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AFRY Reliability Management methods & tools

ELMAS - Event Logic Modeling & Analysis Software

Design for Reliability, Availability, Maintainability and Safety (RAMS)
for Risk Assessment and Asset Lifecycle Management of Systems

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The RAMS (Reliability, Availability, Maintainability and Safety) disciplines are a set of tools and methods,

that make it possible, at all stages of a product, process or system's lifecycle,

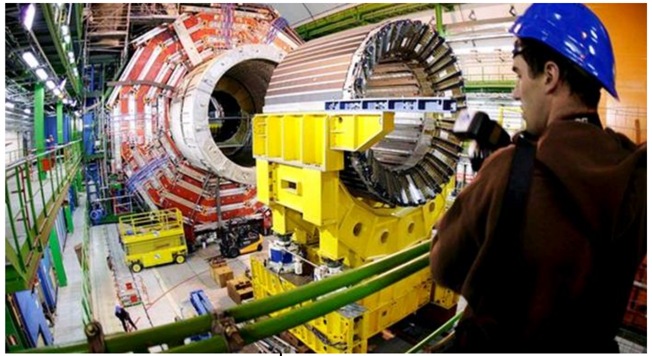
to ensure that it fulfils the mission for which it was designed,

all under conditions of reliability, maintainability, availability, maintenance supportability and well-defined safety.

— Reliability is defined as the probability that a device's performance will remain unchanged over time, after determining the conditions of use. The fundamental parameter for determining the reliability of an object is its failure rate, i.e. the number of failures it undergoes in the set time of one hour. Reliability forecasting techniques make it possible, from the knowledge of the failure rates of individual elements, to determine the failure rate and therefore the reliability of an entire system, whatever its scope of application. If carried out during the design phase, these analyses make it possible to identify the components most prone to failure and intervene with replacements or the inclusion of redundancies.

— To be competitive in the marketplace, a product, process or system must not only be reliable, i.e. subject to failure as little as possible, but also available, i.e. operational. Availability is defined as the probability that a device's performance will be unchanged over time, after determining the conditions of use and assuming that any necessary external means are secured. Availability studies take into account the maintenance to be carried out on the system and the time needed to restore it; the aim is to ensure maximum availability of the system under study, identifying the most critical elements which, due to a higher failure rate or longer repair times, make a system unavailable, thus also affecting costs.

RAMS-terminology



Availability

- **Reliability**
- **Maintainability**
- **Supportability**
  - Maintenance
    - Condition Monitoring
    - Preventive Maintenance
    - Repair

Indicators:

Running hours & failure type and time
Number of failures in a given time interval MTTF, Rel($t_1 \ldots t_2$)

Running hours & PM type and duration
Repair time of failure type_i
CM methods and intervals

Number of failures and PM actions
Total repair and PM time
Logistic delay time caused by
- lack of spare parts and resources
- lack of skill, tools and measuring instrument
- information and management problems

Definitions:

Reliability: The ability of an item to perform a required function under given conditions for a given time interval.

Maintainability: The ability of an item under given conditions of use to be retained in or restored to a state in which it can perform required function when maintenance is performed under given conditions and using stated procedures and resources.

Supportability/Serviceability: The ability of maintenance organization to maintain an item's inbuilt reliability and when it fails to restore it a state it can perform required function according to its inbuilt maintainability.

Item: Any part, component, device, subsystem, functional unit, product, equipment or system that can be individually considered

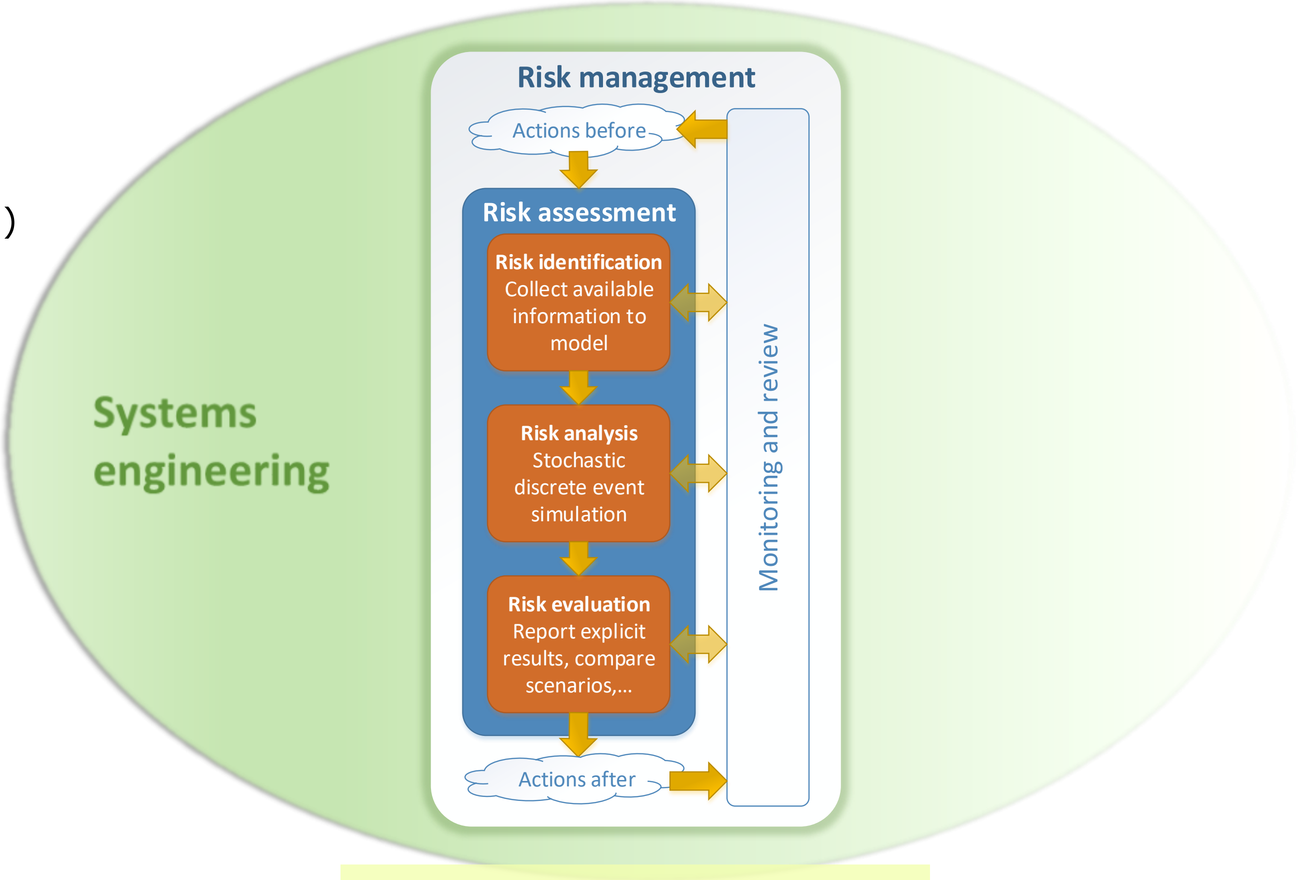
Dependability is the collective term used to describe the **Availability** performance and its influencing factors
Safety – as ability not to harm people, the environment, or any assets during a whole life cycle

AFRY RELIABILITY TOOLS

Risk Assessment – Standard definitions

- Risk
  - Effect of uncertainty on objectives
  - Objectives can have different aspects (such as financial, health and safety, and environmental goals) and can apply at different levels (such as strategic, organization-wide, project, product and process).
- Risk management
  - Coordinated activities to direct and control an organization with regard to risk.
- Risk assessment
  1) **Risk identification –** find, recognize and describe risks
  2) **Risk analysis –** comprehend the nature and determine the level of risk
  3) **Risk evaluation –** compare analysis results with risk criteria to determine whether the risk and its magnitude is acceptable or tolerable

ISO GUIDE 73:2009



ISO 31000:2009, NASA SE 2007

Model-Based Systems Engineering (MBSE)

Risk recognition and classification (qualitative)

- ✓ Fault Tree Analysis (FTA)
- ✓ Failure Modes And Effects And Criticality Analysis (FMEA / FMECA)
- ✓ Criticality classification and risk prioritization

Maintenance / reliability modelling (quantitative)

- ✓ Failure / repair time estimation (probability distribution)
- ✓ Reliability Centered Maintenance (RCM)
- ✓ Downtime, break and repair cost modelling

System operation / behavioral modelling

- ✓ Process flow / block diagram
- ✓ Dynamic production phase / logic modelling
- ✓ Fleet interaction modelling
- ✓ Buffer capacity modelling

History data capitalization / Condition monitoring

- ✓ Failure / maintenance history import
- ✓ Production / stress profile definition
- ✓ Automatic fault tree creation
- ✓ Resource and spare part costs import

