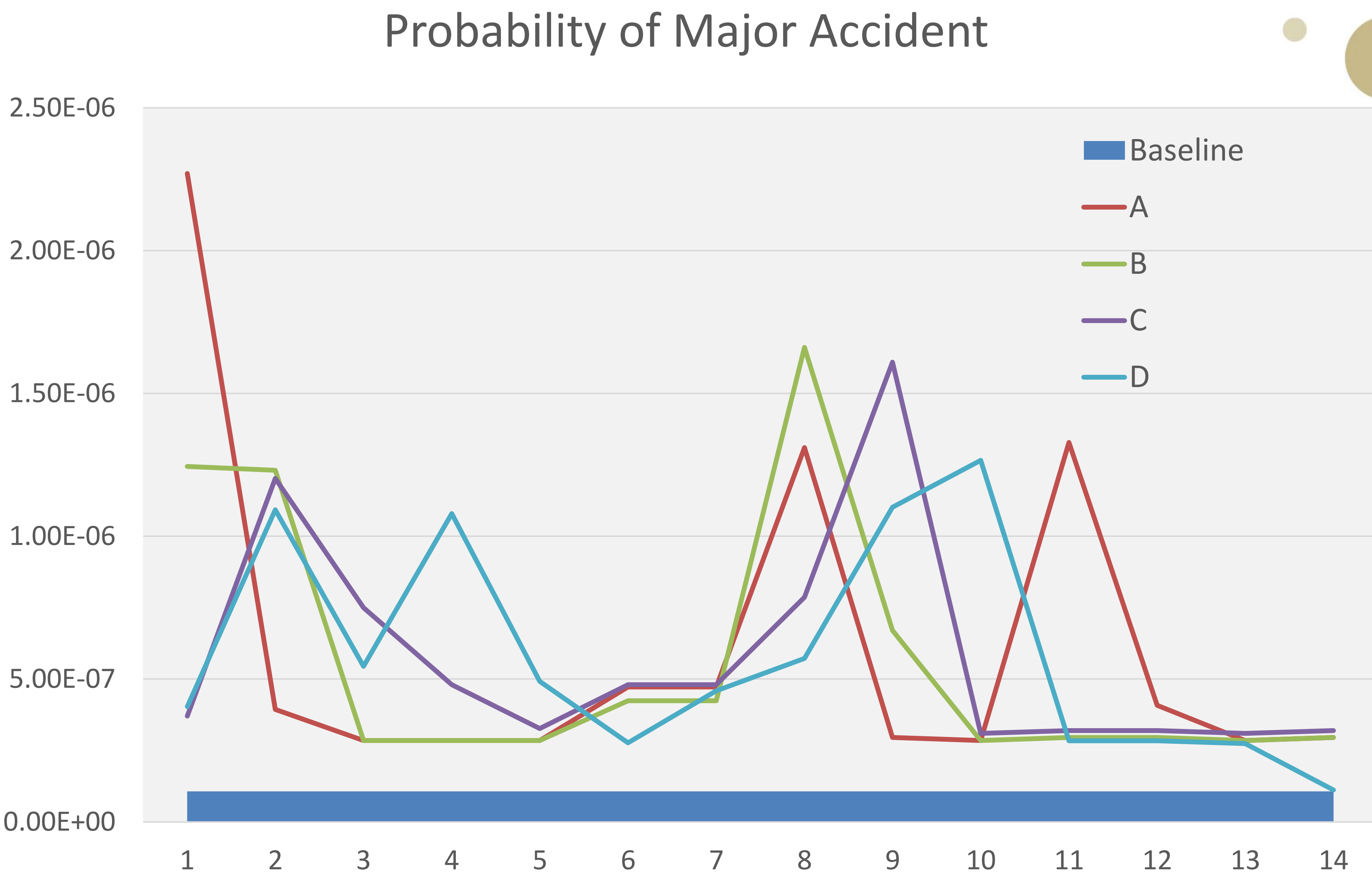
Used to assign probabilities

Work order planning cycle



- Running the model through the four stages of the planning cycle
- Purpose: To illustrate how risk develops over time as a result of changes in activitites

