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Criticality classification – Data sources and requirements

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- Tampere University of Technology: M.Sc. (2005)
  - Thesis: Analysis of failure logic using simulation
- Ramentor Oy: Chief Architect (2004-2020)
  - Development of ELMAS tool
  - Research of reliability and risk analysis methods
- Tampere University: D.Sc. (2020)
  - Dissertation: An Object-Oriented Modelling Framework for Probabilistic Risk and Performance Assessment of Complex Systems
- AFRY: Senior Adviser (2020-)
  - Reliability analysis and risk assessment: Research, development and application to various targets
  - AFRY Reliability Tools
- Comments and questions:
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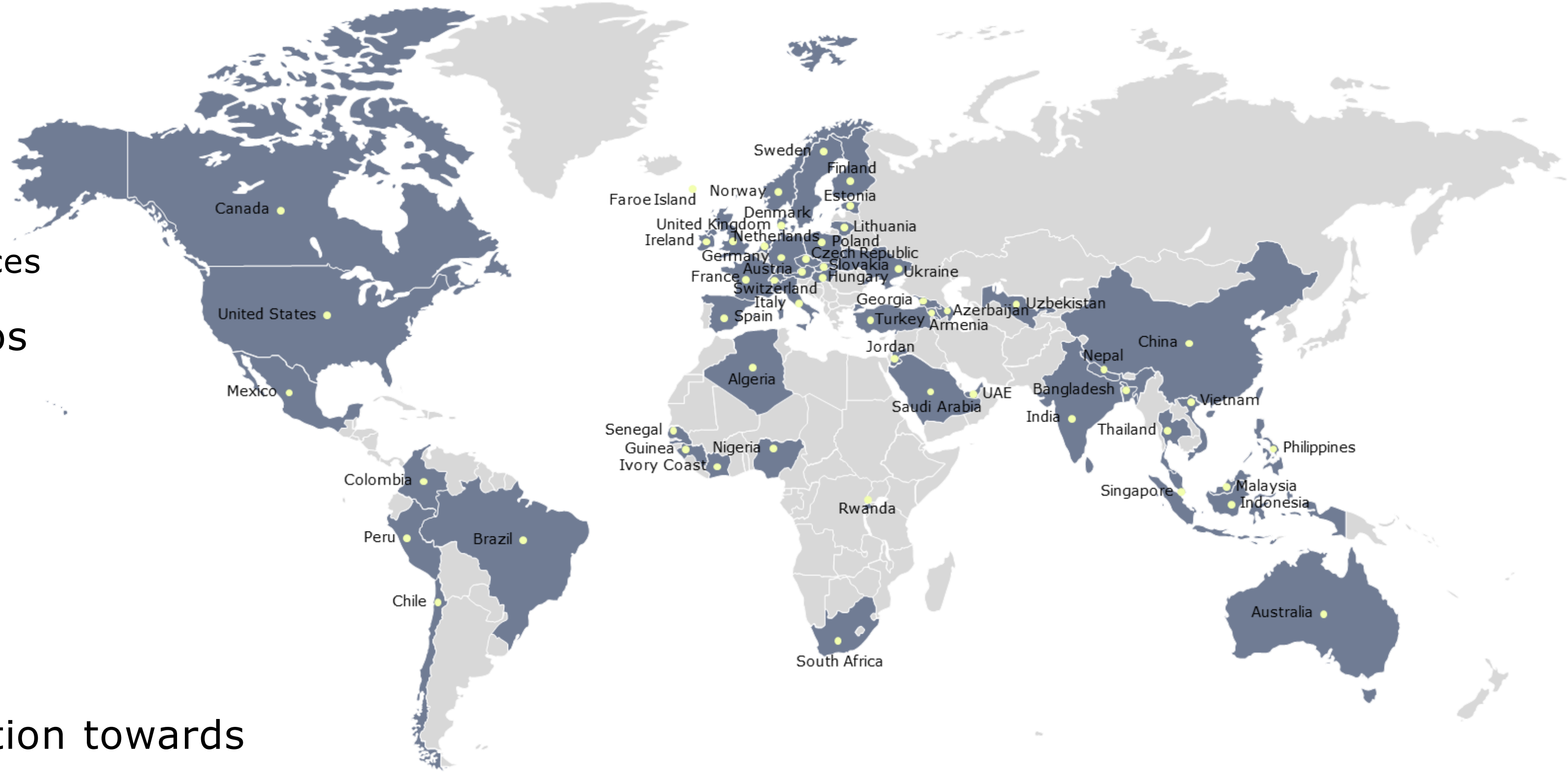
MAKING FUTURE

Engineered by AFRY

- AFRY provides engineering, design, digital and advisory services to accelerate the transition towards a sustainable society.
- Five divisions:
  - Infrastructure
  - Industrial & Digital Solutions
  - Process Industries
  - Energy
  - Management Consulting
- Three main sectors: Infrastructure, Industry and Energy
- ÅF and Pöyry became AFRY
  - In February 2019 ÅF and Pöyry joined forces.
  - In November 2019 ÅF Pöyry launched a new common brand, AFRY.