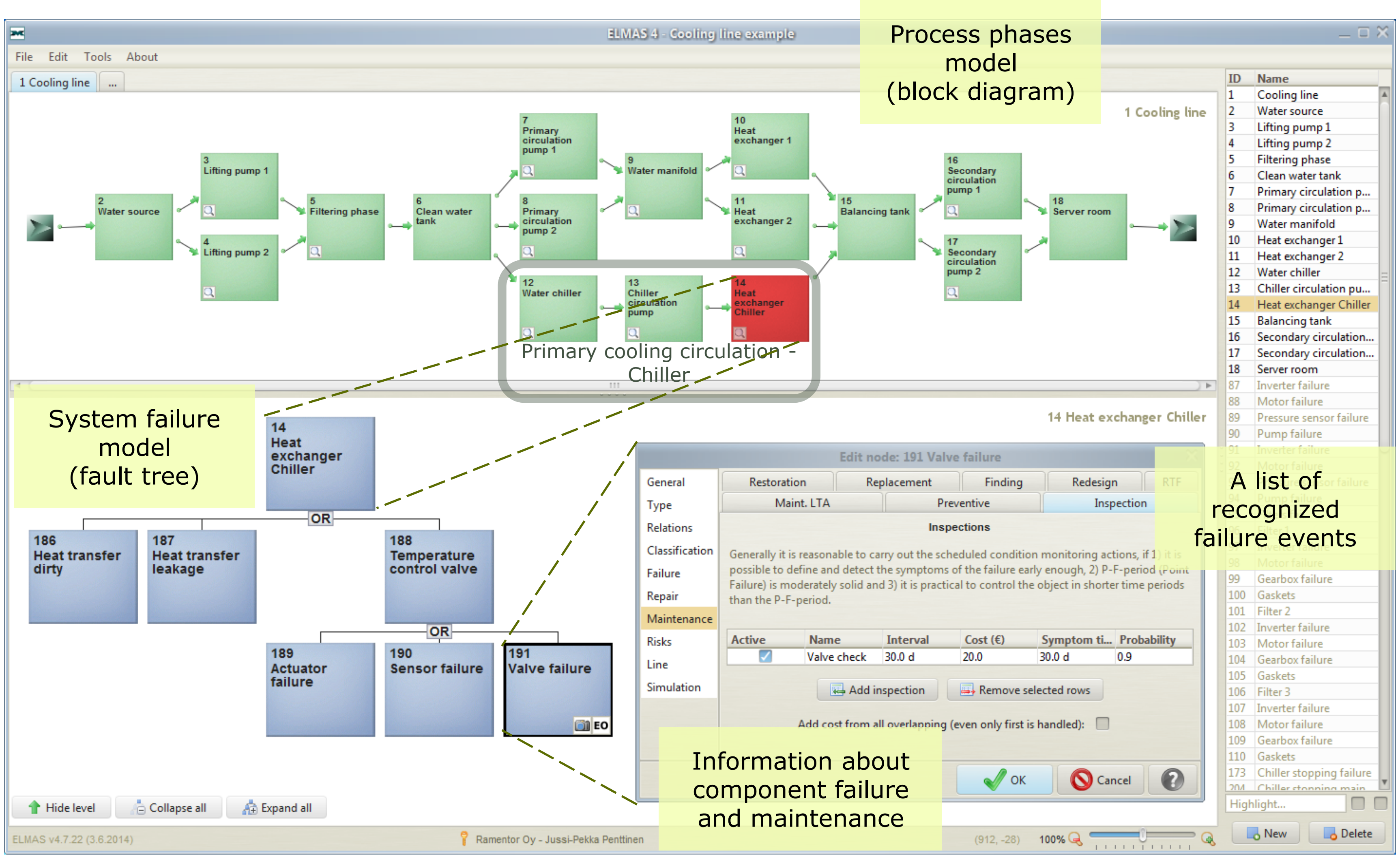
Risk / performance assessment

- ✓ Discrete Event Simulation (DES)
- ✓ Scenario analysis
- ✓ Maintenance optimization
- ✓ Risk-Informed Decision Making (RIDM)

Model-Based Systems Engineering (MBSE) – Maturity increases

ELMAS - Event Logic Modeling and Analysis Software
for RAMS (Reliability, Availability, Maintainability, Safety) analysis

- Modelling and simulation of system/component failures and their consequences
- Analysis combines maintenance data with expert knowledge
- Design, improvement and optimization of reliability and availability
- Risk assessment (RAMS)
- Analysis of Life-cycle-costs (LCC/LCP)
- Fault Tree Analysis (FTA)
- Failure Modes, Effects, and Criticality Analysis (FMECA)
- Reliability Centered Maintenance (RCM)



Process phases model (block diagram)

System failure model (fault tree)

A list of recognized failure events

Information about component failure and maintenance

Edit node: 191 Valve failure

Inspections

Generally it is reasonable to carry out the scheduled condition monitoring actions, if 1) it is possible to define and detect the symptoms of the failure early enough, 2) P-F-period (Point Failure) is moderately solid and 3) it is practical to control the object in shorter time periods than the P-F-period.

Active	Name	Interval	Cost (€)	Symptom ti...	Probability
☑	Valve check	30.0 d	20.0	30.0 d	0.9

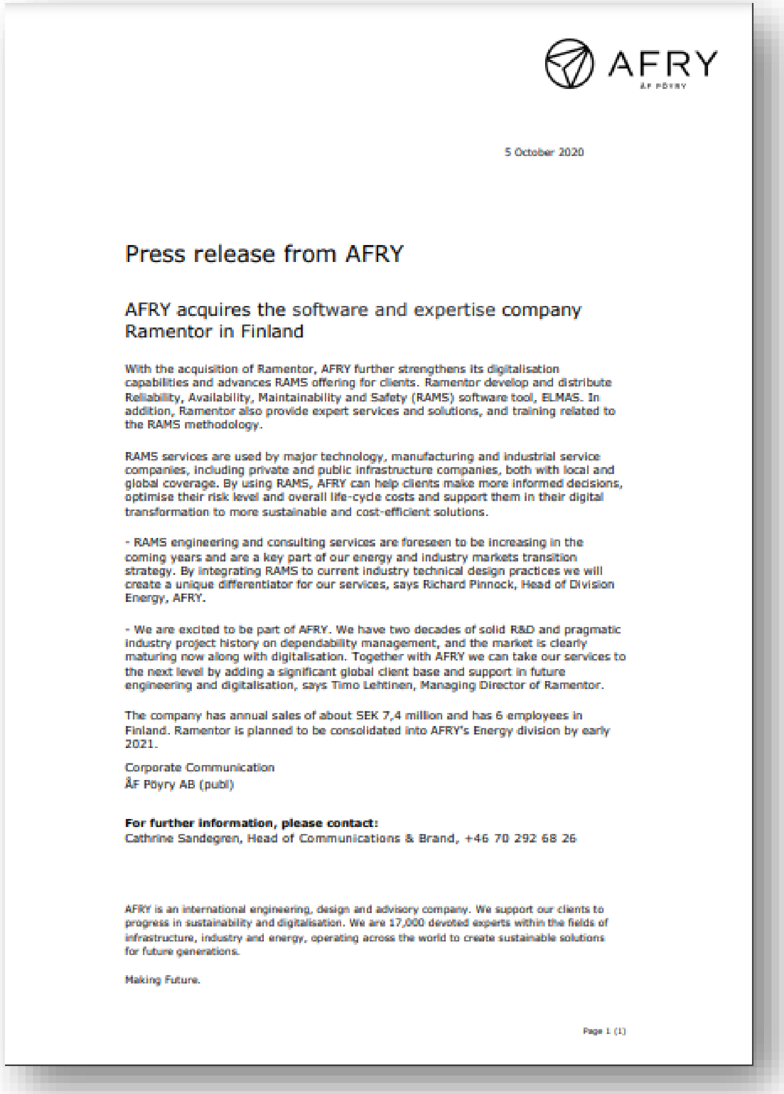
Add cost from all overlapping (even only first is handled): ☐

ID	Name
1	Cooling line
2	Water source
3	Lifting pump 1
4	Lifting pump 2
5	Filtering phase
6	Clean water tank
7	Primary circulation p...
8	Primary circulation p...
9	Water manifold
10	Heat exchanger 1
11	Heat exchanger 2
12	Water chiller
13	Chiller circulation pu...
14	Heat exchanger Chiller
15	Balancing tank
16	Secondary circulation...
17	Secondary circulation...
18	Server room
87	Inverter failure
88	Motor failure
89	Pressure sensor failure
90	Pump failure
91	Inverter failure
92	Motor failure
[illegible]	Pressure sensor failure
94	Pump failure
[illegible]	[illegible]
96	Filter 1
97	Inverter failure
98	Motor failure
99	Gearbox failure
100	Gaskets
101	Filter 2
102	Inverter failure
103	Motor failure
104	Gearbox failure
105	Gaskets
106	Filter 3
107	Inverter failure
108	Motor failure
109	Gearbox failure
110	Gaskets
173	Chiller stopping failure

AFRY has acquired Ramentor

- Software and expertise company founded in 2006 with over 150 industry references
- Methods & tools for reliability (RAMS) engineering and risk assessment

Industry Services	Design for Reliability	Quality & Risk mgmt
Caverion YIT ALGOL EMPOWER ABB maint partner Efora	KONECRANES WÄRTSILÄ KONE ABB CARGOTEC CERN metso	FINGRID Fortum PÖYRY POSIVA TeliaSonera VACON Google elisa NOKIA
Operation & Maintenance	**After Sales Support Service & Warranty**	**Research & Education**
UPM TVO POHJOLAN VOIMA Fortum HELEN RAUTE OUTOKUMPU SSAB nokian RENKAAT	Rolls-Royce KONE KONECRANES Outotec Valmet CARGOTEC WÄRTSILÄ	TAMPERE UNIVERSITY OF TECHNOLOGY VINCIT LAPIN AMK Lapland University of Applied Sciences PSK STANDARDISOINTI promaint PRODUCTION & MAINTENANCE JAMK HAMK HÄMEEN AMMATTIKORKEAKOULU



AFRY ÅF PÖYRY

5 October 2020

Press release from AFRY

AFRY acquires the software and expertise company Ramentor in Finland

With the acquisition of Ramentor, AFRY further strengthens its digitalisation capabilities and advances RAMS offering for clients. Ramentor develop and distribute Reliability, Availability, Maintainability and Safety (RAMS) software tool, ELMAS. In addition, Ramentor also provide expert services and solutions, and training related to the RAMS methodology.

RAMS services are used by major technology, manufacturing and industrial service companies, including private and public infrastructure companies, both with local and global coverage. By using RAMS, AFRY can help clients make more informed decisions, optimise their risk level and overall life-cycle costs and support them in their digital transformation to more sustainable and cost-efficient solutions.

- RAMS engineering and consulting services are foreseen to be increasing in the coming years and are a key part of our energy and industry markets transition strategy. By integrating RAMS to current industry technical design practices we will create a unique differentiator for our services, says Richard Pinnock, Head of Division Energy, AFRY.

- We are excited to be part of AFRY. We have two decades of solid R&D and pragmatic industry project history on dependability management, and the market is clearly maturing now along with digitalisation. Together with AFRY we can take our services to the next level by adding a significant global client base and support in future engineering and digitalisation, says Timo Lehtinen, Managing Director of Ramentor.

The company has annual sales of about SEK 7,4 million and has 6 employees in Finland. Ramentor is planned to be consolidated into AFRY's Energy division by early 2021.

Corporate Communication
ÅF Pöyry AB (publ)

For further information, please contact:
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AFRY is an international engineering, design and advisory company. We support our clients to progress in sustainability and digitalisation. We are 17,000 devoted experts within the fields of infrastructure, industry and energy, operating across the world to create sustainable solutions for future generations.

