AFRY

ÅF PÖYRY

Model Based Reliability Analysis

THTH SPRING WEBINAR 2023
MIIKKA TAMMI

Miikka Tammi

- Tampere University of Technology: M.Sc.
  - 2004
  - Information Technology
- Artekus Oy: Software designer
  - 2004-2006
  - Development of reliability tools
- Ramentor Oy: Manager, Products and Projects
  - 2006-2020
  - Reliability and risk analysis projects to various targets
- **AFRY: Senior Reliability Expert**
  - 2020-
  - Reliability and risk analysis projects to various targets
- Comments and questions:
  - miikka.tammi@afry.com, 040-5341117

Background – AFRY

- AFRY is a European leader in sustainable engineering, design, and advisory with a global reach.
  - 19 000 employees globally (3 000 employees in Finland)
  - Offices in >40 countries (~30 locations in Finland), projects in >100 countries
  - Net sales of approx. 2.2 billion euros
- In 2019 ÅF and Pöyry joined forces and launched a new brand, AFRY.
- Mission: We accelerate the transition towards a sustainable society.
- We are devoted experts in industry, energy and infrastructure sectors, creating impact for generations to come.

Providing leading solutions for generations to come
– Making Future

AFRY
ÅF PÖYRY

Our offerings in six divisions

INFRASTRUCTURE

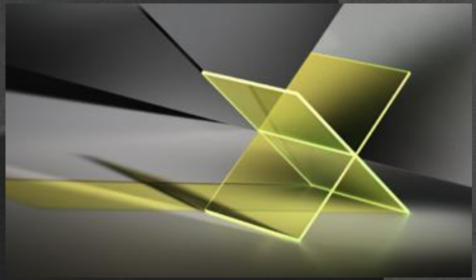
Real estate
Rail & Road
Architecture
Environment
Water

ENERGY

Hydro
Renewables
Nuclear
Transmission & Distribution

INDUSTRIAL & DIGITAL SOLUTIONS

Food & Life Science
Product and Software Design
Automation
Defense



AFRY X

Bioindustry
Clean Energy
Forestry
Infrastructure
Real estate

PROCESS INDUSTRIES

Pulp, Board, paper & tissue
Biorefining
Chemicals
Mining & Metals
Batteries
Textiles
Power-to-X

