Risk based distribution system asset management - looking ahead

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Some improvement options

- Transparency in efficiency sharing with customers
- Improved grid state indicators - improved condition monitoring
- Improved reliability and power quality management in decision processes
- Increased utility service and customer satisfaction focus
- Additional objectives and key performance indicators – in addition to short term profit
- Opens for improved multi criteria risk based grid management
- To utilize all the data that are out there - in a more holistic and coordinated way

Ongoing work - Looking ahead

- The RISK DSAM project
  - Risk-based Distribution System Asset Management

- Project main objective:
  - Improved management of the risk exposure for a distribution company, on planning, operative and physical level as well as on strategy level - related to maintenance and reinvestment strategies

  - Improved concepts, work flows, methods, tools and competence

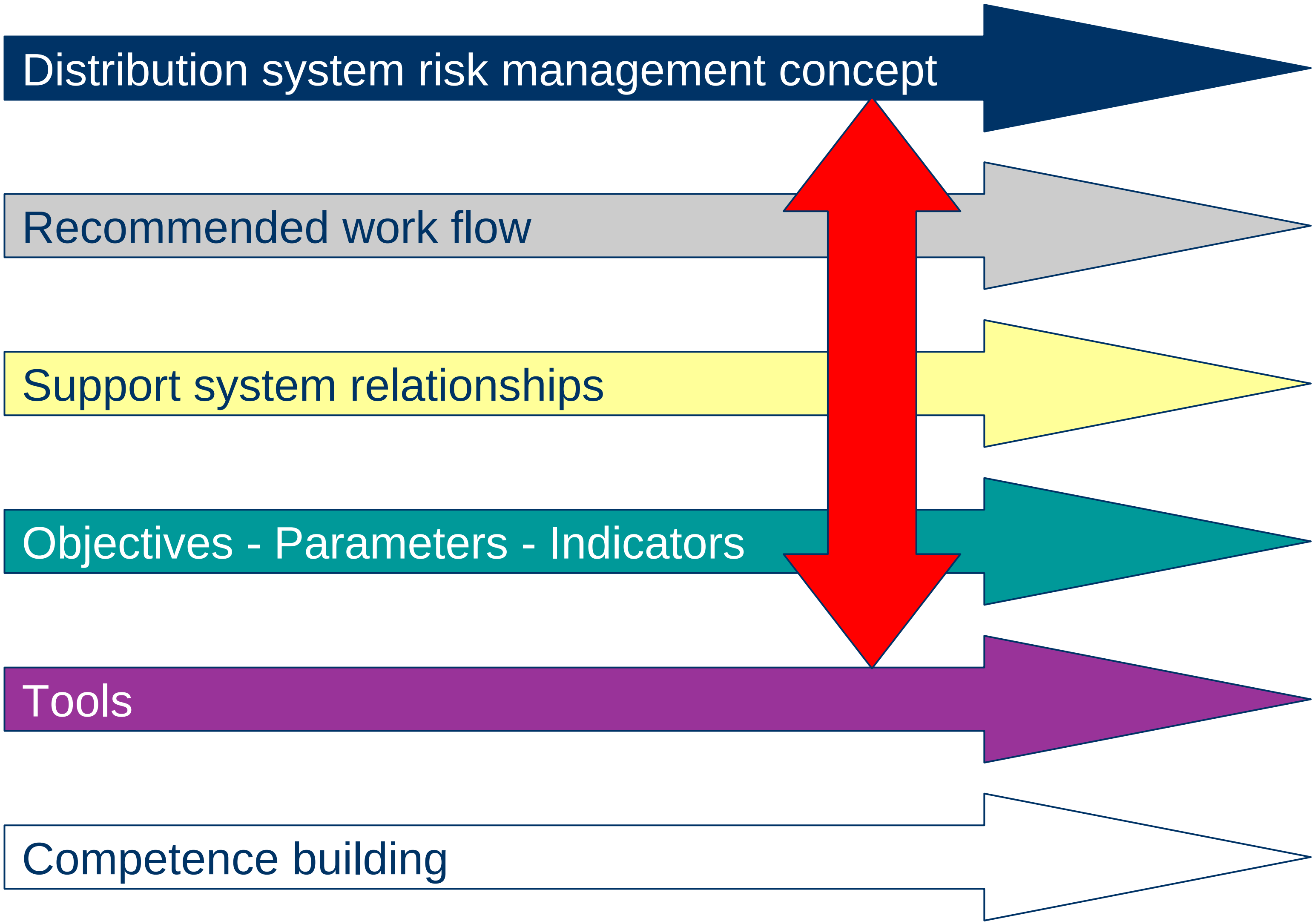
Project Research Partners and user Participation

- National Research Partners:
  - SINTEF Industrial Management, Dept. of Safety and Reliability
  - NTNU, Faculty of Information Technology
    - Dept. of Electrical Power Engineering
    - Dept. of Mathematical Sciences
  - SNF – Institute of Research in Economics and Administration

- International Research Partners:
  - University of Porto/INESC — Portugal
  - Lappeenranta University of Technology — Finland
  - EdF – Electricitè de France R&D — France