AFRY around the world

- Nordic roots with a global reach
  - 19 000 employees
  - Projects across > 100 countries
  - Across > 40 countries with AFRY offices
- Net sales of about 2.4 billion euros
  - 75% of sales in the Nordic Market
  - 75% of project sales
  - 75% of sales to private sector
  - Listed on Nasdaq Stockholm



- Mission: We accelerate the transition towards a sustainable society

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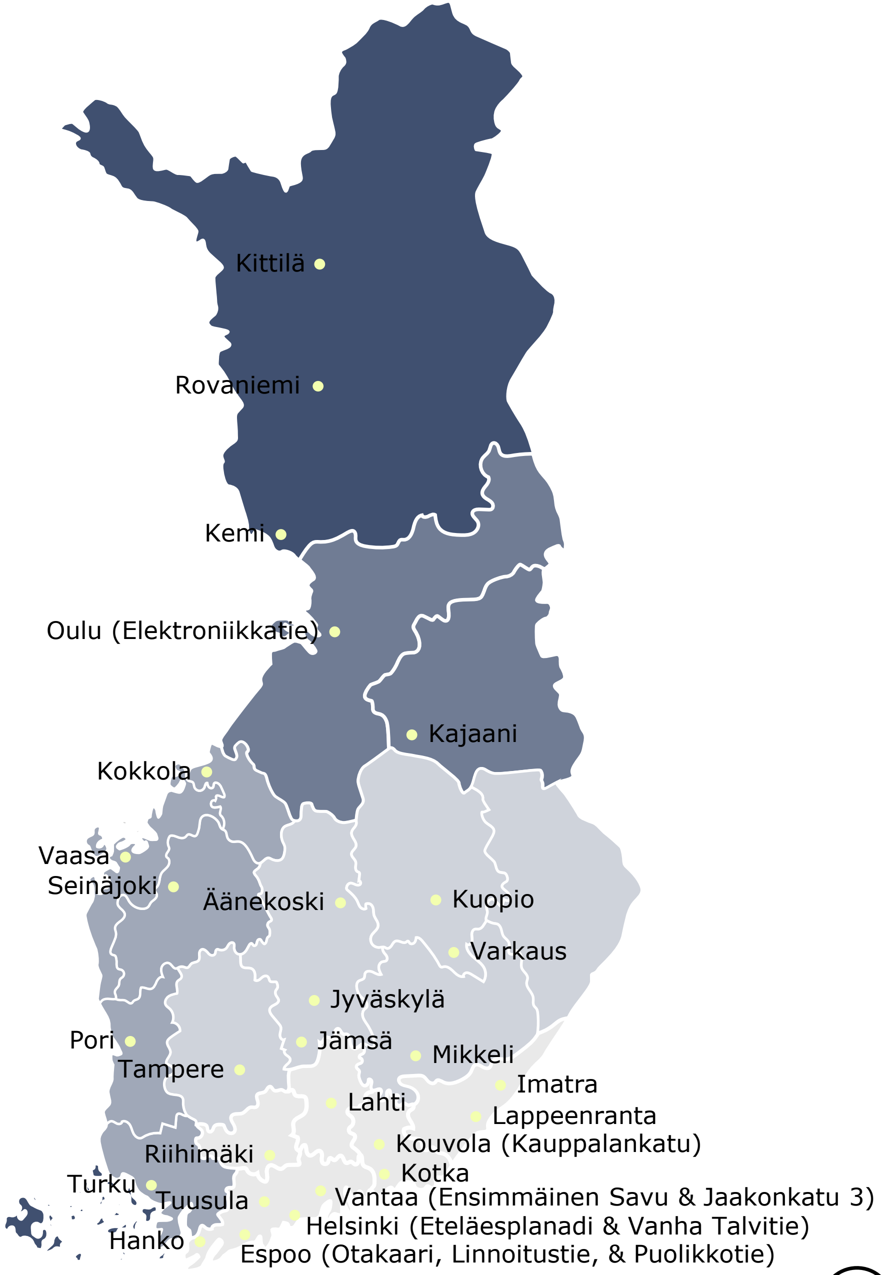
AFRY in Finland

- About 3 000 employees in Finland
- Offices in around 30 locations across Finland, from Hanko to Kittilä