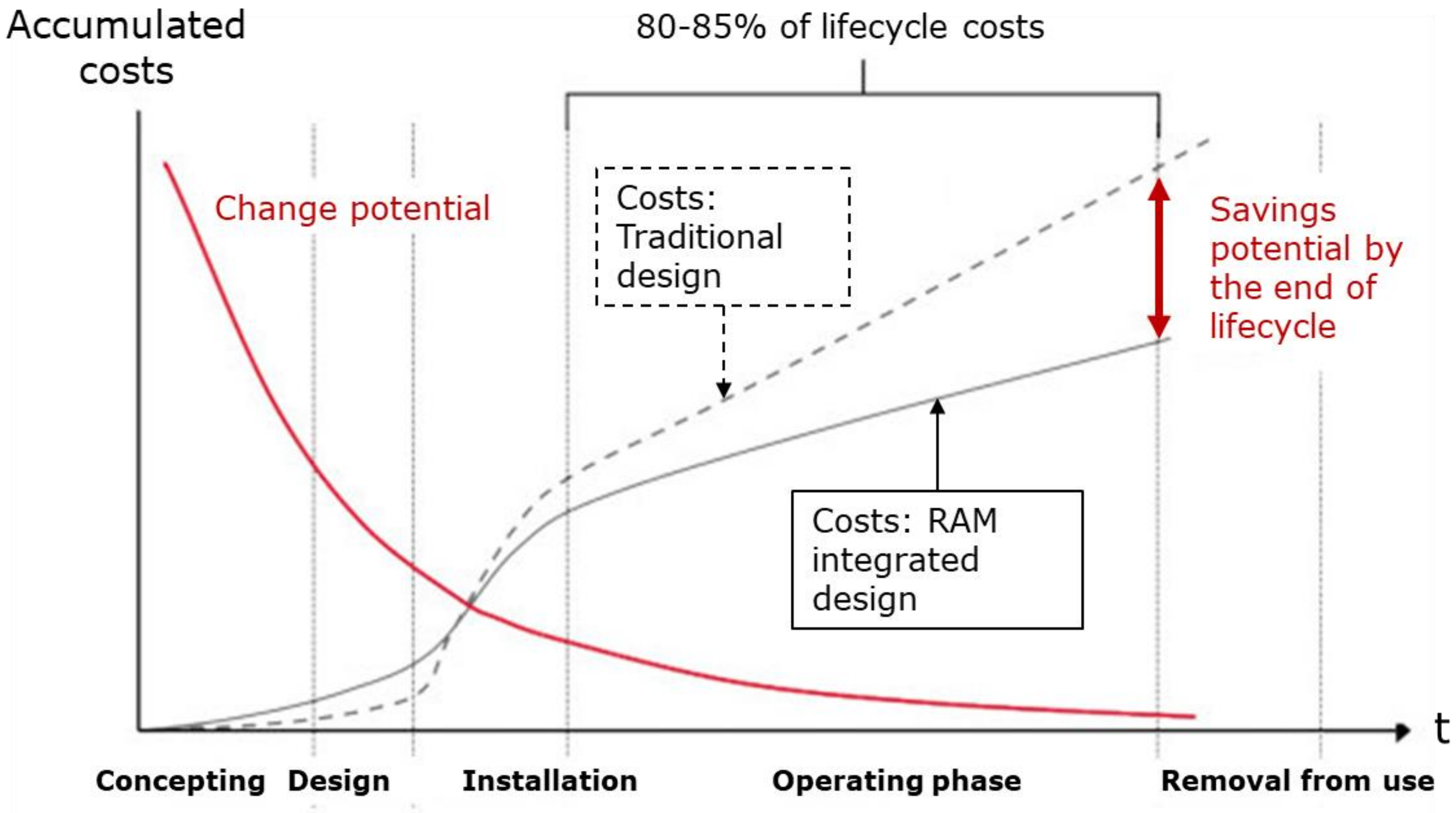
MANAGEMENT CONSULTING

Bioindustry
Energy
Capital
Industry

AFRY
ÅF PÖYRY

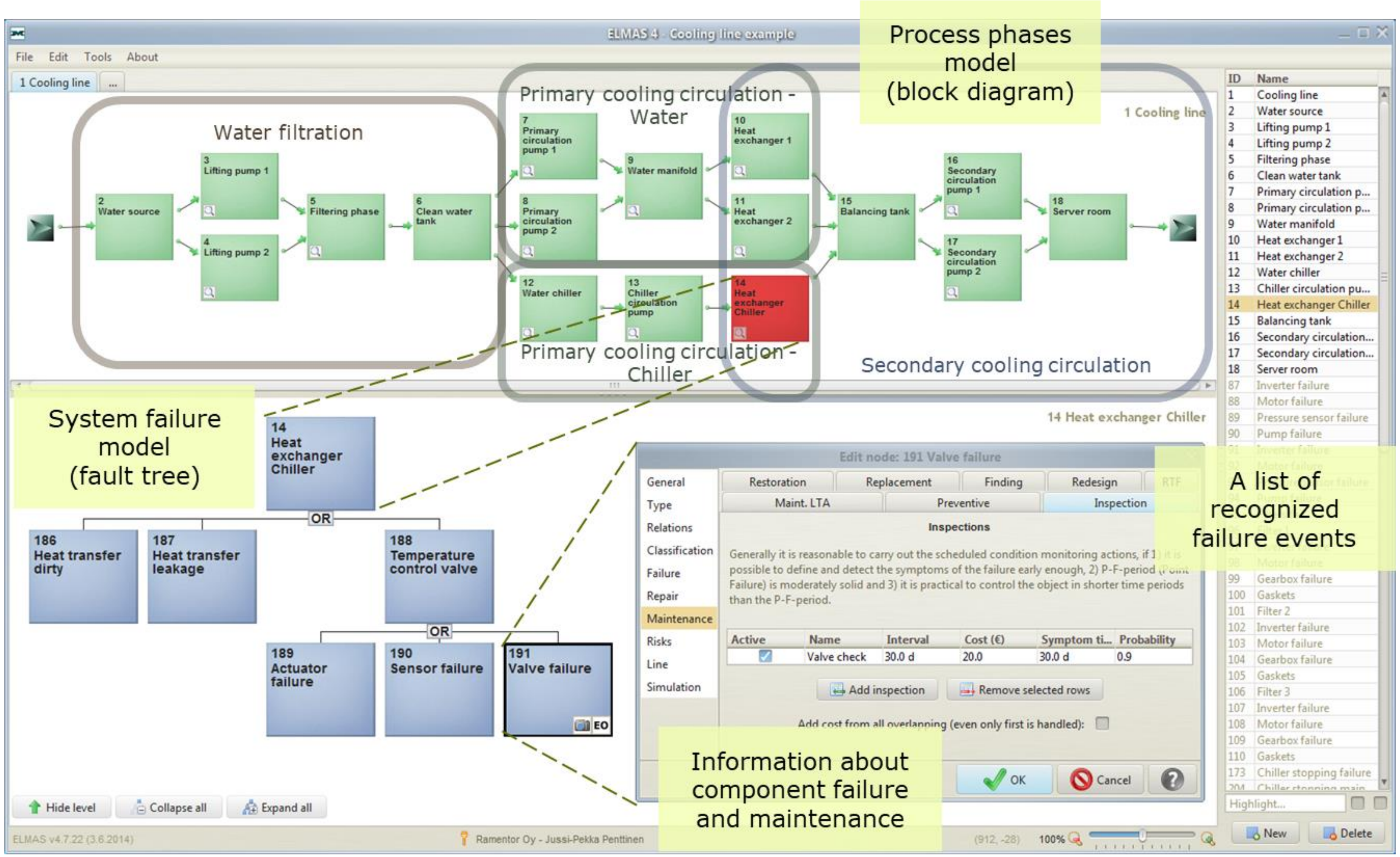
Design for RAM

- **RAM** stands for **R**eliability, **A**vailability and **M**aintainability
- Majority of RAM related decisions have a big effect on lifecycle costs of the system
- The earlier RAM can be affected, the bigger the potential for lifecycle savings will be



Model based reliability and RAM analysis

- Model based RAM analysis is introduced in five parts
  - Simple analysis models based on device hierarchy and history data
  - Modelling of failure modes, causalities and future estimated
  - Scenario analysis
  - RAM analysis at design phase
  - Analysis of complex systems