Draft → Revised → Locked → Execute

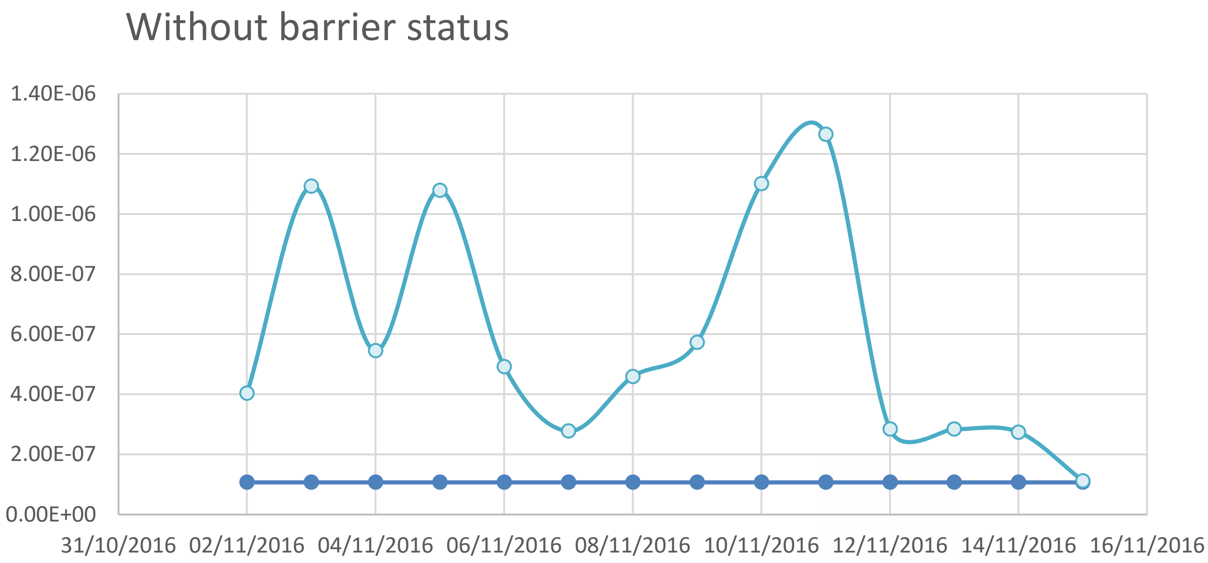


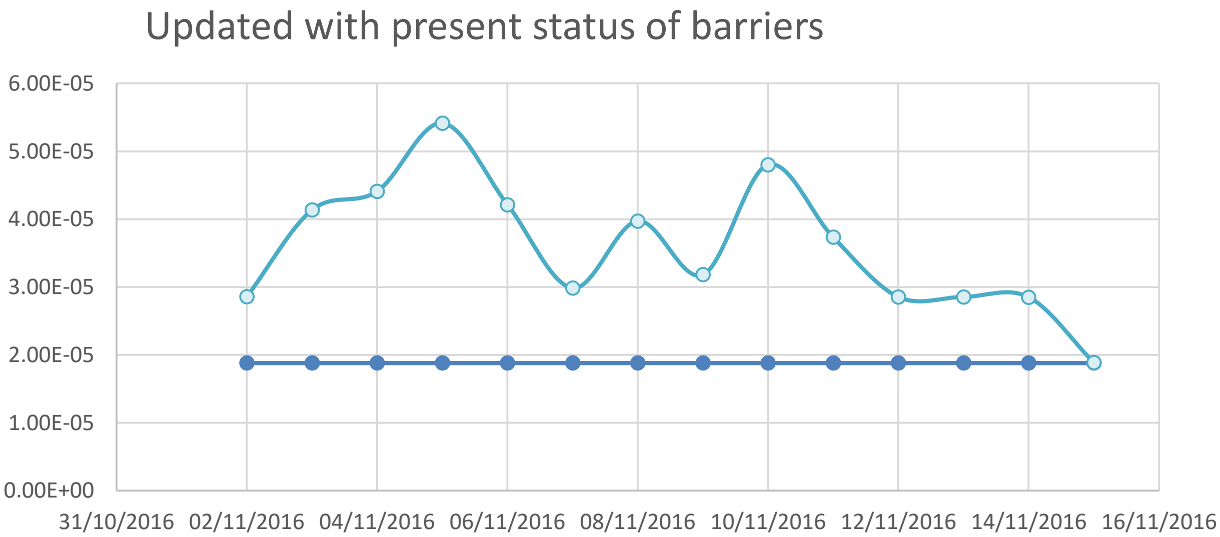
Main reasons for changes in risk

- **Updated knowledge** about the work

  E.g. Surface treatment
- **New** activities
- **Delayed** activities (removed from the plan)
- **Changes** in execution date

Barrier status information





Baseline risk changes

Change in shape of risk curves

Important to consider barrier status when planning work

Feedback – plus and minus

- Offshore expect risk to be «removed» when they receive the plan
- Can be used in the whole planning cycle (3 months) and in different decision contexts
  - Early risk evaluation of preventive maintenance work
  - Avoid risk peaks when execution date of work changes
  - Quickly see the effect of high priority jobs (that «bypass» the planning cycle)
- Support to reduce uncertainty
  - Information in Work Permits can be made available much earlier
- Needs to be automated
  - Manual feed to the model is too time-consuming
  - Requires plant specific knowledge

Future work

- Have been trying to get a more comprehensive case study from Statoil – so far no success
- What is acceptable risk in the short term?
  - How high «peaks» can be accepted?
  - Does it make sense to accumulate risk?
- More work on the fundamentals
  - Getting a better grip on uncertainty to improve risk management

Potential use

- When preparing Work Orders
  - How much will «my» WO contribute to risk, based on the plant status as it is today?
  - Identify limitations to be taken into account in planning
- When preparing plans up to 3 months ahead and to Work Order Plan
  - Earlier identification of all WOs with high risk
  - More consistent comparison and evaluation
- During preparation of Work Permits
  - Which WPs represent a high risk? Prioritize
- Work Permit Meeting (approval)
  - Better and more consistent basis for comparing, approving and modifying activities

Work required

- Developing a MIRMAP risk analysis will require significant effort
  - Similar order as QRAs that are performed today
  - Replacing existing QRAs will imply similar effort
  - Model can be run on a daily basis with very limited effort
- Risk model “templates” for activities?
  - Many similarities between plants
  - A library of models will save time and effort

Availability of data

- Input from the QRA will be applied
  - Technical systems, consequences – relatively static information, long intervals for update (years?)
- Daily updates
  - Types of activities, number of activities, where they are taking place, how many people are involved, systems/-components that have failed, maintenance status, etc.
  - Data collection must be automatic to make this feasible and cost-effective in practice.
- Information is typically available in the maintenance management/planning system and the work permit system.

Conclusion

- The main «finding» from MIRMAP is that we need to remind ourselves why we do risk analysis!
- After we understood this, we could use standard risk analysis methods to develop suitable input to decisions

- Testing has indicated:
  - Can identify high risk contributors among activities
  - Sensitive to differences
  - Can support understanding of why risk is high
  - Can improve planning