Finland

Finnish Lapland	3
Oulu	2
West Coast	5
Finnish Lakeland	7
Southern Finland	10



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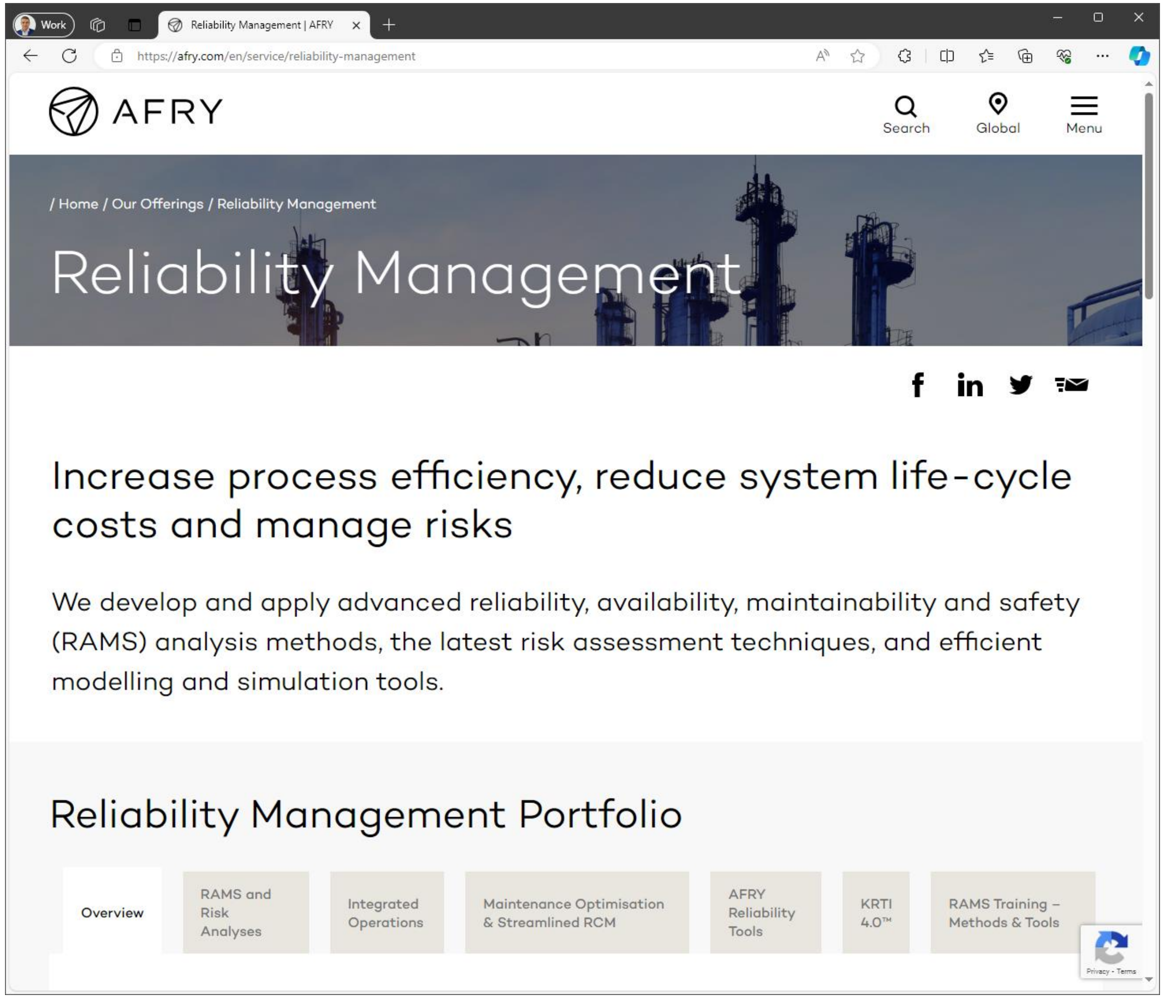
AFRY Reliability Management

- **AFRY Reliability Management**: Provides advanced RAMS analysis and risk assessment services using efficient tools
  - AFRY Reliability Management section
  - RAMS analysis services
- **Expertise**: Eight experts each with 10-20 years of experience across various industry sectors
- **Experience**: Over 200 successfully completed projects related to reliability and risk assessment since 2010
- **AFRY Reliability Tools** portal: Provides analysis tools and instruction documents
  - Web page: http://reliability.afry.com
  - Contact: reliability@afry.com