AFRY
ÅF PÖYRY

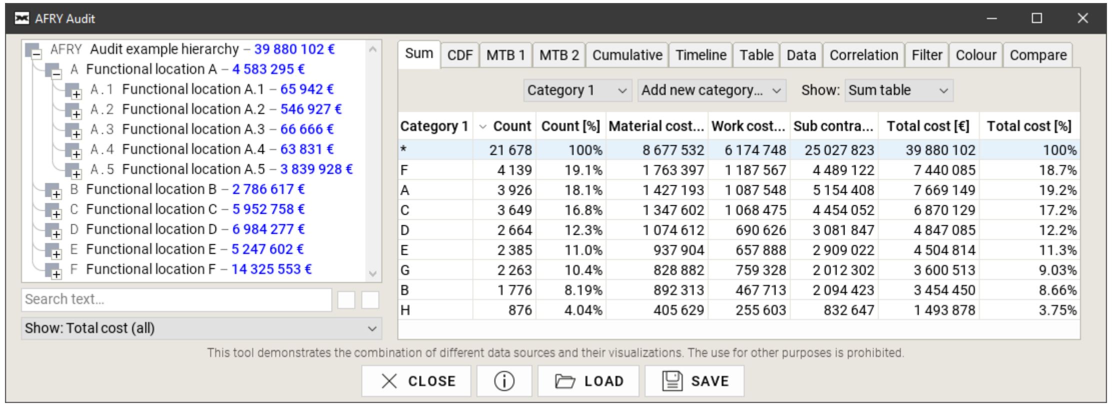
History Data Audit

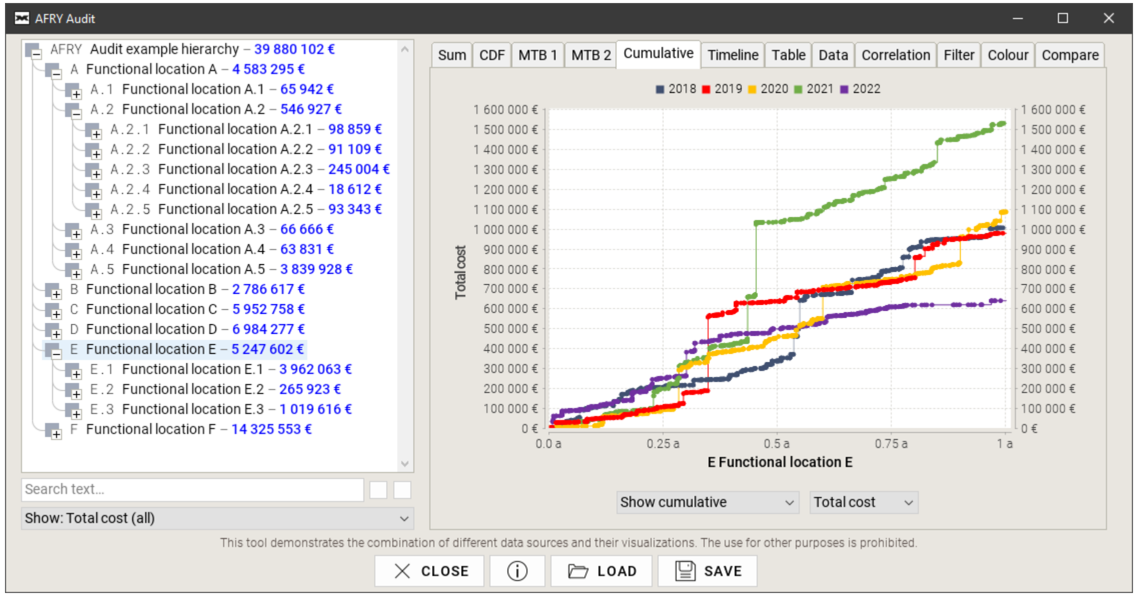
— A tool for understanding history data

— Combines and visualizes data from
  - — event history (CMMS)
  - — automation systems (DCS)
  - — manufacturing process (MES)
  - — condition monitoring
  - — etc.

— Various analysis perspectives turn the data into knowledge that supports decision making

— Helps to identify trends in history data and creates TOP listings





MODEL BASED RELIABILITY ANALYSIS

1) Audit ➔ 2) Modelling ➔ 3) Scenarios

Data lake

Device hierarchy (CMMS)

Event history (CMMS)
- Notification history: Functional location, equipment, notification type, work centre, failure code, breakdown, priority, ABC, …
- Order history: Costs

Breakdown durations (CMMS) / Production losses (MES)

Other data sources
- Automation (DCS), Condition monitoring, …

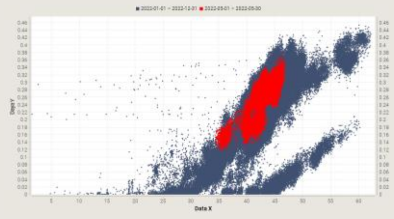
Data API / Excel

What is happening?

1) Audit:
- Data-based analyses
- Criticalities

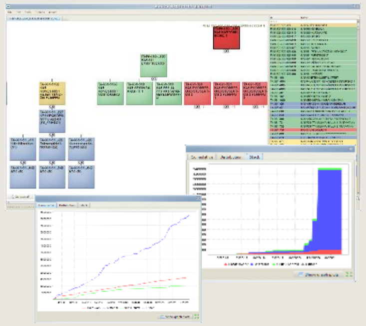
What does it mean in the long run?

2) RAM modelling:
- Failure modes
- Future estimates
- Causalities and correlations



Where should I invest?