Making Future.

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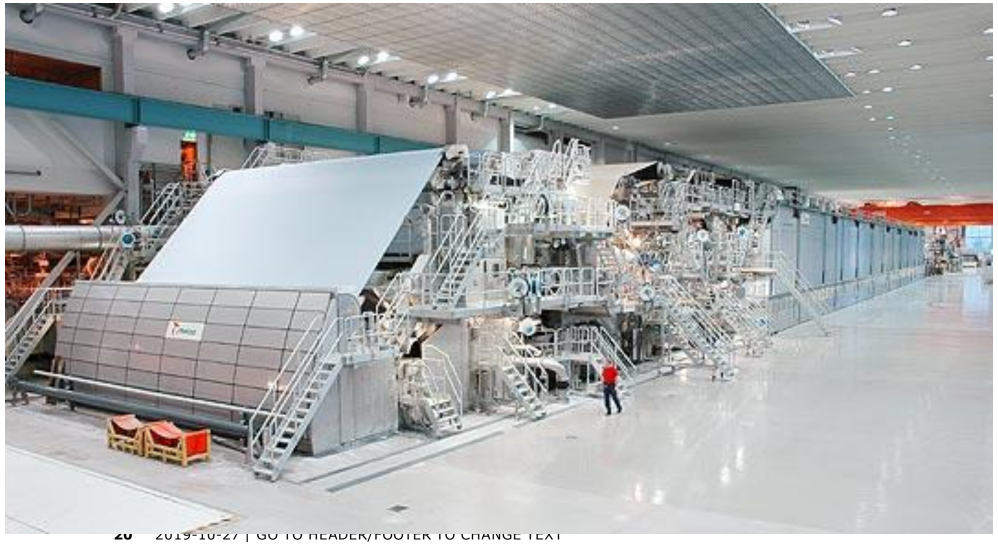
Examples of Reliability & Availability Analysis



Microsoft announces intent to build a new datacenter region in Finland, accelerating sustainable digital transformation and enabling large scale carbon-free district heating

Power grid connections in Espoo, Kirkkonummi and Vihti DC sites

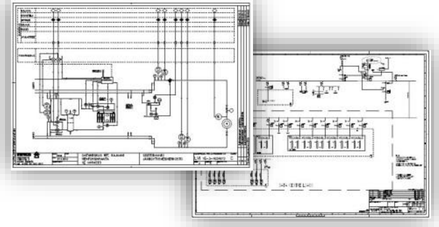
Pre-reading material, conceptual for discussion purposes

25 February 2021

Microsoft FINGRID fortum For a cleaner world AFRY ÅF PÖYRY

DataCenter RAM analysis with ELMAS

Drawings



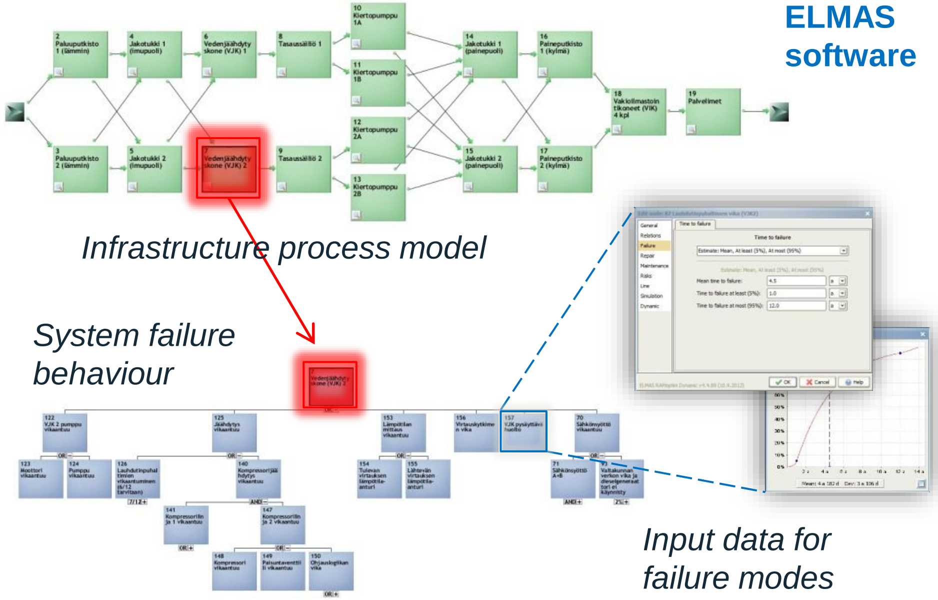
Failure Data

cigré
INTERNATIONAL COUNCIL
ON LARGE ELECTRIC SYSTEMS

entsoe
Reliable Sustainable Connected

FINGRID

Reliability model



ELMAS software

Infrastructure process model

System failure behaviour

Time to failure

Estimate: Mean, At least (5%), At most (95%)

Mean time to failure: 4.5 a

Time to failure at least (5%): 1.0 a

Time to failure at most (95%): 12.0 a

Mean: 4 a 182 d Dev: 3 a 106 d

Input data for failure modes

SIMULATION

Availability calculations

- Power delivery availability
- Cooling system availability
- *DC infrastructure availability*

Improvement actions

- Optimized maintenance plan
- Effect of alternative components
- Concurrent maintainability
- Spare parts on-site / off-site etc.

Cost risk calculations

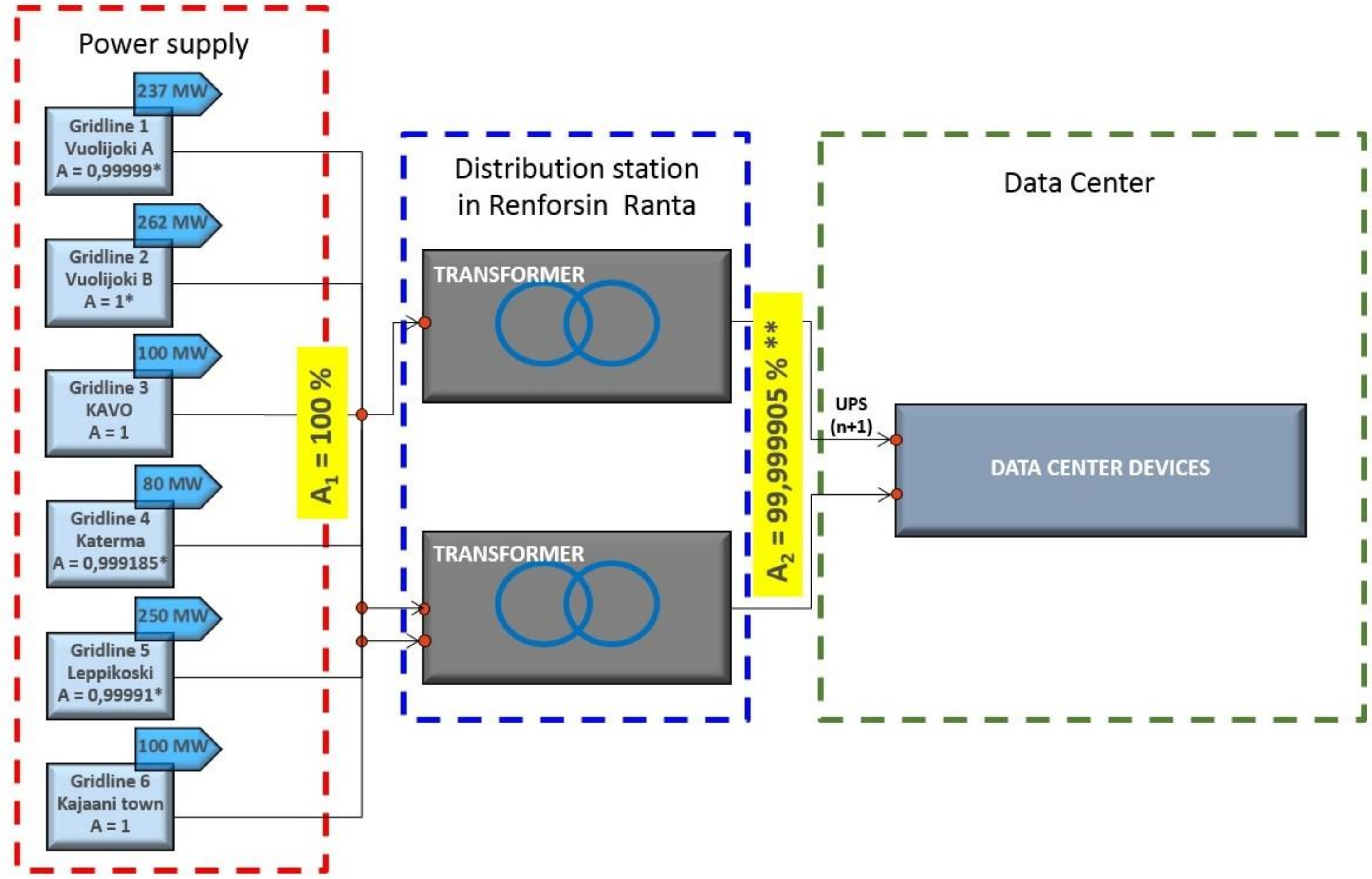
- LCC calculations
- Balancing different cost factors