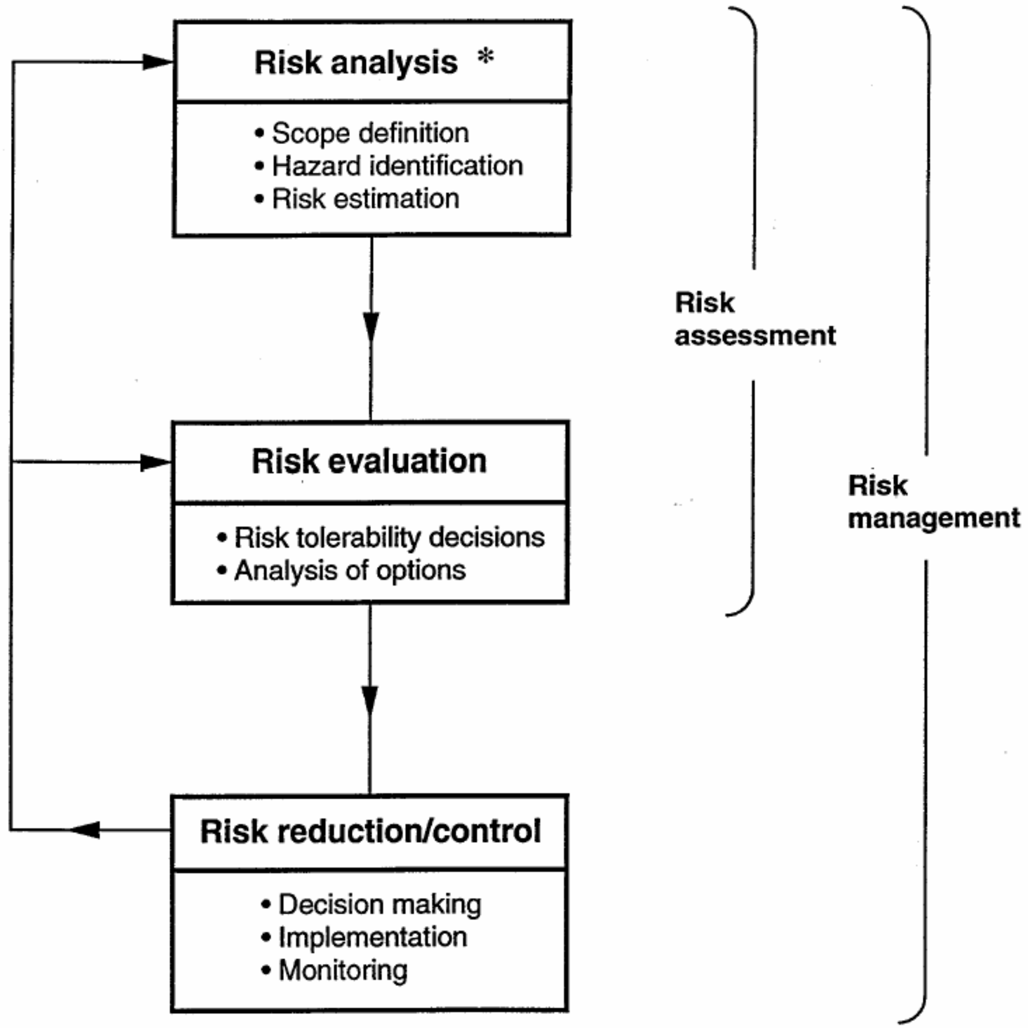
- National User Participation (DNOs):
  - Hafslund Nett AS
  - Lyse Nett AS
  - Fredrikstad Energiverk/Energi 1
  - Statkraftalliansens Nettgruppe (BKK, TEV, Agder, Skagerak og Istad)

Six RISK DSAM aspects



Concept (IEC)

IEC 60300-3-9 Dependability management Part 3 Application guide
Section 9 Risk analysis of technological systems