3) Scenario analysis:
- Maintenance optimization
- Return on investment
- Spare parts

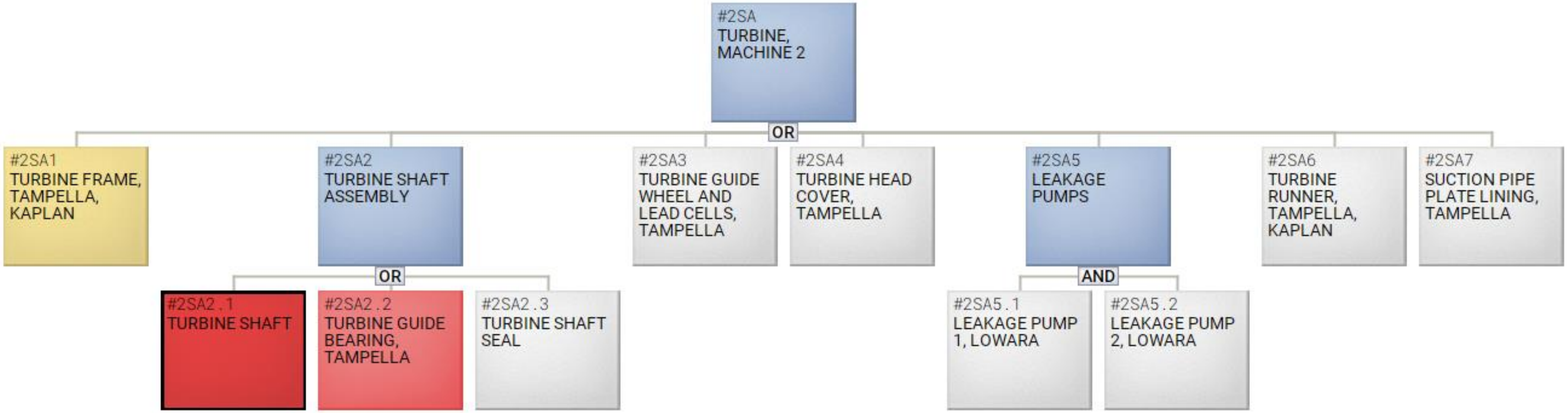


Experts' knowledge, Failure trend estimates

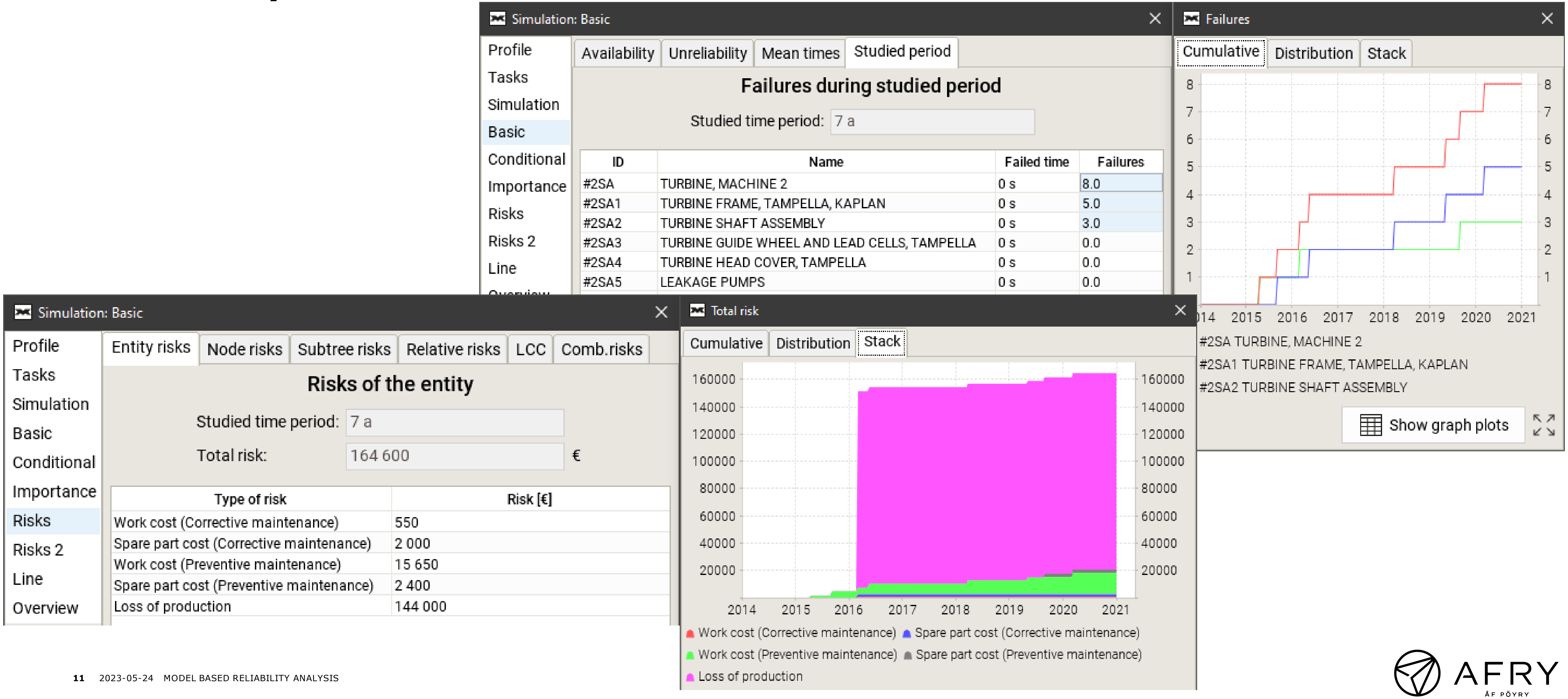
Potential investments, big repairs and other scenarios