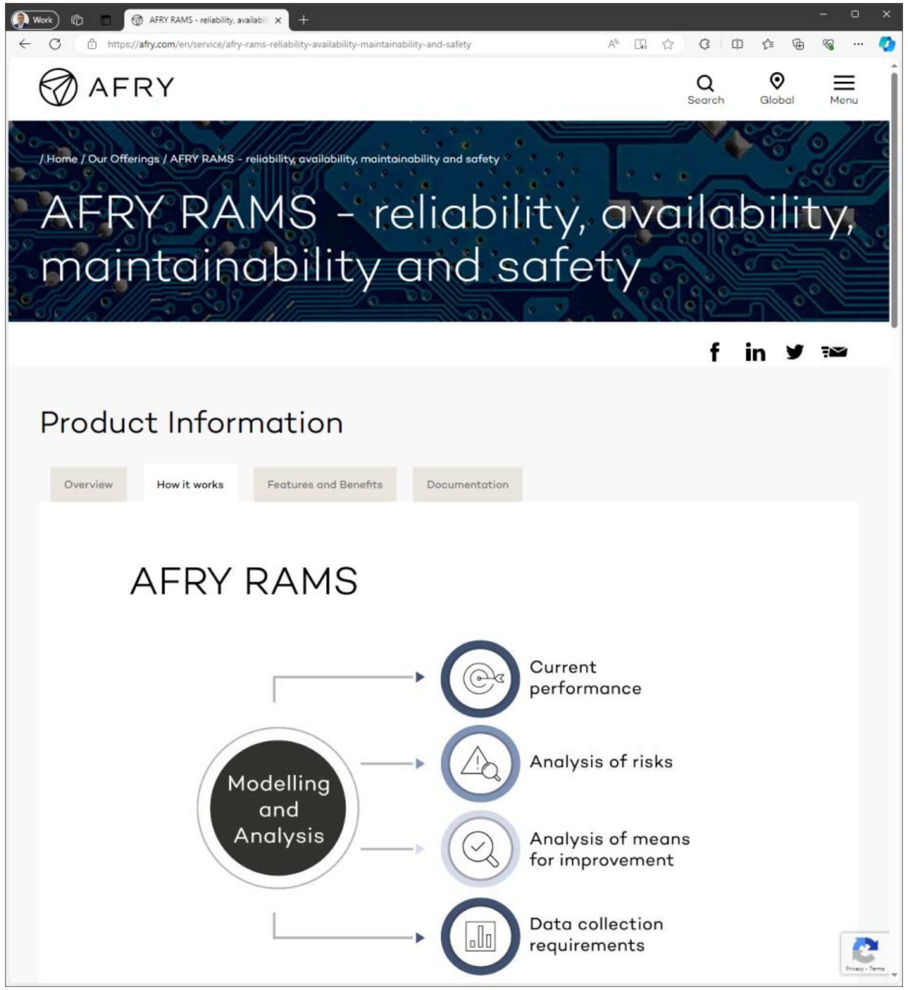


AFRY Reliability Management – Key services

- Model-based RAMS analyses (**AFRY ELMAS** tool)
  - Optimise Reliability, Availability, Maintainability and Supportability/Safety (RAMS) factors
  - Predict overall costs and forecast resource requirements
- O&M data analyses (**AFRY Audit** tool)
  - Translate data into valuable insights for resource prioritization and investment planning
- Criticality classification (**AFRY Criti** tool)
  - Improve operational availability and prioritise maintenance actions

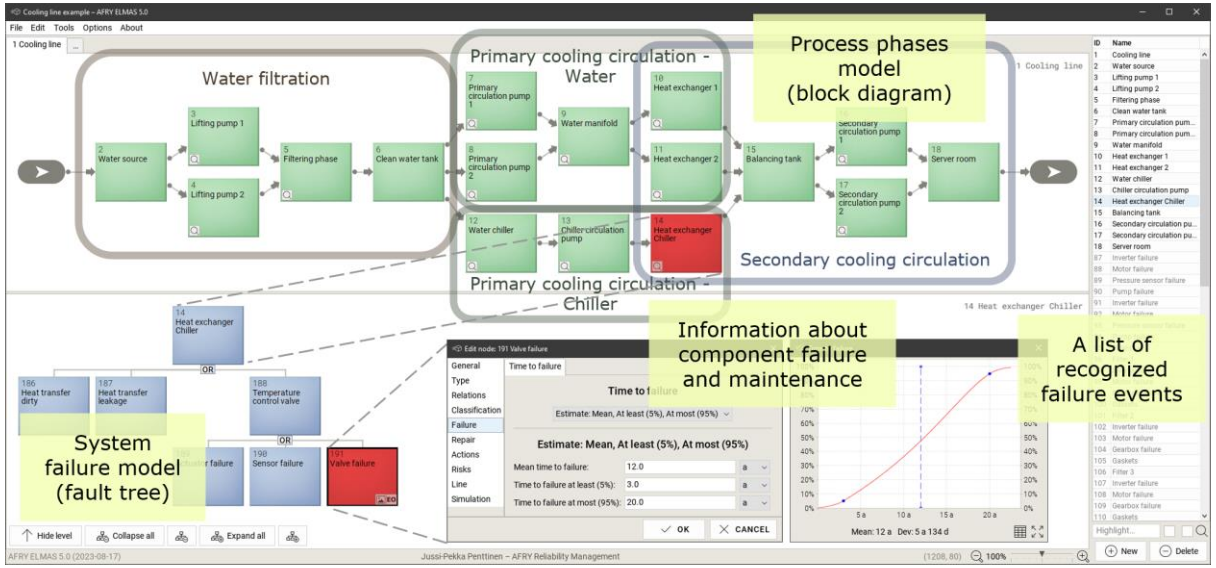
Various other services and tools, for example:

- RAMS requirements allocation (**AFRY Alloc** tool)
- Fleet availability analysis (**AFRY Fleet** tool)
- Spare part optimization (**AFRY Stock** tool)