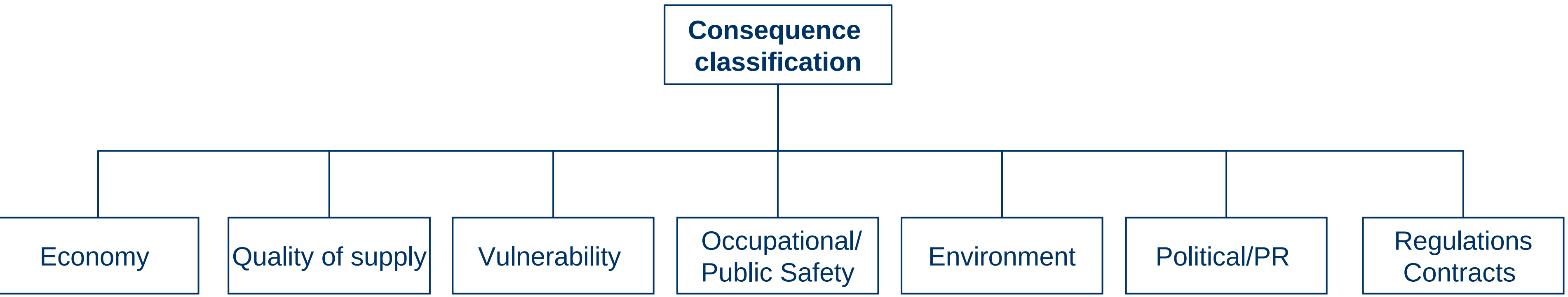


Risk management –

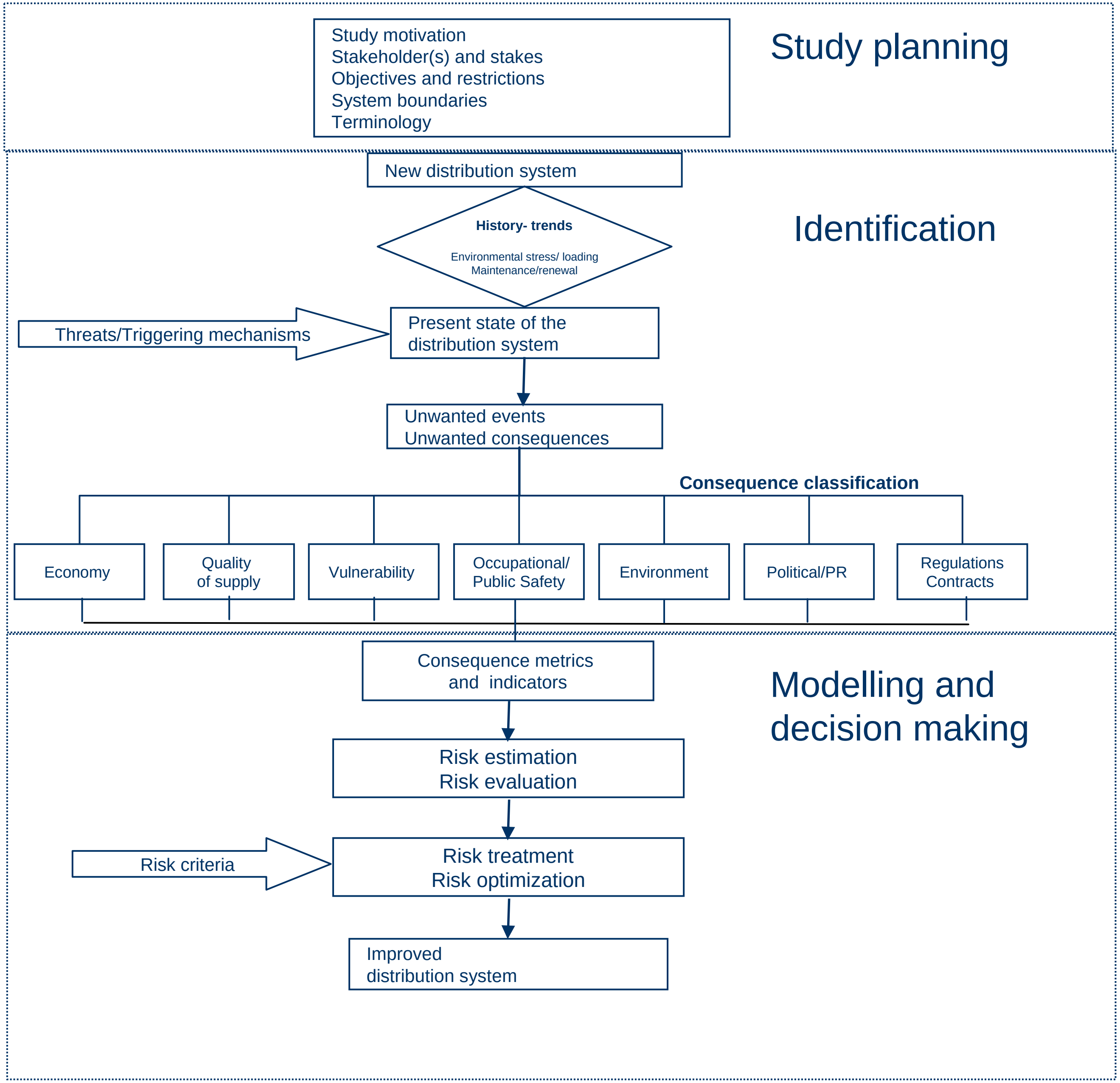
Sub process relationships – ISO/IEC Guide 73 *Risk Management – Vocabulary – Guidelines for use in standards*.

Risk Management			
	Risk Assessment		
		Risk Analysis	
			Risk Scenario Identification
			Risk Estimation
		Risk Evaluation	
	Risk Treatment		
		Risk Avoidance	
		Risk Optimization	
		Risk Transfer	
		Risk Retention	
	Risk Acceptance		
	Risk Communication		

Classifying risk



Concept/workflow



Ongoing work:
Key Performance Indicators

Key Performance Indicators give Asset Management Decision Support Example from a Norwegian Utility Prototype

Network Information System(NetBas)
- Documentation, GIS, topology
- Analysis (load flow, short circuit)
- Reliability
- LCC
- Maintenance management
- Fault data management
- Health, environment and safety

Other data sources and systems
- ERP (Economy System)
- CIS (Customer Information System)

Grid company:
- Company strategy
- Focus areas
- Preferences

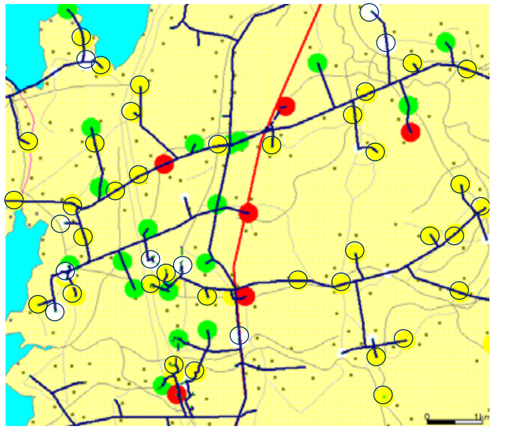
Analysis
- Criteria
- Weighing
- Categories

NetBas visualization of results
- Electrical rating
- Technical condition
- Availability
- Economy
- Health, environment and safety