AFRY
ÅF PÖYRY

Scenario analysis example: Turbine Machine

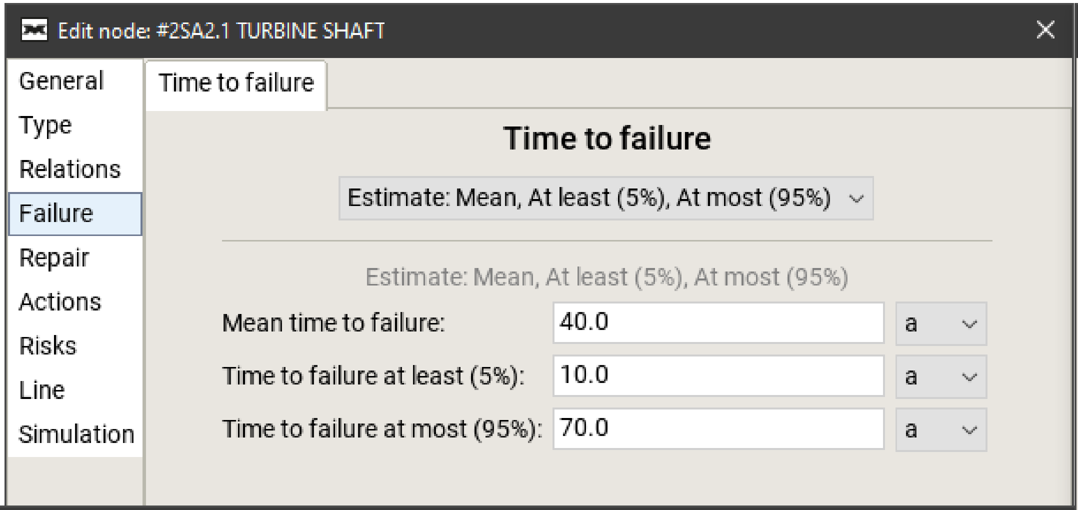


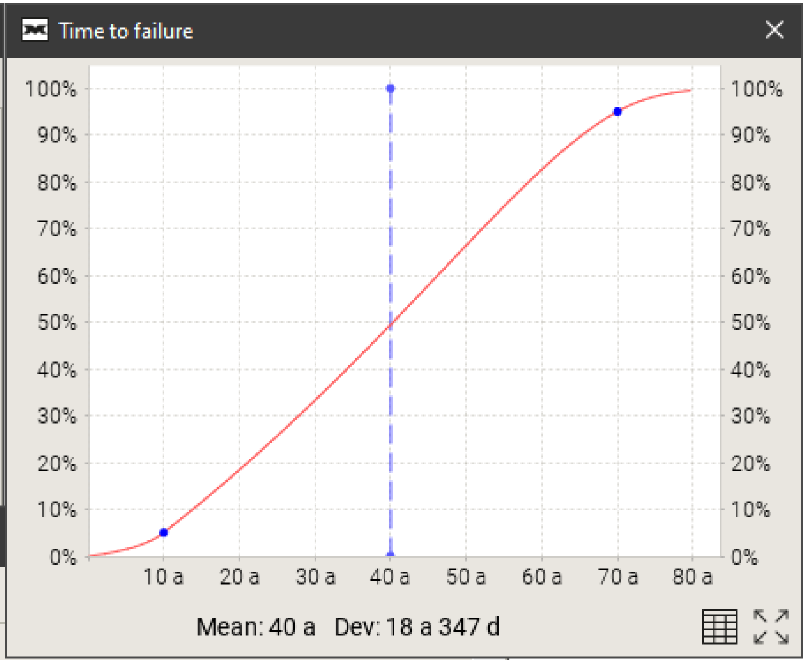
History data: Cumulative failures and costs