Investment costs

Availability

Energy efficiency

Power supply availability block diagram



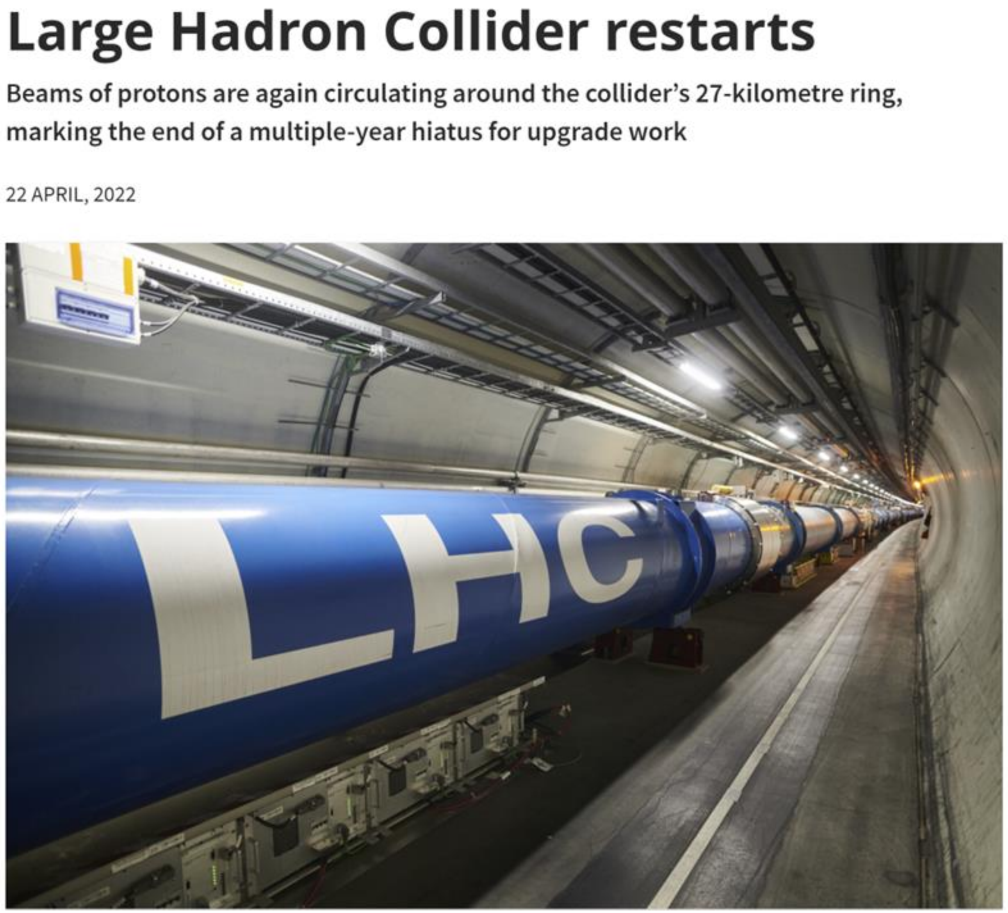
Datacenter xxx has a reliable power delivery infrastructure. There are six separate electricity feeds from the national grid with reliability of each being from 99,999% to 100%. Previous power delivery outage was in 1981 (15 seconds).

A = availability

*Availability figure is based on national grid operator Fingrid actual statistics 1992-2017

** Figure based on availability model updated 4.10.2017

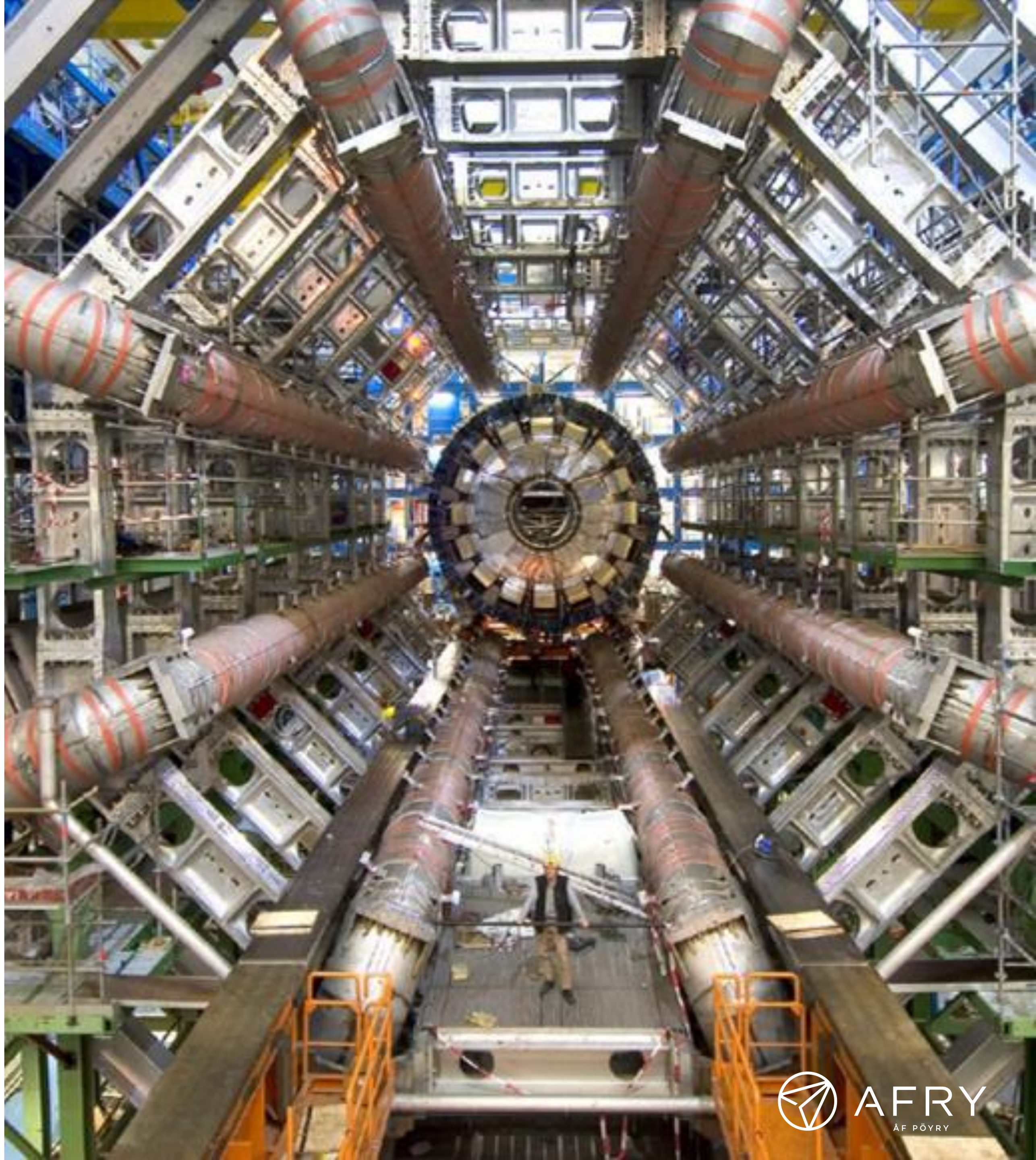
Example of a complex system & process

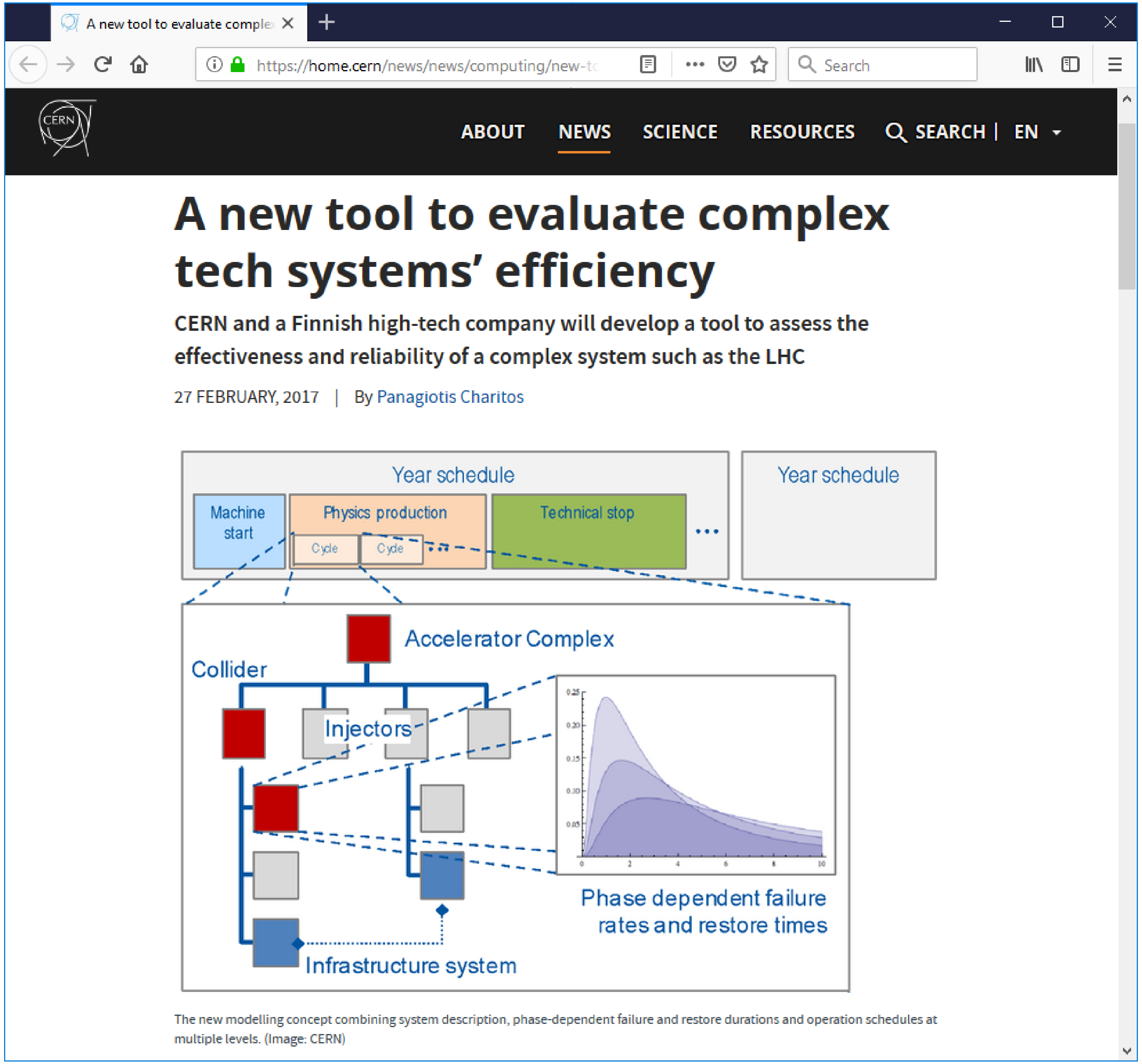


Large Hadron Collider restarts

Beams of protons are again circulating around the collider's 27-kilometre ring, marking the end of a multiple-year hiatus for upgrade work

22 APRIL, 2022





A new tool to evaluate complex tech systems’ efficiency

CERN and a Finnish high-tech company will develop a tool to assess the effectiveness and reliability of a complex system such as the LHC