KPI

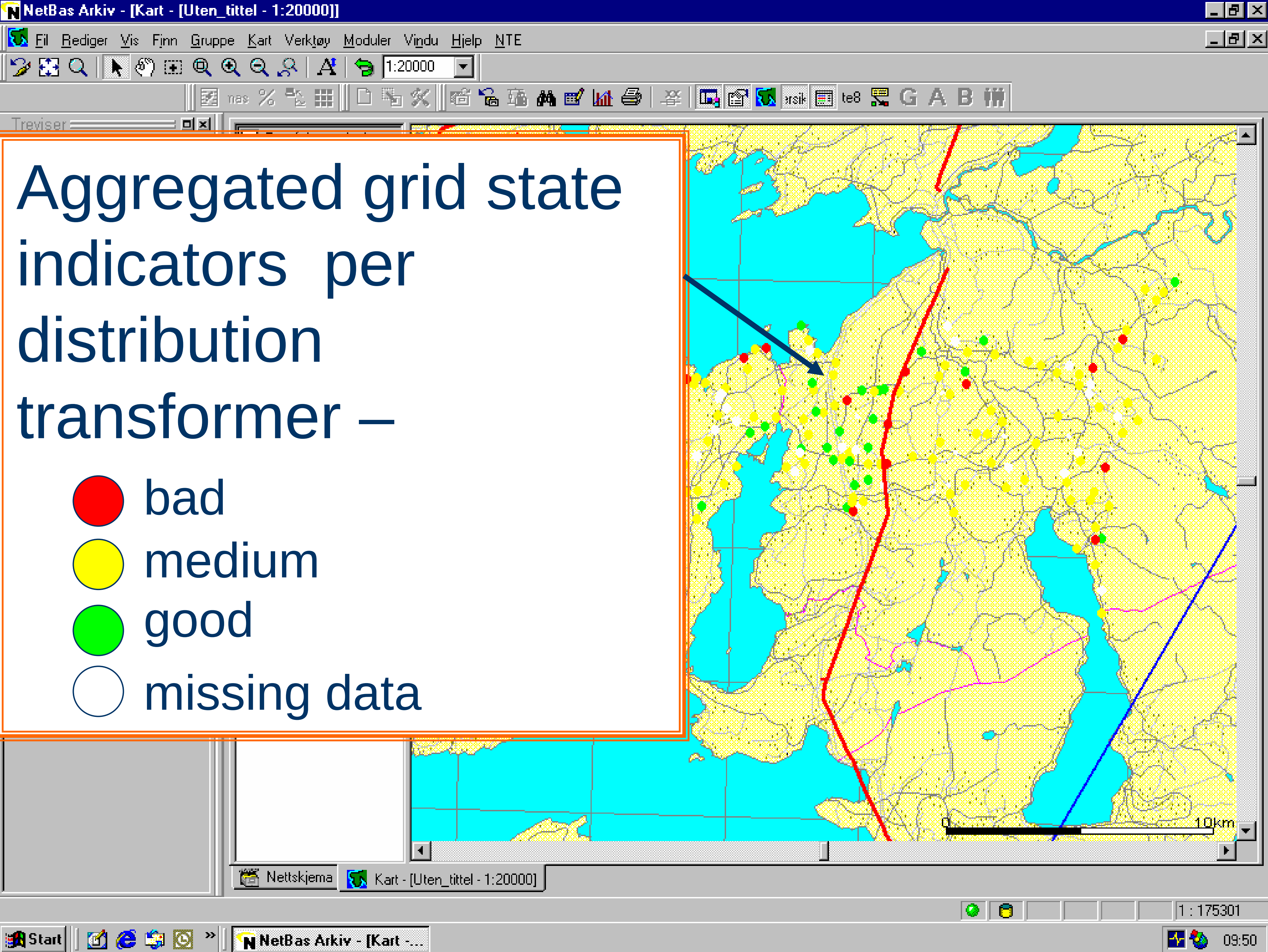
Decisions to be made:
- Identify problem areas
- Budget
- Propose solutions and actions
- Cost benefit

NIS used for presentation of results



Aggregated grid state indicators per distribution transformer –

- bad
- medium
- good
- missing data



Quantitative and qualitative parameters

- Transformation into predefined states by comparing current values with a pre-defined set of criteria

Categorization of low-level indicators in one out of 4 possible states

State		Description	Criteria	Weighting
WHITE	-	Inadequate input data		α_{White}
GREEN	OK	No actions necessary	U > 218	α_{Green}
YELLOW	Warning	Fulfills functional requirements, but actions may be necessary	U < 218	α_{Yellow}
RED	Alarm	Does not fulfill functional requirements, actions required	U < 207	α_{Red}

U – Lowest measured (or calculated) voltage in the low-voltage network [V] (230 V system)

Relative weighting of the 4 possible states. Based on an intuitive assumption that "red" indicators are more important than "yellow" and "green", the 4 states have been given different relative weight (white indicators are not included, and have $\alpha_{White} = 0$).

Relative weighing of indicators

Table 2 Examples of low-level indicators for a transformer

Low-level indicator	Value	Red	Yellow	Green	Weight
1. Technical solution	**Orient. core**	-	Non-ori. core	Orient. core	$w_{i,1}$
2. Age	**30 years**	≥ 45 years	≥ 35 years	< 35 years	$w_{i,2}$
3. Technical condition	**40**	≤ 25 %	≤ 50 %	> 50 %	$w_{i,3}$
4. Degree of utilization	**92**	≥ 100 %	≥ 90 %	< 90 %	$w_{i,4}$

Relative weighting of the low-level indicators. These different low-level indicators may have different importance (weight) when assessing the actual component. The weighting can be based on a subjective assessment.

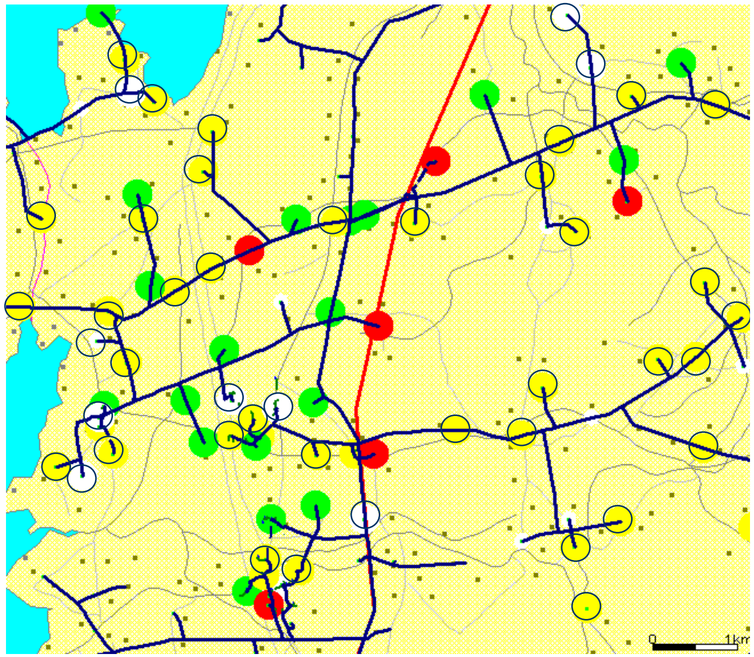
- Aggregated component indicator:

$$PI_{Part\,i} = \frac{\alpha_{Green} \sum_{j,Green} w_{i,j} + \alpha_{Yellow} \sum_{j,Yellow} w_{i,j} + \alpha_{Red} \sum_{j,Red} w_{i,j}}{\sum_{j,Green} w_{i,j} + \sum_{j,Yellow} w_{i,j} + \sum_{j,Red} w_{i,j}}$$