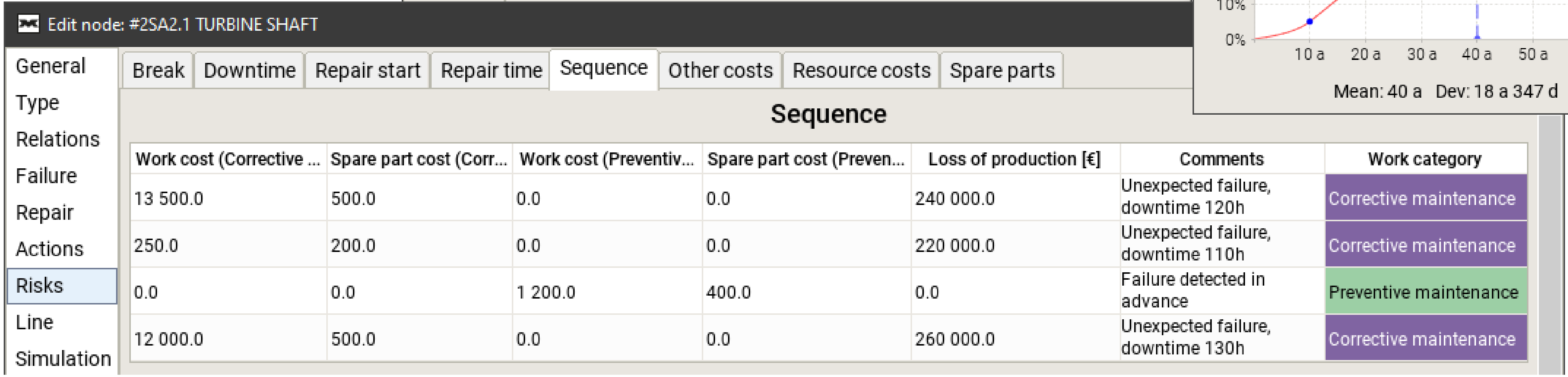


AFRY
ÅF PÖYRY

Failure and cost estimations for future

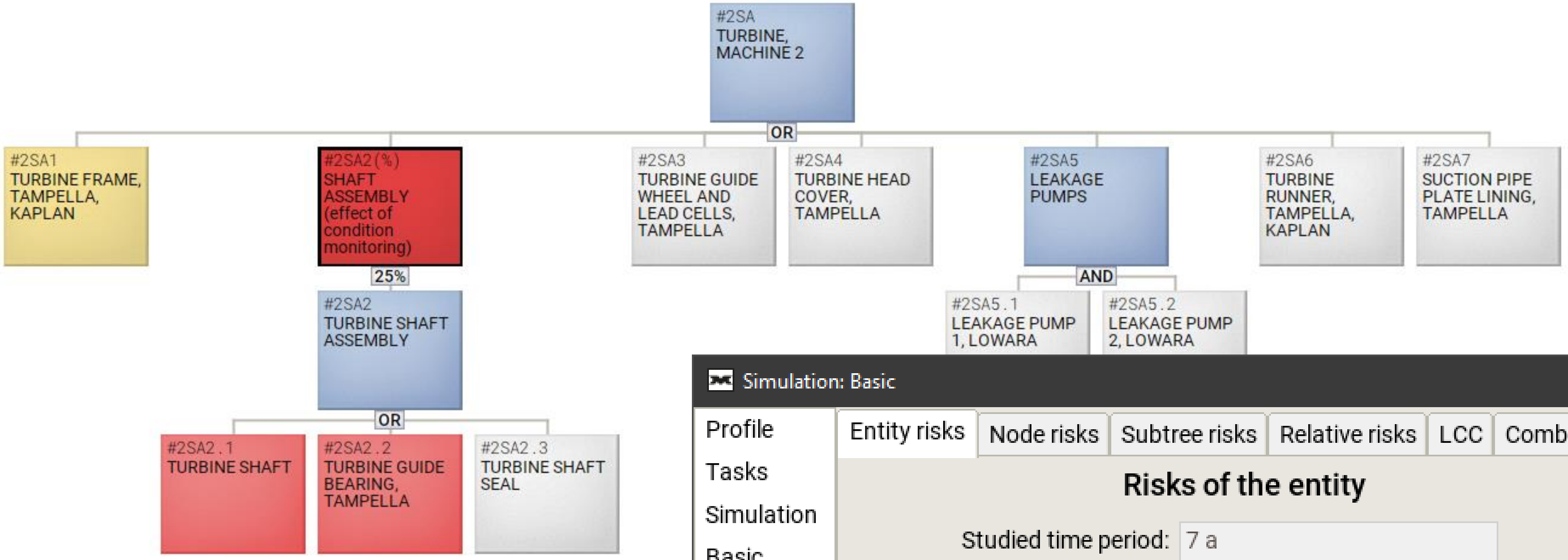


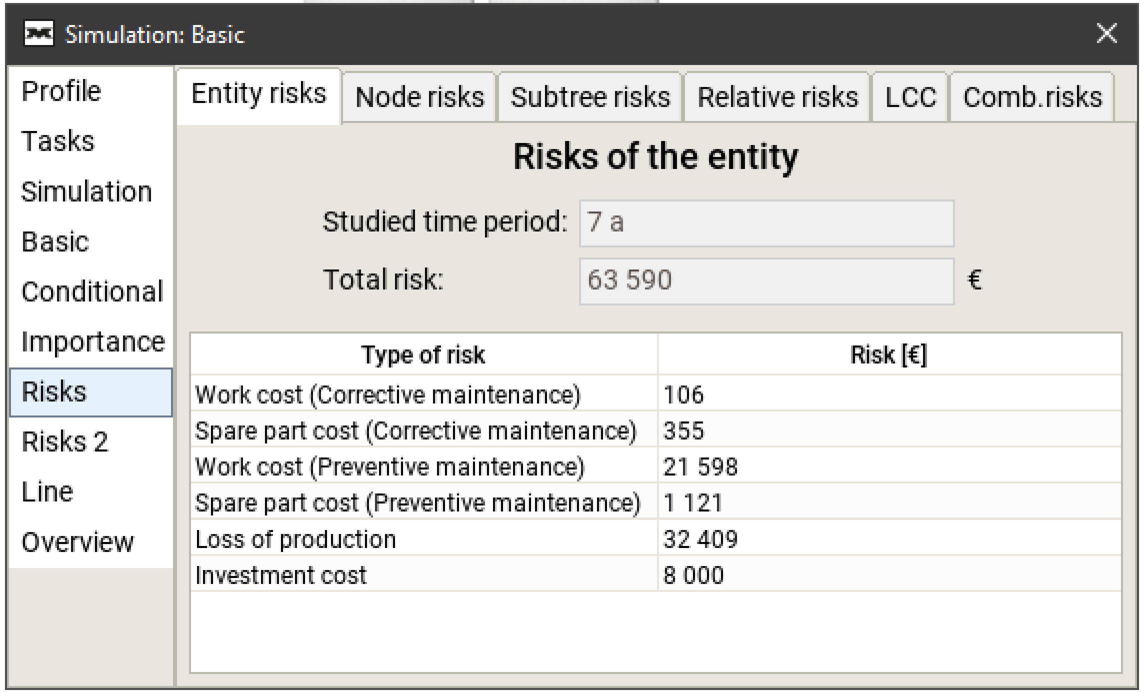




Work cost (Corrective ...	Spare part cost (Corr...	Work cost (Preventiv...	Spare part cost (Preven...	Loss of production [€]	Comments	Work category
13 500.0	500.0	0.0	0.0	240 000.0	Unexpected failure, downtime 120h	Corrective maintenance
250.0	200.0	0.0	0.0	220 000.0	Unexpected failure, downtime 110h	Corrective maintenance
0.0	0.0	1 200.0	400.0	0.0	Failure detected in advance	Preventive maintenance
12 000.0	500.0	0.0	0.0	260 000.0	Unexpected failure, downtime 130h	Corrective maintenance