27 FEBRUARY, 2017 | By Panagiotis Charitos

The new modelling concept combining system description, phase-dependent failure and restore durations and operation schedules at multiple levels. (Image: CERN)

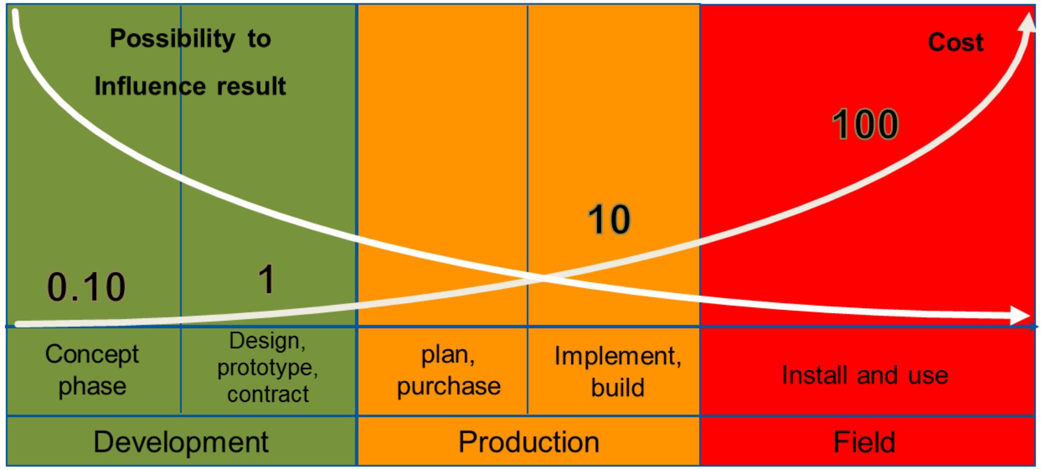
ELMAS in CERN

- ramentor.com/cern-fcc-rams-project-using-elmas/
- ramentor.com/dissertation-niemi/
- ramentor.com/world-class-maintenance/

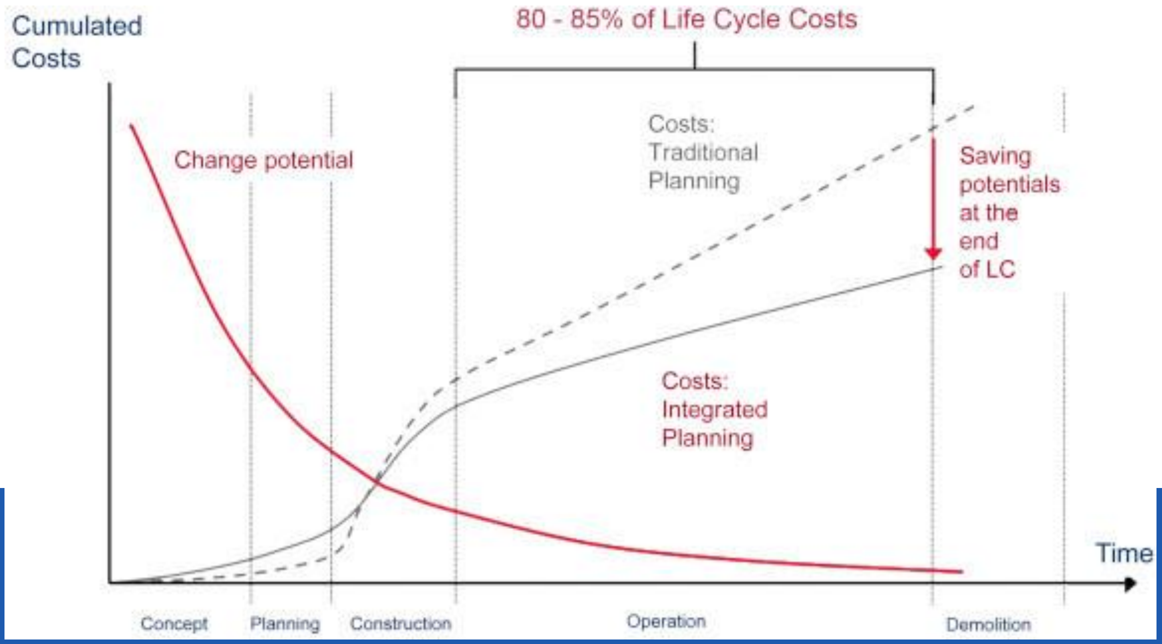
Initial motivation for CERN

- Evaluate the suitability of **industrial reliability methods** for the domain of particle accelerators…
- …taking the **LHC as a case study**
- Identify and analyse possible **design and operational scenarios** for a Future Circular Collider
- Assess potential of methods for HL-LHC
- Identify **key impact factors** on availability and luminosity production

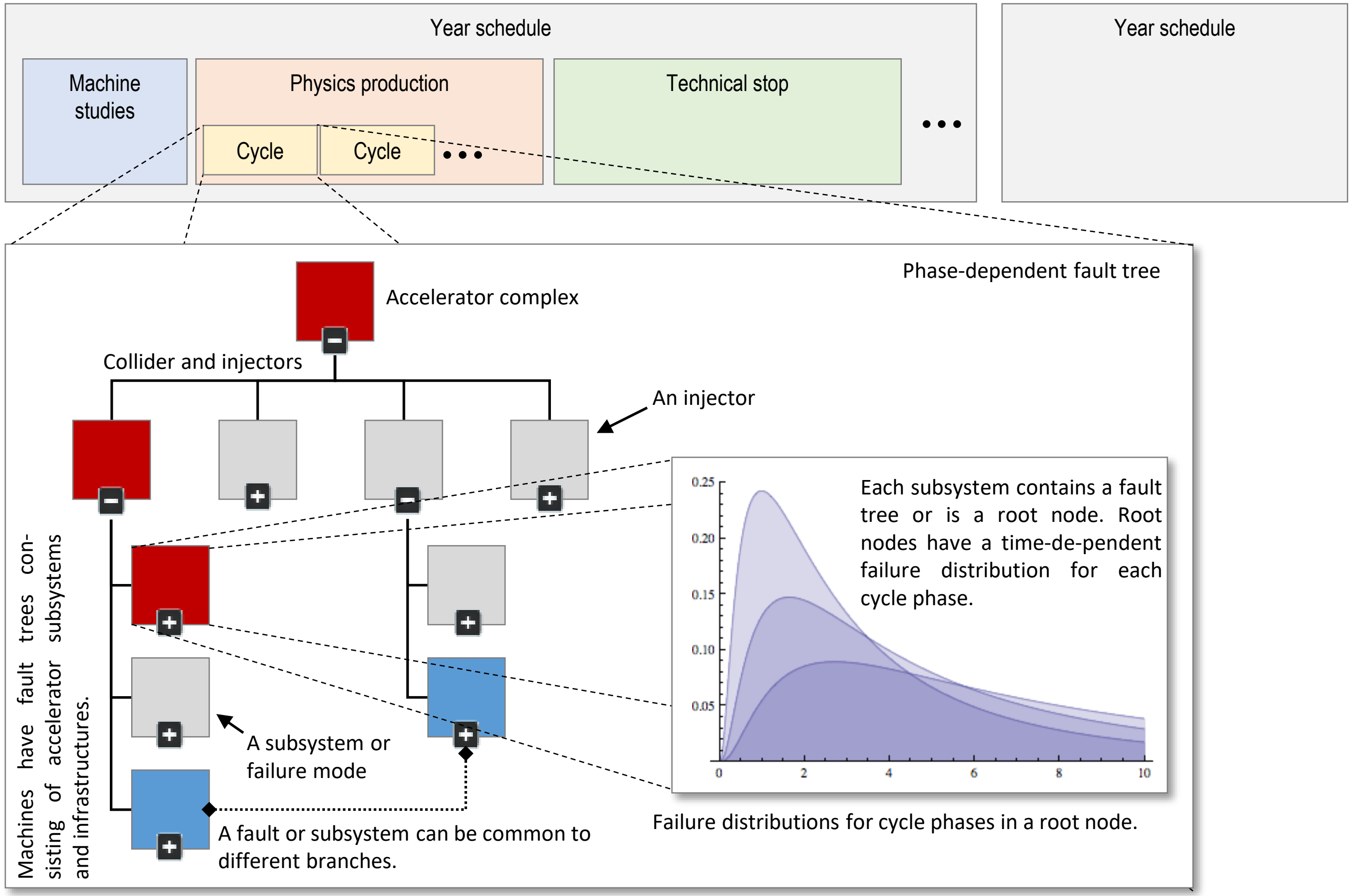
"A key quality attribute of a Future Circular Collider is the availability performance (RAMS)"



"Potential to improve the design is highest at the start of the study"