Experience

- Choose sensible indicators
  - That reflect important company strategies
  - That utilize current information; data quality and data availability will partly be present due to regulatory requirements

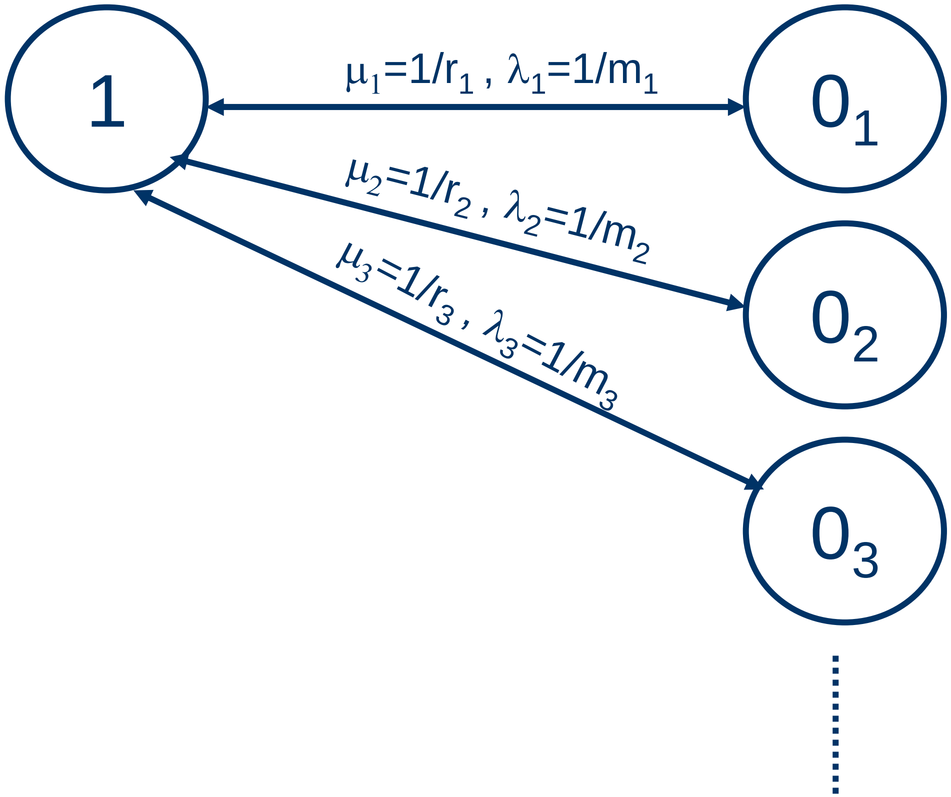
- Detailed studies must follow before decisions are made, but network indicators will tell where to put effort



Ongoing work:
Life time models - Failure models for network components as a basis for asset management

To better understand fault mechanisms and failure modes are important in a risk based asset management approach,