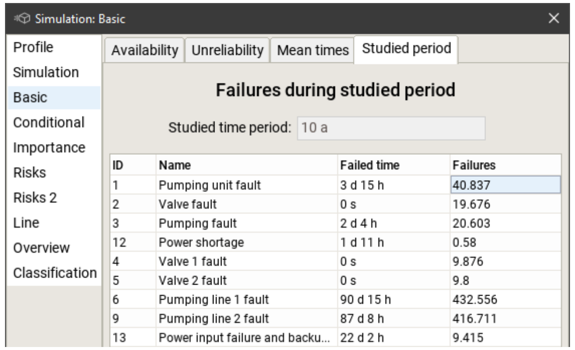
AFRY RELIABILITY MANAGEMENT

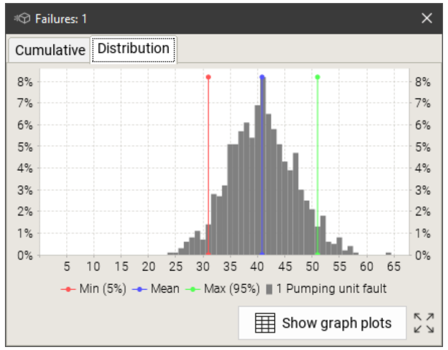
Model-based RAMS analysis



Why?

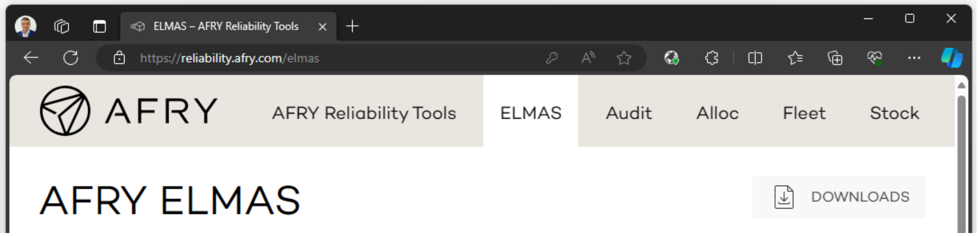
- **Risk assessment:** Understand overall consequences of potential failures and identify optimal corrective actions.
- **Early-stage verification:** Ensure that the project meets the RAMS benchmarks, enhancing CAPEX/OPEX accuracy.
- **Investment planning:** Identify the most critical components and the most beneficial investments.





How?

- **AFRY ELMAS tool:** Comprehensive simulation tool for advanced Fault Tree Analysis (FTA), Reliability Block Diagram (RBD), etc.
- **Systematic analysis:** Modelling of failure behavior, cause-consequence logic, maintenance actions, cost risks, etc.



Results:

1) **Maintenance planning:** Identify efficient improvements to condition monitoring, maintenance actions, etc.
2) **Optimization:** Improve Reliability, Availability, Maintainability and Supportability/Safety (RAMS) factors with low costs.
3) **Scenario analysis:** Evaluate design solutions and investments.

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O&M data analysis

Why?

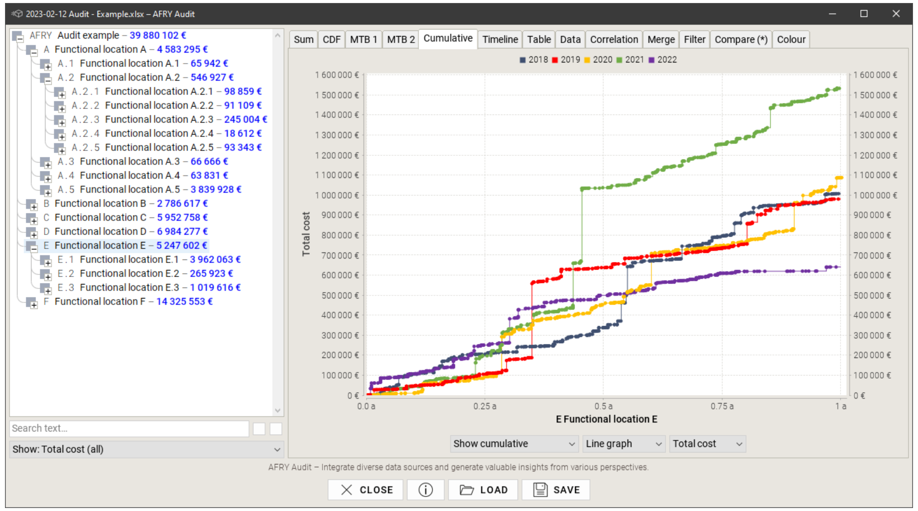
- **Informed decisions:** Systematic analysis ensures comprehensive situational awareness and identifies potential improvement targets.
- **Capitalisation of data:** Collected data serves as valuable capital that can be refined into useful insights and enhanced operation.
- **Fast results:** A data-based approach efficiently provides a wide range of valuable results while minimising client workload.