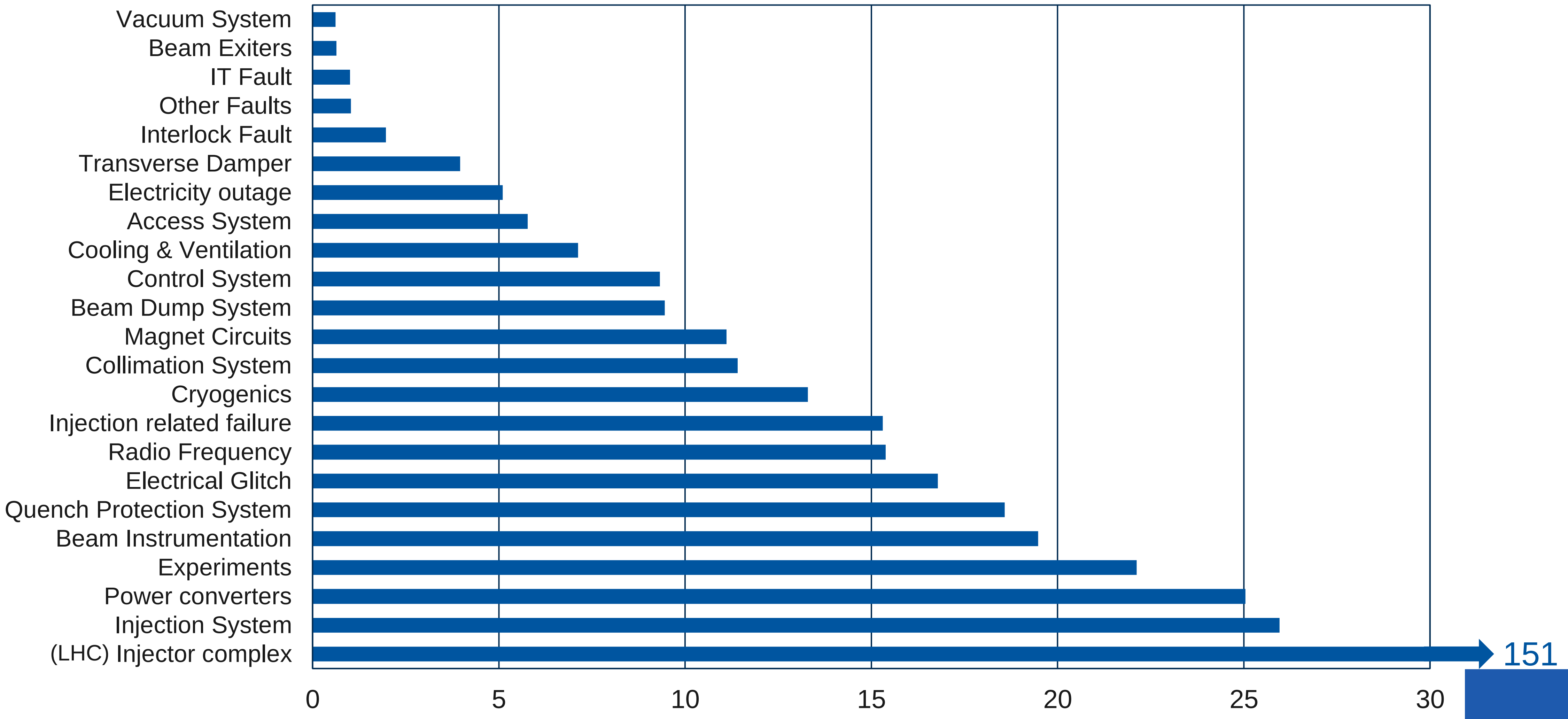
FCC Availability Study - Modelling Approach



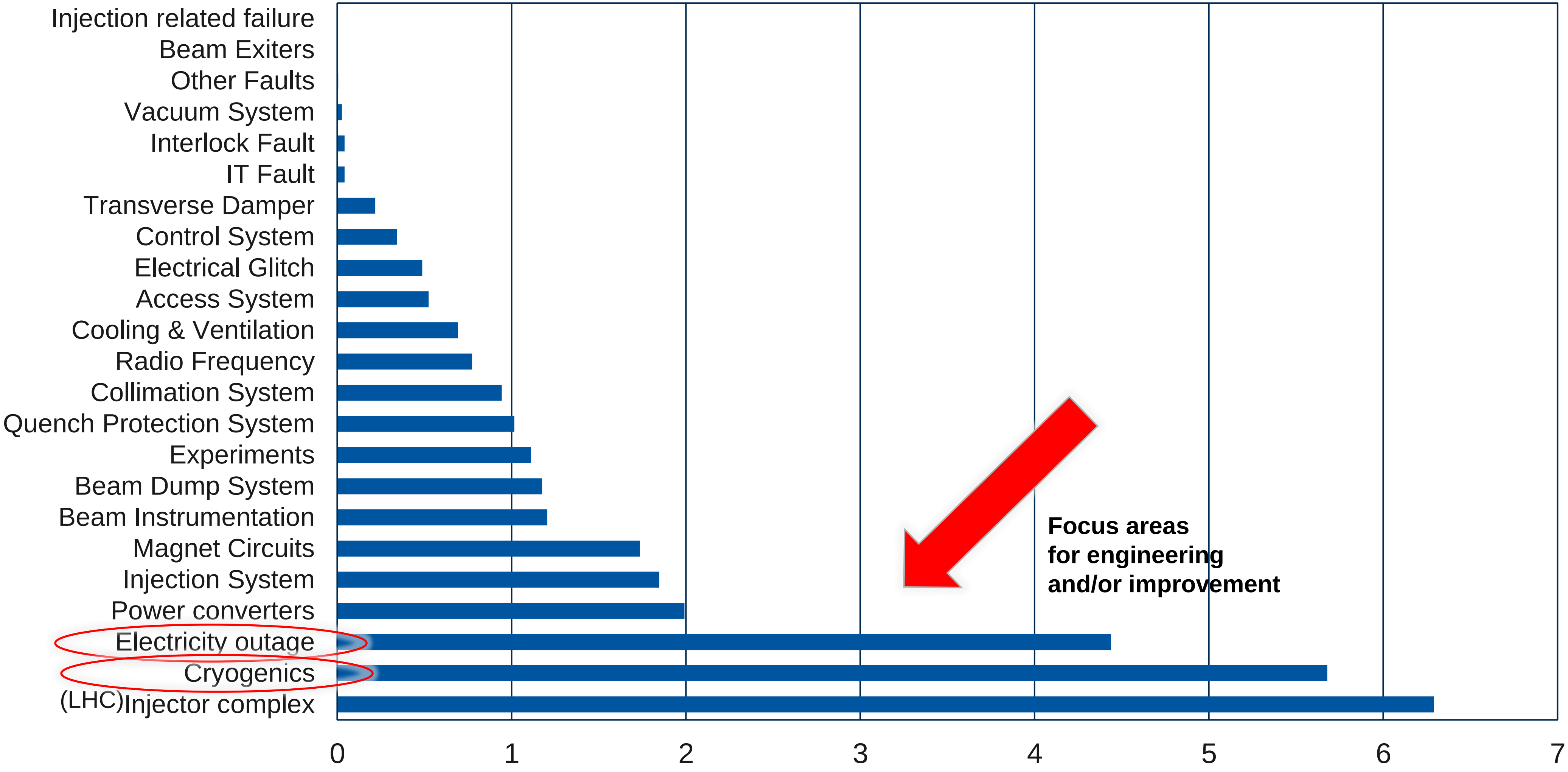
- Simulation model of accelerator operation:
  - accelerator cycles, injections & luminosity production
- Fault tree model of system availability/reliability:
  - Failure rates + repair times

For more details: https://doi.org/10.1103/PhysRevAccelBeams.19.121003

Availability budget: Failures / 100 days



Availability budget: Unavailability [%]

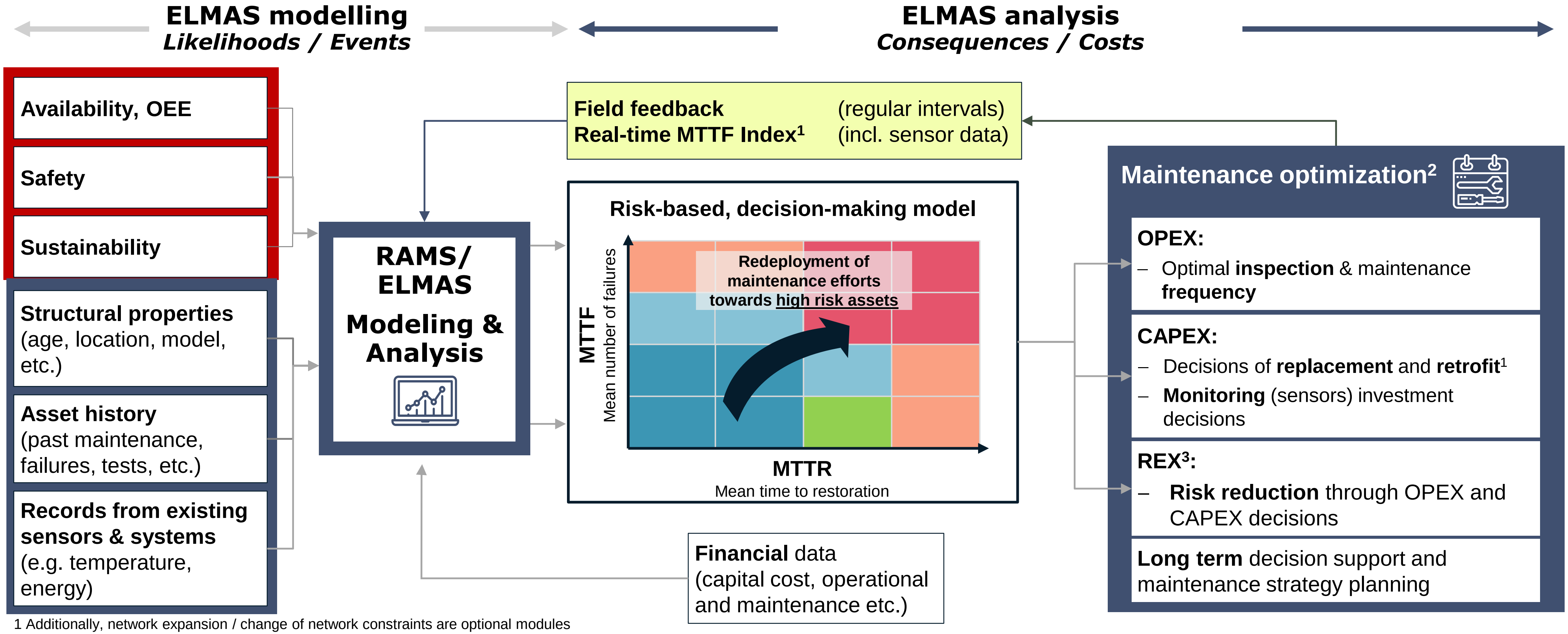


Focus areas for engineering and/or improvement

“For many events, roughly 80% of the effects come from 20% of the causes”

Vilfredo Pareto

ELMAS software is applied end-to-end to optimize resources and investments on the assets with highest failure consequences and cost risks



ELMAS modelling
Likelihoods / Events

ELMAS analysis
Consequences / Costs

Availability, OEE

Safety

Sustainability

Structural properties (age, location, model, etc.)

Asset history (past maintenance, failures, tests, etc.)

Records from existing sensors & systems (e.g. temperature, energy)

RAMS/ ELMAS
Modeling & Analysis

Field feedback (regular intervals)
Real-time MTTF Index[1] (incl. sensor data)

Risk-based, decision-making model

Financial data (capital cost, operational and maintenance etc.)