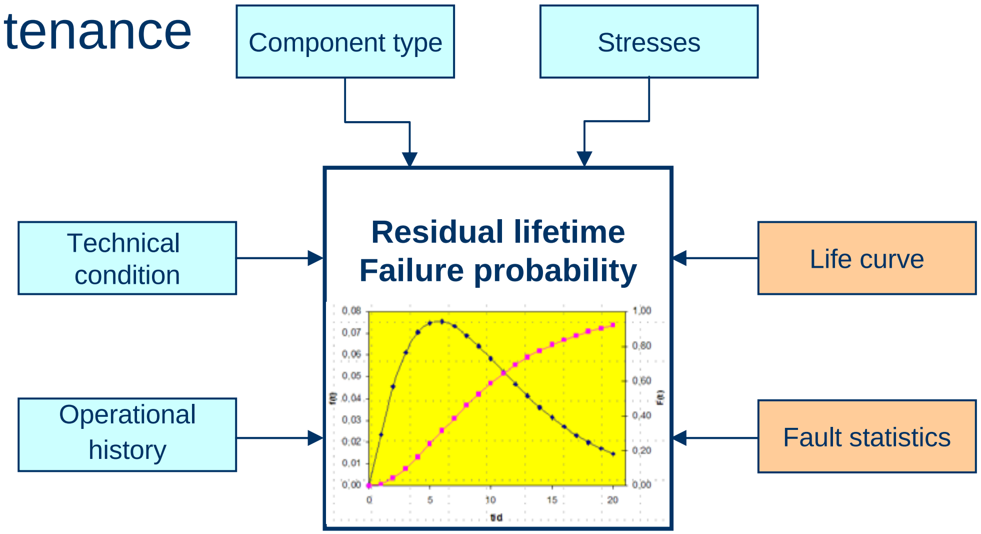
Multi fault state Markov process



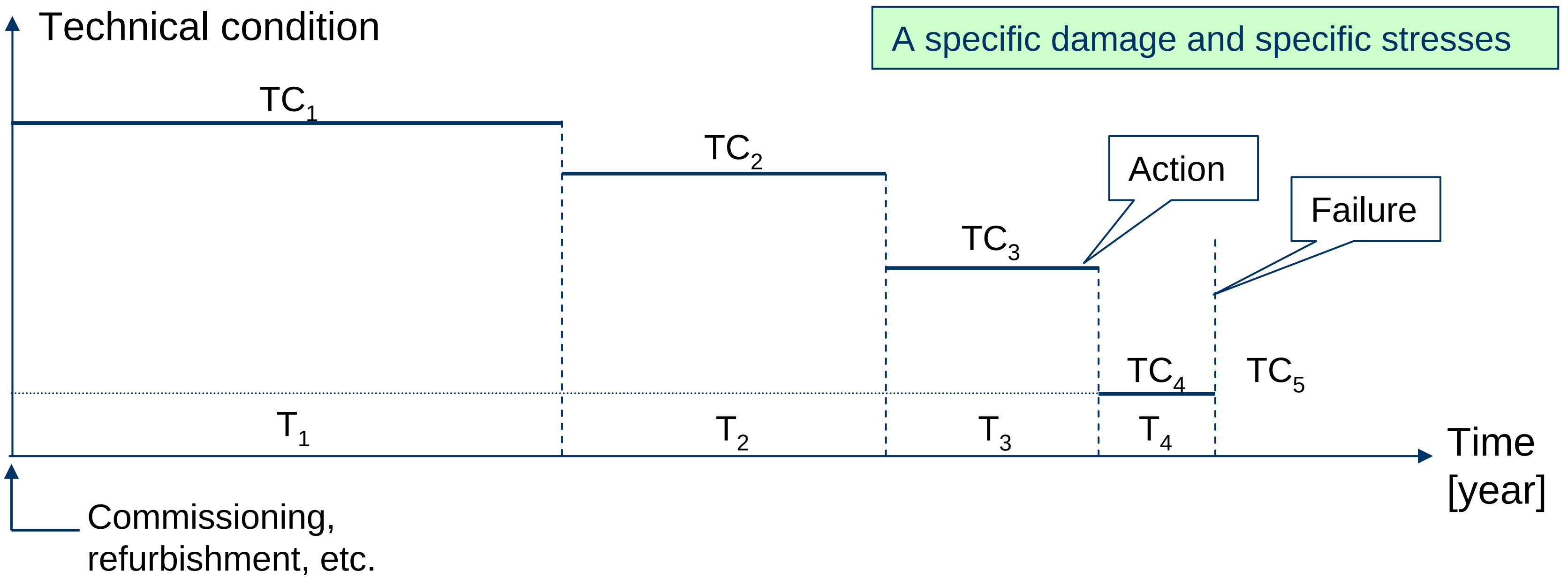
Modelling objective

- For a specific component (type) and failure mechanism:
  - Estimate residual lifetime
  - Estimate the failure probability for each year

- Basis for
  - Condition monitoring, maintenance and renewal (0-5 years)
  - Analysis of reinvestment needs (5 years ->)



Life curve (simplified)