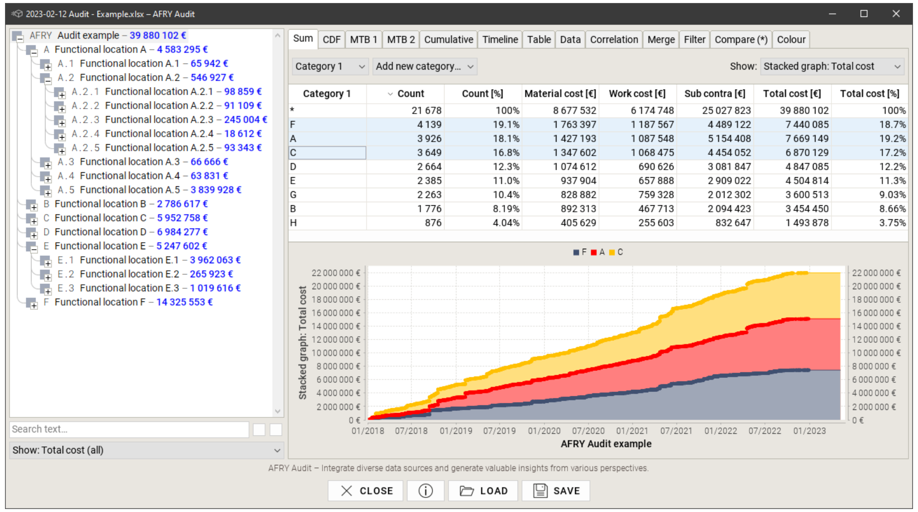
How?

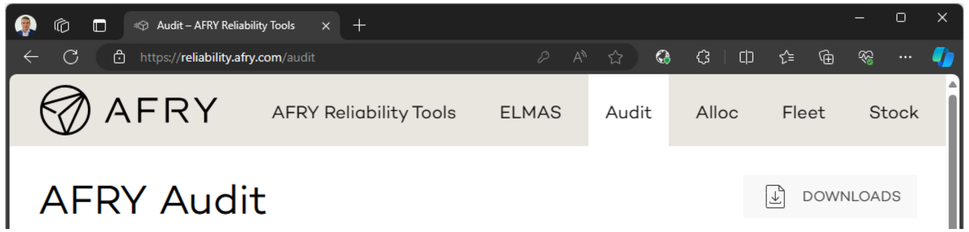
- **AFRY Audit tool:** AFRY has developed an efficient tool for generating illustrative analysis perspectives from O&M data.
- **Systematic analysis:** Device hierarchy, event history, costs and all other available data are analysed to reveal critical equipment, trend changes, correlations, hidden costs, and other valuable insights.

Results:

1) **History audit:** The history data is refined into a clear and structured view of operational reliability, availability and costs.
2) **Improvement targets:** The analysis identifies key areas for enhancements and quantifies the improvement potential.
3) **Continuous improvement:** The analysis can be regularly repeated with updated data to facilitate a streamlined follow-up process.







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The fleets consist of multiple systems. The systems can refer to vehicles or any other items that encounter failures and require actions offered by maintenance organizations.

Fleet availability analysis

Why?

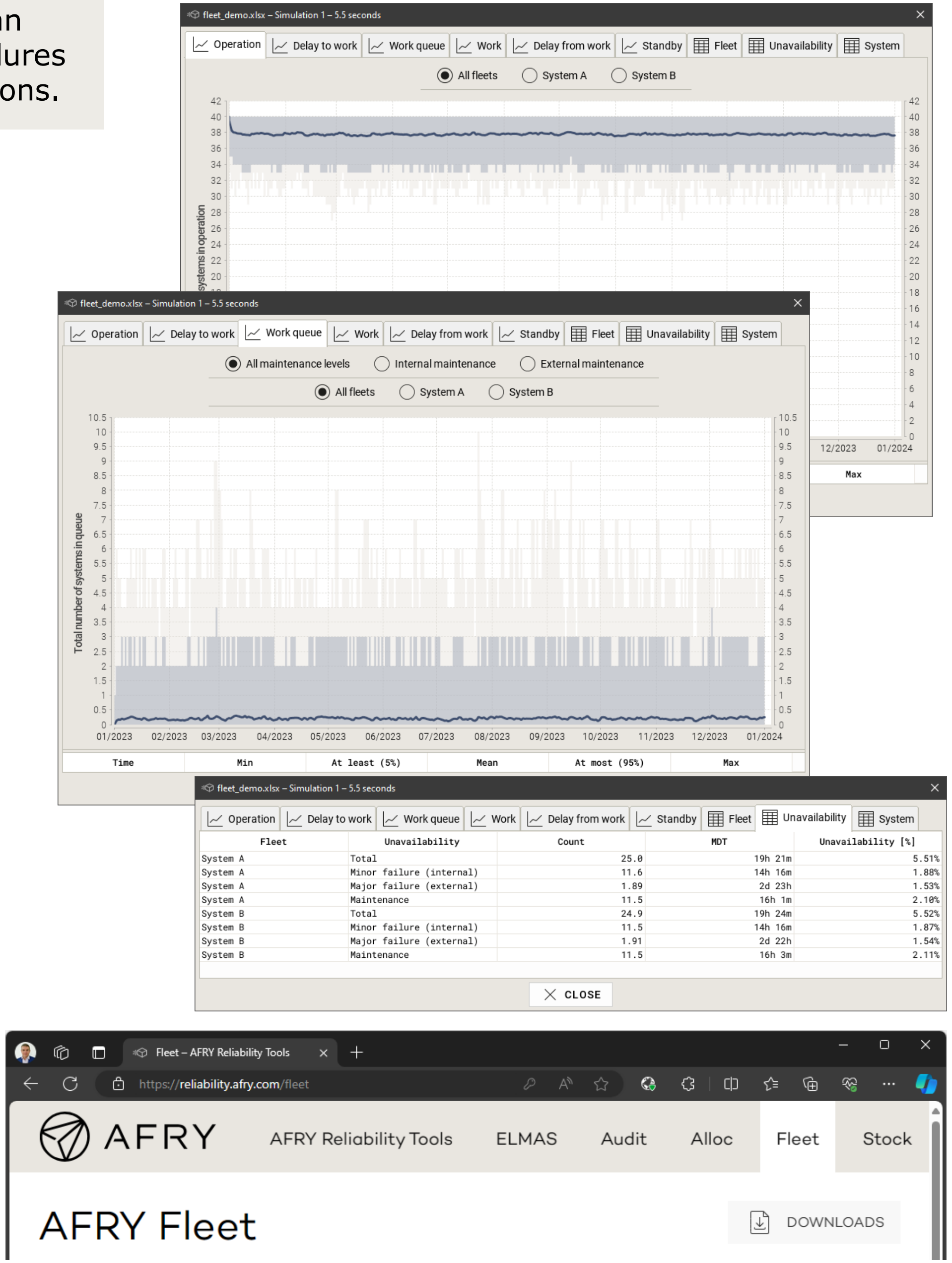
- **Informed decisions:** Systematic analysis ensures the right situation awareness and identifies the most potential improvement targets.
- **Ensure adequate resources:** To guarantee successful fleet maintenance, it is crucial to have an appropriate number of maintenance personnel, workshops and other essential resources.
- **Compare scenarios:** Assess the capability of the maintenance organization to handle the workload in different operational scenarios.