Maintenance optimization[2]

OPEX:
- Optimal **inspection** & maintenance **frequency**

CAPEX:
- Decisions of **replacement** and **retrofit**[1]
- **Monitoring** (sensors) investment decisions

REX[3]:
- **Risk reduction** through OPEX and CAPEX decisions

Long term decision support and maintenance strategy planning

1 Additionally, network expansion / change of network constraints are optional modules
2 Includes several scenarios based on risk perception and appetite
3 REX: Risk cost (Value at Risk): Current value of expected future failure costs

ELMAS FOR ASSET LIFECYCLE MANAGEMENT

1) Analytics ➔ 2) Simulation ➔ 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

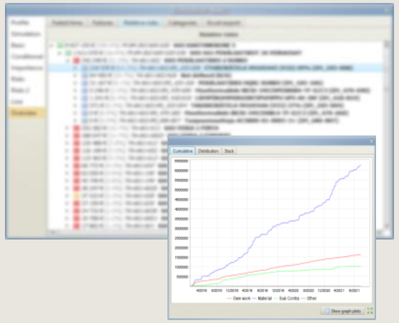
Data API / Excel

What is happening?

1) ELMAS analytics:
- Criticality classification

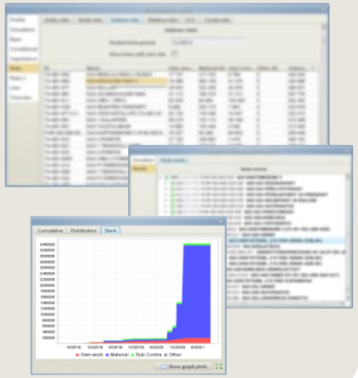
What does this mean in the long run?

2) ELMAS simulation:
- Life cycle mgmt.
- Spare parts



Where should I invest?

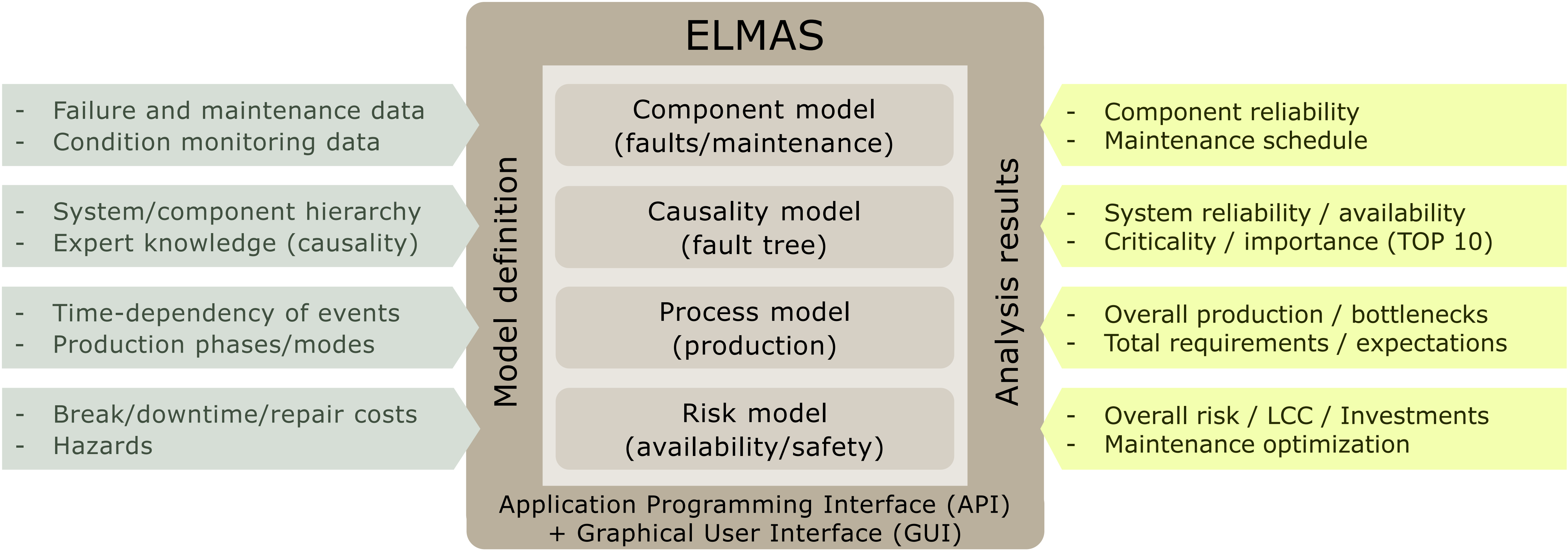
3) ELMAS scenarios:
- Maintenance optimization
- Return on investment



Failure trend estimates

Expert knowledge / Scenarios / Investments

ELMAS – Levels of Modelling and Analysis



ELMAS

Model definition

- Failure and maintenance data
- Condition monitoring data

Component model (faults/maintenance)

- Component reliability
- Maintenance schedule

- System/component hierarchy
- Expert knowledge (causality)

Causality model (fault tree)

- System reliability / availability
- Criticality / importance (TOP 10)

- Time-dependency of events
- Production phases/modes

Process model (production)

- Overall production / bottlenecks
- Total requirements / expectations

- Break/downtime/repair costs
- Hazards

Risk model (availability/safety)

- Overall risk / LCC / Investments
- Maintenance optimization

Analysis results

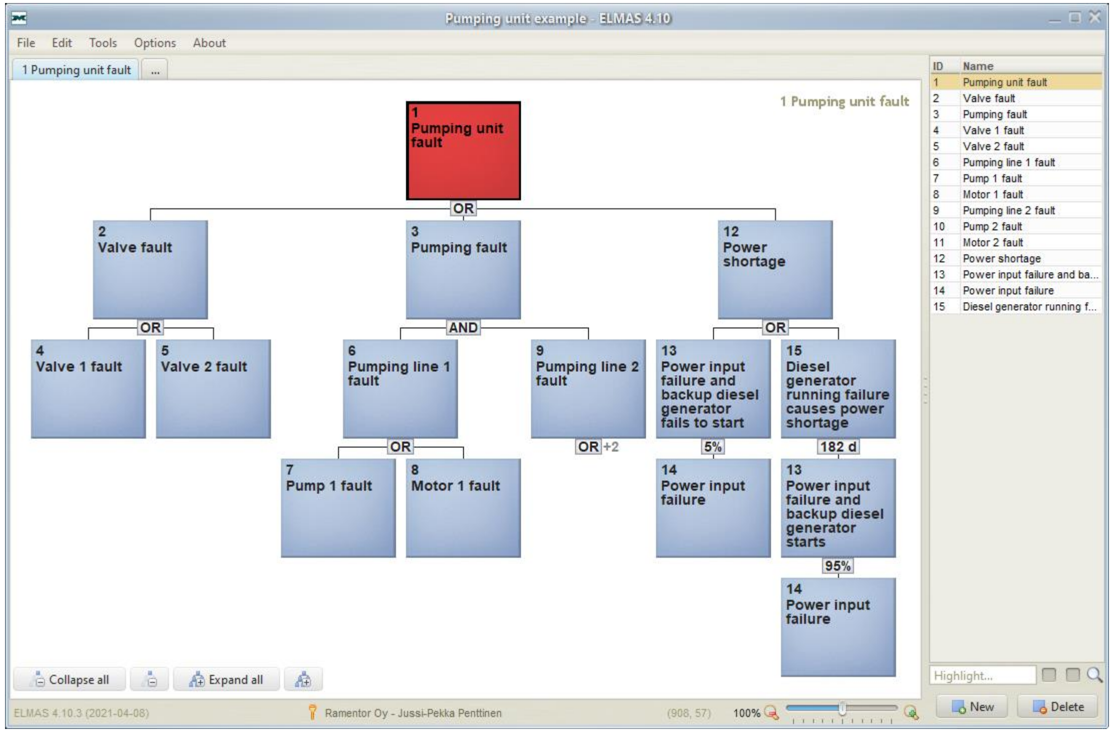
Application Programming Interface (API)
+ Graphical User Interface (GUI)

Data → API/GUI → ELMAS → API/GUI → Results

EVENT LOGIC MODELLING AND ANALYSIS SOFTWARE

ELMAS 4.9 – Advanced Fault Tree Modeling

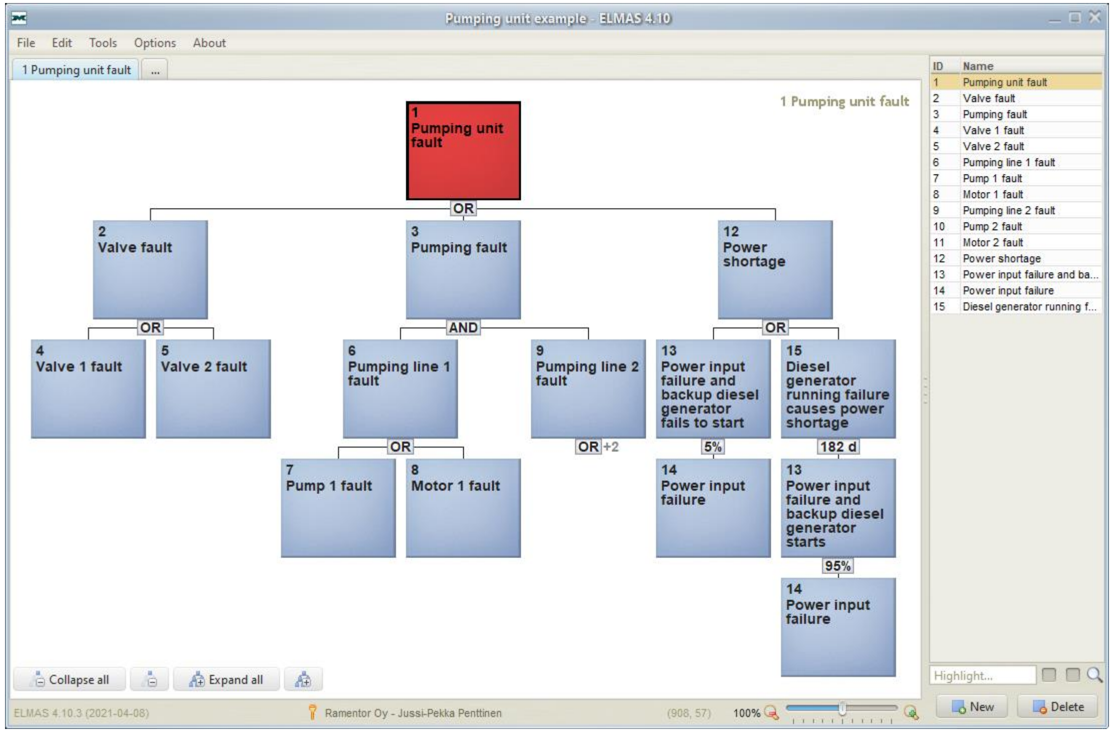
- Graphical presentation of logical tree diagram
  - Efficient handling of large (>1000 faults) trees
- Advanced failure logic and time distribution definitions
  - Standard logic gates, probabilities and delays included
  - Create failure and repair distributions based on experts’ best estimates or by importing history data (distribution fitting)
- Stochastic discrete event simulation (DES)
  - For systems that are too complex to be modelled using analytical techniques
- Customizable criticality classification
  - Include qualitative analyses and risk prioritization, such as Failure modes and effects and criticality analysis (FMECA)
- Dynamic modelling
  - Include dynamic process phase/mode changes
  - Include chains of consequences and dynamic delays
  - Include maintenance schedule and special actions