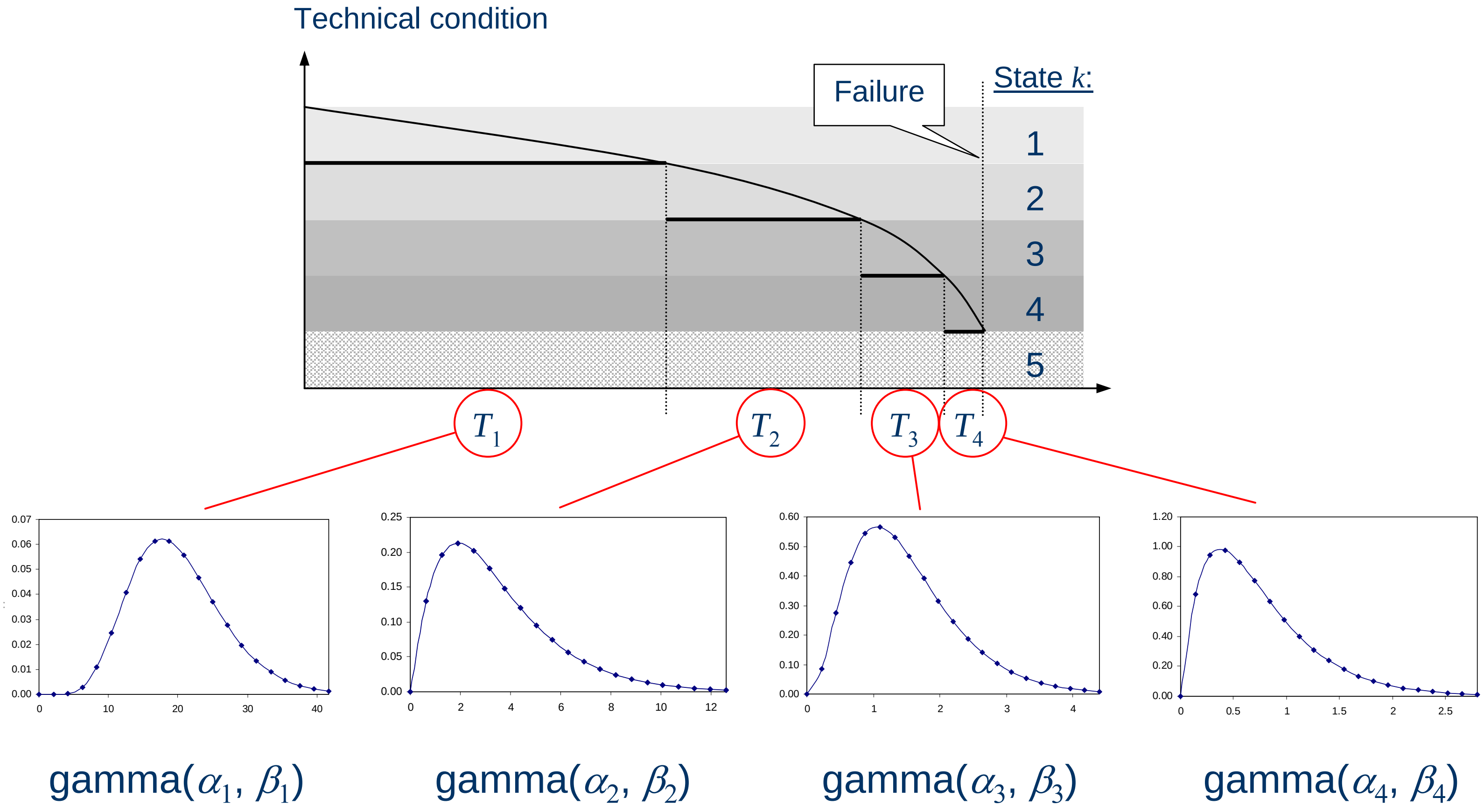


State	Description (EBL Handbooks)
1	No indication of deterioration.
2	Some indication of deterioration. The condition is noticeably worse than as new.
3	Serious deterioration. The condition is considerably worse than as new.
4	The condition is critical.
5	Failure.

Main state modeling

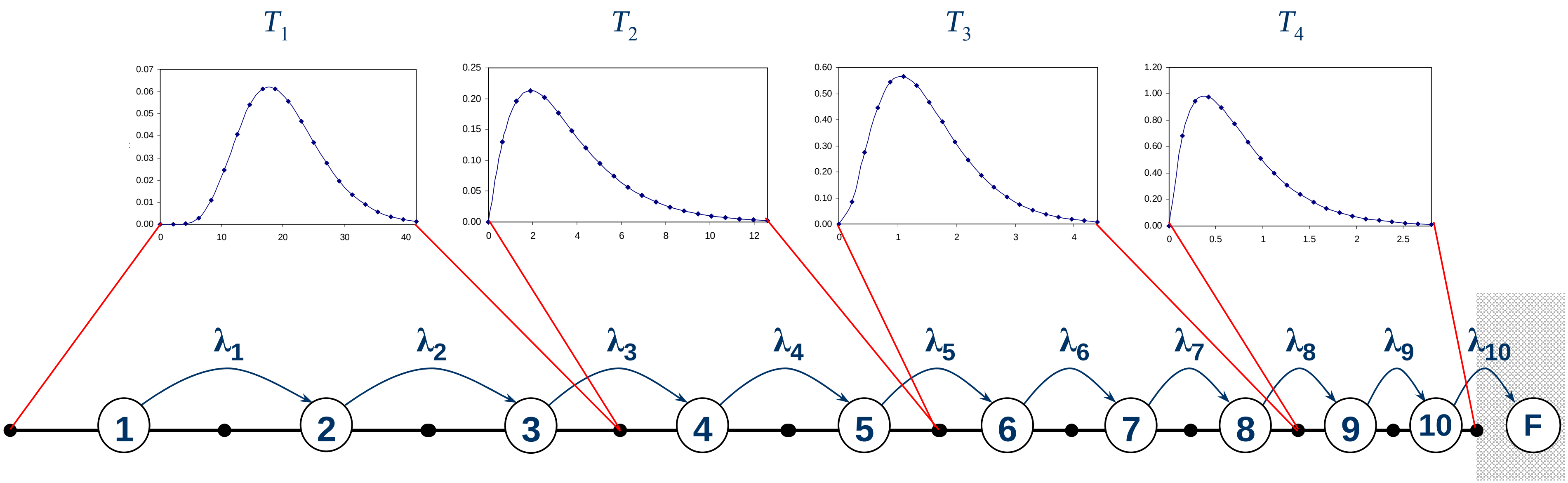
- Assumption: $T_k \sim \text{gamma}(\alpha_k, \beta_k)$

$$f(t) = \frac{1}{\beta^{\alpha_k}\Gamma(\alpha_k)} \cdot t^{\alpha_k - 1} \cdot e^{-\frac{t}{\beta_k}} dt$$



Main state model → Markov chain

- Gamma distributions are transferred into a chain of exponential distributions.



Expert judge-ment on *Circuit breaker*

1. Component description	
Component:	**Operating mechanism / energy storage**
Type:	Hydraulic
2. Fault description	
Fault mode:	**Lack of energy**
Causes:	Poor gaskets Corrosion Defect pumps etc.
Fault progress:	Increasing leakage causing lack of energy and stuck breaker
3. Normal operational state	
Parameter	Description
Number of couplings	0-10 per year

4. Criteria for assessing the states	
Main state	Criteria
2	Visible corrosion, sweaty gaskets, minor leakages
3	Coupling time or tension time significantly changed Leakage
4	Major leakage (compressor starts frequently)
5 (failure)	Insufficient coupling energy (stuck breaker)

5. Duration of state 1-4					
		T_1	T_2	T_3	T_4
Typical (expected) duration of state 1-4:	time [years]	10	10	5	1
10^{th} percentile of the duration of state 1-4:	time [years]	5	5	2	0,1

Tool for calculation of failure prob. of a specific component of a certain condition

	Expected values	10th percentile	alfa	beta
1	10,00	5,00	5,33	1,87
2	10,00	5,00	5,33	1,87
3	5,00	2,00	3,43	1,46
4	1,00	0,10	0,97	1,03
Sum:	26,00			

Based on expert judgment:

Sub-component:	Operating mechanism / energy storage
Type:	Hydraulic
Failure type:	Lack of energy
Expert:	NN
Company:	XX