How?

- **AFRY Fleet Tool:** AFRY has developed a customisable tool for modelling and simulation-based analysis of fleet O&M.
- **Comprehensive model:** System failures, maintenance resources and levels, standby systems, logistics delays, spare parts, queuing priorities, special skills/tools and other details can be included.

Results:

1) **Availability metrics:** Enables calculating the probabilities for unavailability in different operational scenarios and life-cycle phases.
2) **Workload metrics:** Provides estimates for maintenance wait times and occupancy rates of personnel, workshops or other resources.
3) **Bottlenecks:** Identifies the main causes for potential fleet unavailability and evaluates the possibilities to prevent them.



Criticality Classification

- Criticality classification is a method for **recognizing and defining equipment criticalities** in process industry systems.
- The method evaluates equipment based on several criteria and calculates a criticality index using the selections:
  - Time between failures, Production loss, Quality cost, Repair or consequential cost, Safety risks, Environmental risks
  - A weight factor is assigned for each criteria
- Similar method with different criteria can be applied to assess spare part criticalities.

- The **standard PSK 6800 – Criticality Classification of Equipment in Industry** was published in 2008.
- The standard was created by a PSK standardization work group, which includes the leading experts from big Finnish industrial companies.
- While PSK 6800 serves as a good generic method, it’s essential to **customize the classification selections and weight factors** to tailor the method for each specific environment.

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Criticality Classification – Purpose

- Criticality classification can be used, for example, to the following purposes:
  - Creating a maintenance action plan
  - Guiding maintenance actions (e.g., work prioritization)
  - Assessing RAMS requirements for equipment during the design phase (e.g., identifying critical components)
  - Identifying equipment that requires more detailed analyses
- Criticality classification is especially suitable for large systems with vast number of components
  - The lightweight analysis does not go deeper than the equipment level
- The results got from criticality classification can be analyzed further with more detailed analysis methods, for example:
  - Fault Tree Analysis (FTA)
  - Failure Mode and Effects Analysis (FMEA)
- The criticality index can be used for ABC classification:
  - Class A: Typically, about 20% of equipment that cause 80% of the total costs
  - Class B: Typically, about 30% of equipment that cause 15% of the total cots
  - Class C: Typically, about 50% of equipment that cause 5% of the total costs

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Criticality Classification – Data fields

1) Target equipment
   - Identifier and name
   - Sub-process, mechanical/automation, etc.
2) Time between failures [$\mathbf{p}$]
   - Describes how often equipment failures occur
   - Four multiplier levels: $\mathbf{p}$ = 1 (over 5 years), 2 (2-5 years), 4 (0.5-2 years) or 8 (0-0.5 years)
3) Production loss [$\mathbf{M_p}$, $\mathbf{W_p}$]
   - Describes duration of failure consequence from production point of view
   - Five multiplier levels: $\mathbf{M_p}$ = 0, 1, 2, 3 or 4
   - Weight factor: $\mathbf{W_p}$ = 0-100 (describes the failure consequence for production: e.g. failure slowing process by 50% leads to multiplier 50)
4) Quality cost [multiplier: $\mathbf{M_q}$, fixed weight: $\mathbf{W_q}$]
   - Describes failure consequence for production quality
   - Five multiplier levels: $\mathbf{M_q}$ = 0, 1, 2, 3 or 4
5) Repair or consequential cost [$\mathbf{M_r}$, $\mathbf{W_r}$]
   - Describes costs coming from failure repair
   - Five multiplier levels: $\mathbf{M_r}$ = 0, 1, 2, 3 or 4
6) Safety risks [$\mathbf{M_s}$, $\mathbf{W_s}$]
   - Describes safety risks coming from failure
   - Five multiplier levels: $\mathbf{M_s}$ = 0, 2, 4, 8 or 16
7) Environmental risks [$\mathbf{M_e}$, $\mathbf{W_e}$]
   - Describes environmental risks coming from failure
   - Five multiplier levels: $\mathbf{M_e}$ = 0, 2, 4, 8 or 16