Improvement actions and new simulation





Risks of the entity

Studied time period: 7 a

Total risk: 63 590 €

Type of risk	Risk [€]
Work cost (Corrective maintenance)	106
Spare part cost (Corrective maintenance)	355
Work cost (Preventive maintenance)	21 598
Spare part cost (Preventive maintenance)	1 121
Loss of production	32 409
Investment cost	8 000

RAM modeling and analysis at design phase

- RAM modeling and analysis at design phase is done based on design documentation, expert knowledge and generic failure databases
- Advantages of design for RAM
  - Possibility to significantly improve system availability and reliability
  - Provides an estimate for expected system availability and reliability
  - Calculates how different improvement actions affect system availability
  - Verifies design plan from maintenance point of view
  - Helps to understanding and acknowledging the remaining biggest risk factors
  - Small work efforts have potential to make huge savings during lifecycle

Modeling and analysis of complex systems

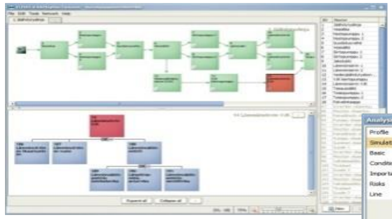
Complex System Modelling & Analysis

Phase 1
Creating the System Failure Model

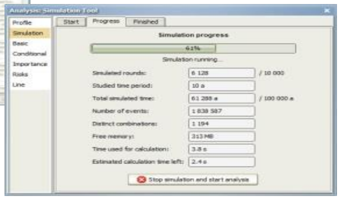
System failure model describes cause-consequence relations of equipment failures and system level affects to operation and costs

Modelling and Simulation

- Modelling complex systems
- Simulating system operation during it’s life cycle



System failure model



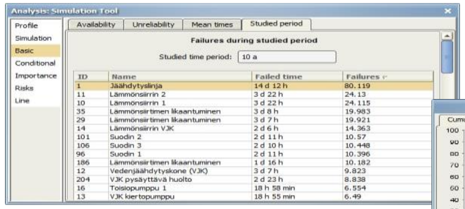
Simulation tool

Phase 2
Definition of the Critical Equipment

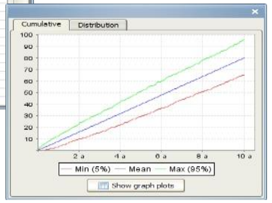
Defining and selecting of critical equipment is possible based on the system failure model and simulation results

RAM Results

- Achieving results concerning system availability, equipment criticalities, cost risks etc



Most critical equipment



Predicted failure trends

RCM Analysis

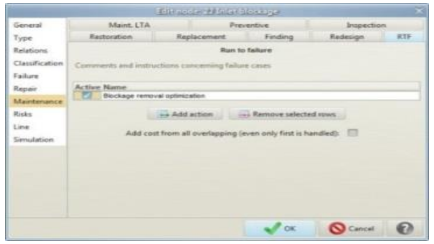
Phase 3
Development of an Action Plan

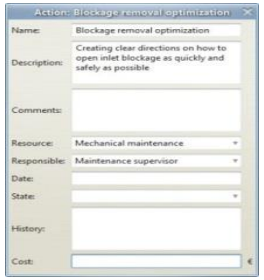
Defining applicable and cost effective actions for the critical equipment minority based on Reliability Centred Maintenance (RCM) methodology

Action Planning

- Updating and creating RCM-based maintenance action plans

Maintenance action planning



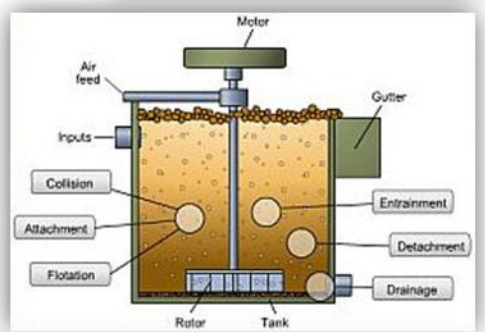


Advantages of continuous RAM development

— Possibility to improve system availability and reliability
— Understanding which factors lowers availability and reliability the most
— Finding out how different improvement actions can improve system availability
— Allows focusing maintenance resources to the right targets
— Possibility to optimize system maintenance supportability
— Better understanding on system risk factors and how to prepare for them

Case example: Mineral Processing Line

- Flotation process
  - Six processing tanks
  - Installed in series
  - Forming three tank pair units
- Goal of process
  - Recover metal particles from the slurry flowing through the tanks
  - with the help of rising air bubbles from the bottom of the processing tank