Technical condition:	new	1	+ 2 -	+ 3 -	+ 4 -
			x		

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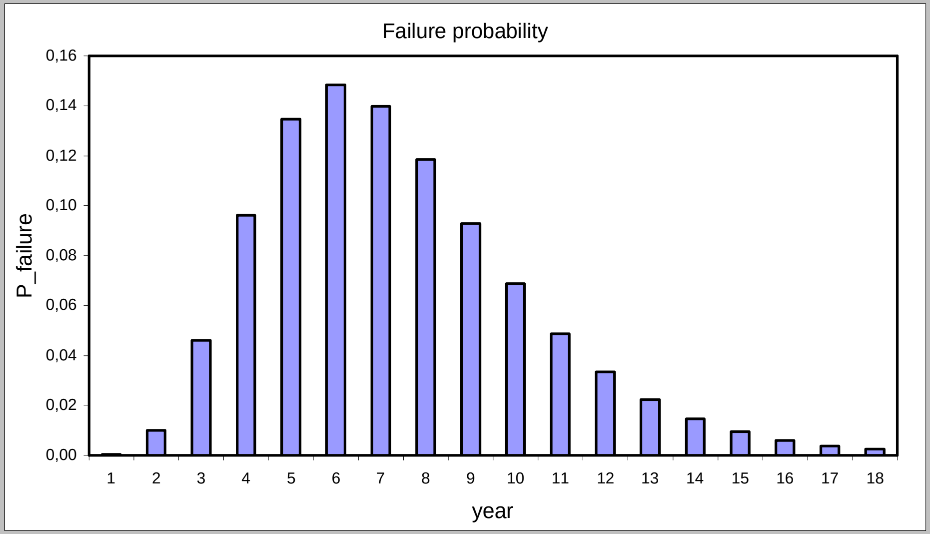
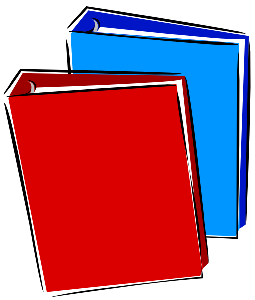
Next year

year	Failure probability	Cumulative probability
1	0,000329	0,000329
2	0,010102	0,010432
3	0,046032	0,056464
4	0,096251	0,152715
5	0,134641	0,287356
6	0,148304	0,435660
7	0,139832	0,575492
8	0,118422	0,693914
9	0,092837	0,786751
10	0,068732	0,855483
11	0,048731	0,904215
12	0,033421	0,937636
13	0,022337	0,959972
14	0,014630	0,974602
15	0,009430	0,984032
16	0,005940	0,989972
17	0,003806	0,993778
18	0,002380	0,996158
19	0,001479	0,997637
20	0,000914	0,998550

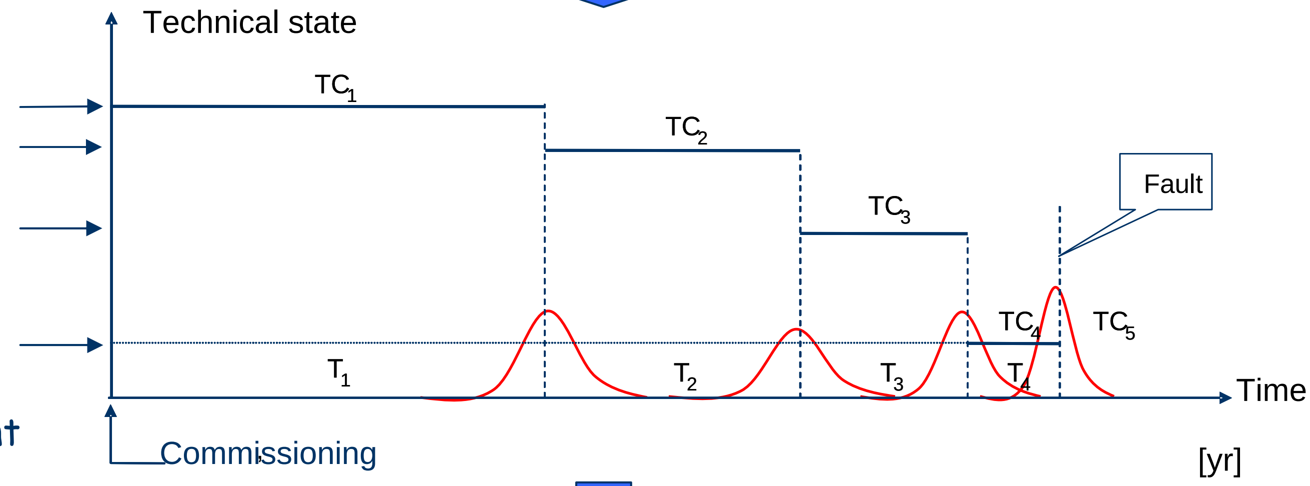


Application of the method

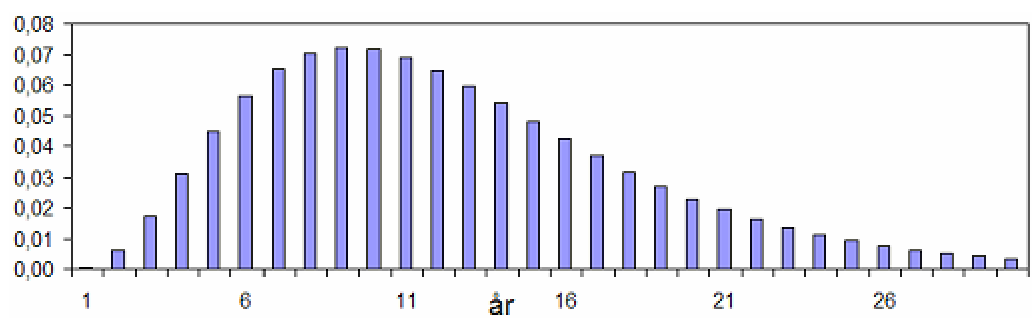
- Answer to the basic question: What is the probability of failure in e.g. the next 5 years?
- Calculate the expected costs of unwanted events
- Calculate economical utilitarian value of maintenance and re-investment projects
- Document a project's effect on various “qualitative” elements (health, environment, safety, PR, etc.)
- Quantify the effect of different maintenance strategies



Guidelines for Condition assessment



Failure probability




To protect against acts of God - still a challenge, but…
akkurat nå

the distribution system will be useful for many years….