Criticality index: $K = p \times (W_s \times M_s + W_e \times M_e + W_p \times M_p + W_q \times M_q + W_r \times M_r)$

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Translations for criticality classification

Source	P&I Diagram	Equip-ment supplier / Event history (CMMS)	Engineering data + Expert knowledge + Model-based dependability analyses			HAZOP studies (IEC 61882) risk matrix	
Translations	Model broker / DEXPI + Filter	Import / Filtering	Import / Workshops			Translation if the scale is different	
PSK 6800	1) Target item ID + Name	2) Time between failures	3) Production loss	4) Quality costs	5) Repair costs	6) Safety risks	7) Environ-mental risks

Fields included in criticality classification (Standard PSK 6800: Criticality Classification of Equipment in Industry)

1) Target items – Data source: PI diagrams

Challenges:

- Going through all possible equipment locations requires a lot of resources.
- It is challenging to understand which equipment types can be safely filtered out of classification scope without ignoring too many possibly critical equipment.

Procedure:

- Create an intelligent PI diagram.
  - Model broker, etc.
- Filter the equipment based on equipment type.
  - For example, leave out informative instrumentation.
- Option: Read functional location / equipment list from HAZOP study
  - In which cases the target items of HAZOP and criticality classification differ?

2a) Time between failures – Data source: Equipment supplier

Challenges:

— Not a high priority for equipment supplier to provide the needed information.

— In many cases equipment suppliers do not have any practical knowledge about equipment failure rates.

Procedure:

— Create and use a data interface to import failure information from equipment suppliers.

— Expert verification is required to reject unrealistic failure rate values.

— Option: If no data is available, establish baseline failure rate values for various equipment types and then collaborate with maintenance experts to fine-tune them individually.

2b) Time between failures – Data source: Event history

Challenges:

- Collected system history data can contain irrelevant failure events that can distort the true failure rate of equipment.
  - For example, repairing a bent protective cover on a pump

Procedure:

- Read the event history from CMMS.
- Filter events that are not failures.
- Calculate mean time between failures.

- Option: If no data is available, establish baseline failure rate values for various equipment types and then collaborate with maintenance experts to fine-tune them individually.

3) Production loss – Data sources: Expert knowledge

Challenges:

- Challenging to automatise as production loss information includes a lot of variables
  - Affecting factors include, for example, equipment capacity, redundancy, bypass possibilities and effect of buffer storages
- The dependability model could offer insights into the potential production losses resulting from failures, but such systematic detailed analyses are not commonly made.

Procedure:

- Currently there are no clear data import sources available.
- Manual definition as an expert estimate by operations and maintenance specialists is currently required.

4) Quality costs – Data sources: Expert knowledge

Challenges:

- Quality issues are usually very complex events with multiple affecting factors.
- Quality costs are not a designed parameter for equipment, and understanding of it requires experience about the specific process.

Procedure:

- Currently there are no clear data import sources available.
- Manual definition as an expert estimate by operations and maintenance specialists is currently required.

5) Repair costs – Data sources: Spare part cost list + expert

Challenges:

- Equipment can have various replaceable components with different costs.
- Some equipment failures can be repaired without any replacement needs
  - For example, pump blockage
- Some equipment failures can require replacing multiple components

Procedure:

- Import of an equipment spare part cost list can act as a baseline information for experts.
- Manual definition as an expert estimate by operations and maintenance specialists is currently required.
  - For example, estimate the cost of the most probable repair procedure

6) Safety and 7) Environmental risks – Data source: HAZOP

Challenges:

- HAZOP does not always distinguish safety and environmental risks in separate data fields
- HAZOP includes human errors, which are not considered in criticality classification
  - Criticality classification considers only failures that can be avoided with proper maintenance

Procedure:

- Use a data interface to import HAZOP tables
- Ignore the rows that consider human errors
  - Interpret from text field if no separate type column
- Identify the corresponding equipment of each HAZOP row
  - Interpret from text field if no separate equipment column
- Read safety and/or environmental risk:
  - Interpret from text field if no separate column for risk type

Translations for criticality classification

<table>
<tr><td>Source</td><td>P&I Diagram</td><td>Equip-ment supplier</td><td>Event history (CMMS)</td><td colspan="3">Engineering data +
Expert knowledge +
Model-based dependability analyses</td><td colspan="2">HAZOP studies
(IEC 61882)
risk matrix</td></tr>
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Fields included in criticality classification (Standard PSK 6800: Criticality Classification of Equipment in Industry)

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Comments or Questions?

Making Future

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