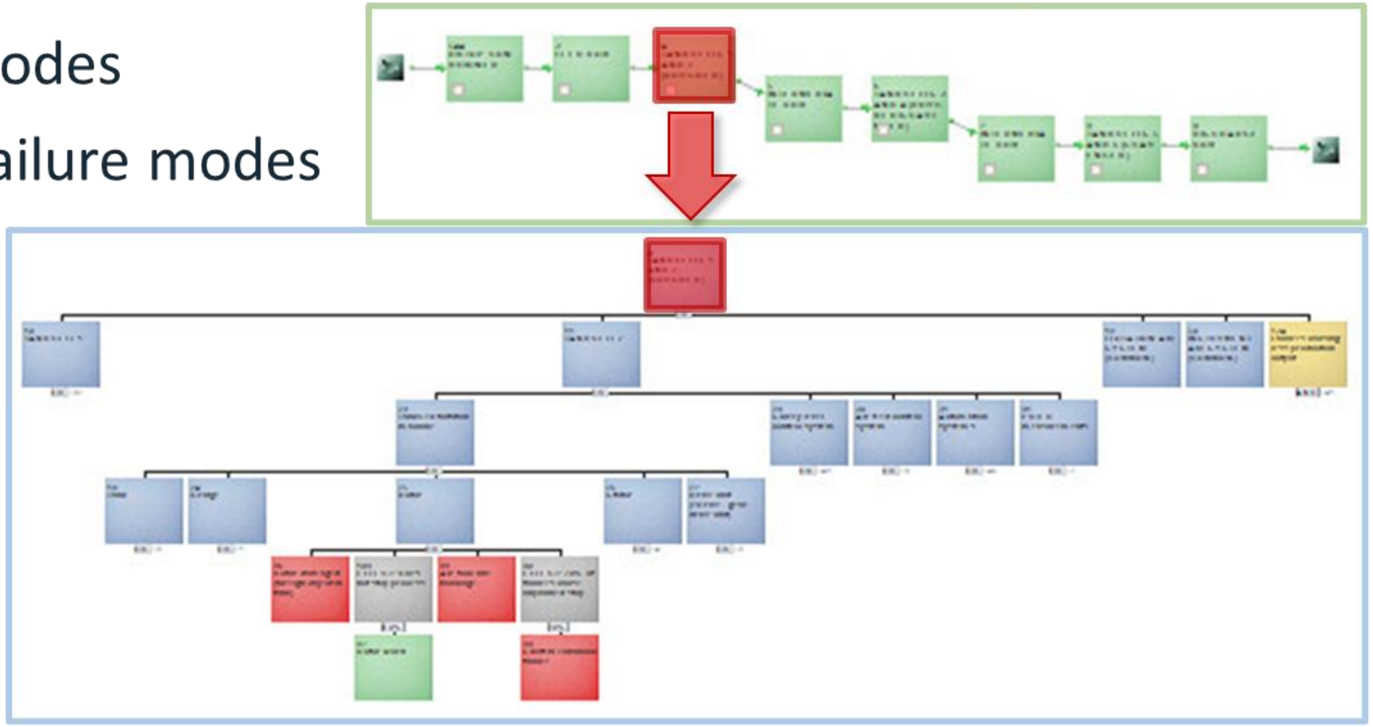
Case example: Mineral Processing Line

- The main goals of the project were:
  1) **Determine the availability and OEE** of the analyzed process line
  2) **Locate critical failure modes** for the line operation
  3) **Create methods for increasing the OEE value** of the process
- Project team (Experts from Ramentor and client) created a model
  - All mechanical and automation components included
  - Components of processing tanks and supporting systems included
  - Also process and user-related faults included
- Overall equipment effectiveness (OEE)
  - In addition to availability also performance (and quality) included

AFRY
ÅF PÖYRY

Case example: Mineral Processing Line

- The **flow characteristics** model of the flotation process was combined with extensive **fault tree analytics**
- 600 nodes
- 200 failure modes



Case example: Mineral Processing Line

1) The failure events slowing down the production had a major effect on the line OEE value (High availability, Low OEE)
   - Failures stopping the production caused **30%** of the total loss
   - Failures slowing down the process **70%** of the total loss

➡ **Focus on the situations slowing down the process**

2) About **10%** of the failure modes caused over **83%** of the total lost production

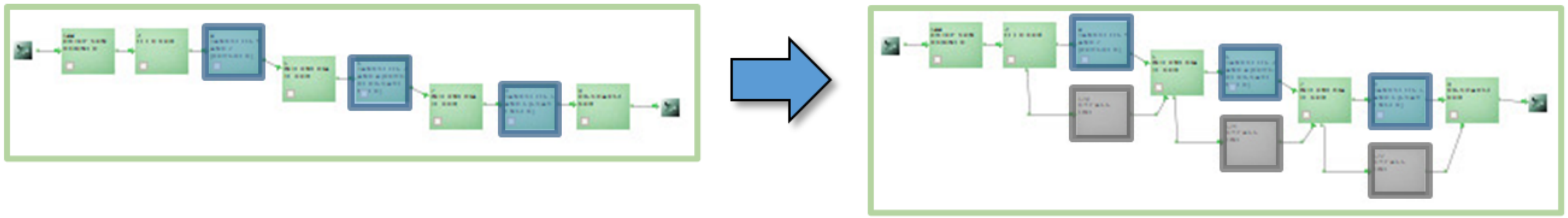
➡ **Focus on the highest impact failure modes**

AFRY
ÅF PÖYRY

Case example: Mineral Processing Line

- The effect of maintenance bypass lines installation shown
  - Direct the process flow around when a tank pair on repair
  - Only minor slowing down for the process during bypass

Tank pairs   Maintenance bypass lines



- MPL manufacturer can justify the investment to customer
  - Lost production decreases by millions of euros during 10 years
  - The installation is quite inexpensive -> Very good investment!

Questions or Comments?

AFRY
ÅF PÖYRY

Making Future

AFRY
ÅF PÖYRY