ID	Name
1	Pumping unit fault
2	Valve fault
3	Pumping fault
4	Valve 1 fault
5	Valve 2 fault
6	Pumping line 1 fault
7	Pump 1 fault
8	Motor 1 fault
9	Pumping line 2 fault
10	Pump 2 fault
11	Motor 2 fault
12	Power shortage
13	Power input failure and ba...
14	Power input failure
15	Diesel generator running f...

ELMAS FTA

- Graphical presentation of logical tree diagram
  - Efficient handling of large trees (>10 000 faults)
- Advanced failure logic and time distribution definitions
  - Standard logic gates, probabilities and delays included
  - Create failure and repair distributions based on experts’ best estimates or by importing history data (distribution fitting)
- Stochastic discrete event simulation (DES)
  - Various risk and reliability analysis results based on simulation
- Include qualitative analysis for risk prioritization
  - Failure modes and effects and criticality analysis (FMECA), PSK 6800, or customized domain specific criticality classification
- Include dynamic process modelling
  - Process phase/mode changes, buffers/other delays, etc.
- Automatized fault tree creation / criticality classification



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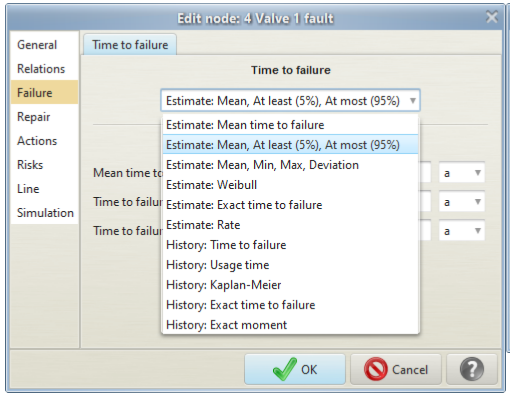
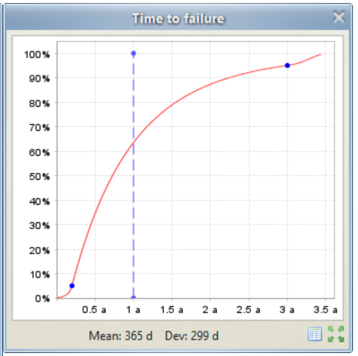
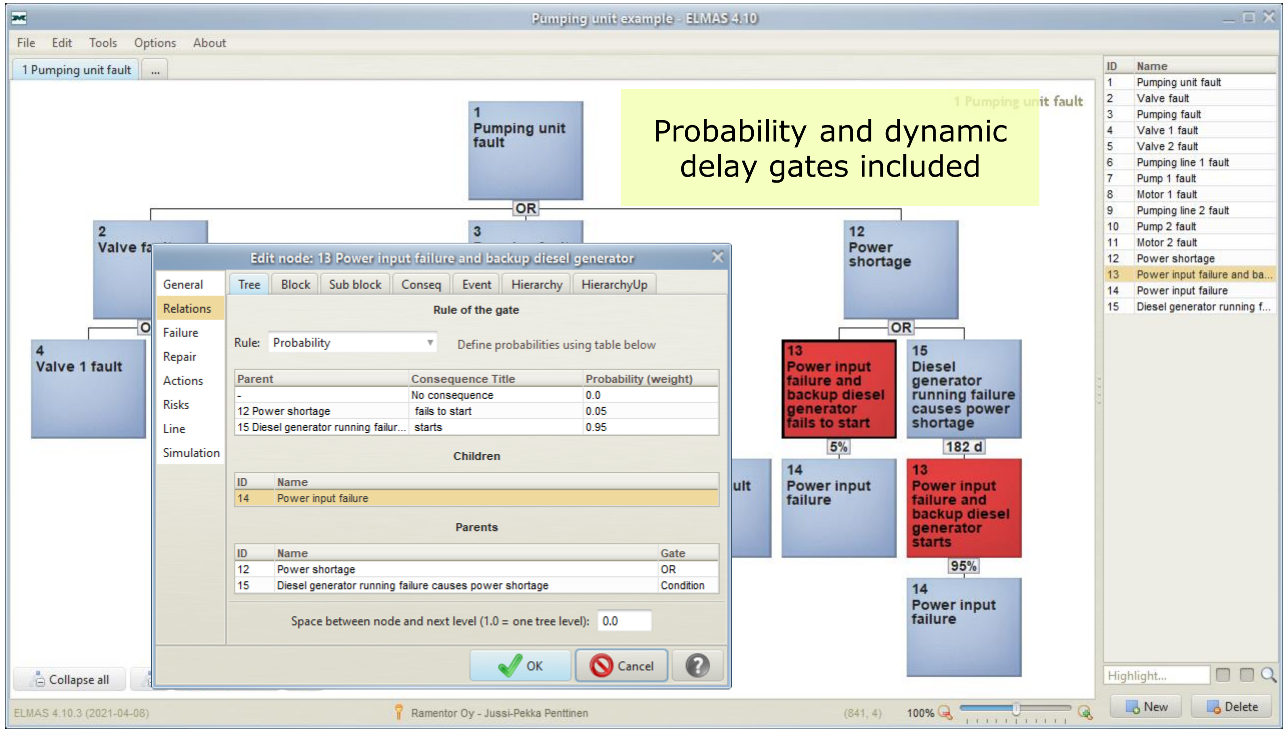




Mean: 365 d Dev: 299 d

EVENT LOGIC MODELLING AND ANALYSIS SOFTWARE

ELMAS 4.9 – Failure logic and distributions



Probability and dynamic delay gates included

Edit node: 13 Power input failure and backup diesel generator

Rule of the gate

Rule: Probability — Define probabilities using table below

Parent	Consequence Title	Probability (weight)
-	No consequence	0.0
12 Power shortage	fails to start	0.05
15 Diesel generator running failur...	starts	0.95

Children

ID	Name
14	Power input failure

Parents

ID	Name	Gate
12	Power shortage	OR
15	Diesel generator running failure causes power shortage	Condition

Space between node and next level (1.0 = one tree level): 0.0

ID	Name
1	Pumping unit fault
2	Valve fault
3	Pumping fault
4	Valve 1 fault
5	Valve 2 fault
6	Pumping line 1 fault
7	Pump 1 fault
8	Motor 1 fault
9	Pumping line 2 fault
10	Pump 2 fault
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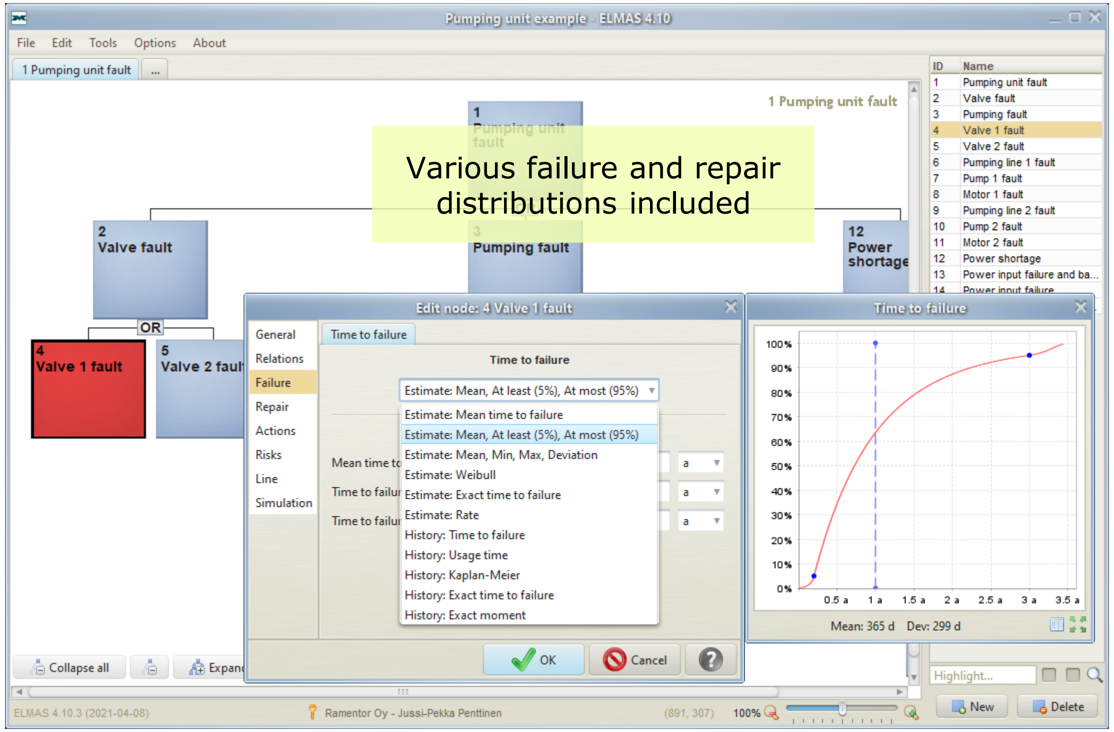
12	Power shortage
13	Power input failure and ba...
14	Power input failure
15	Diesel generator running f...



Various failure and repair distributions included

Edit node: 4 Valve 1 fault

Time to failure

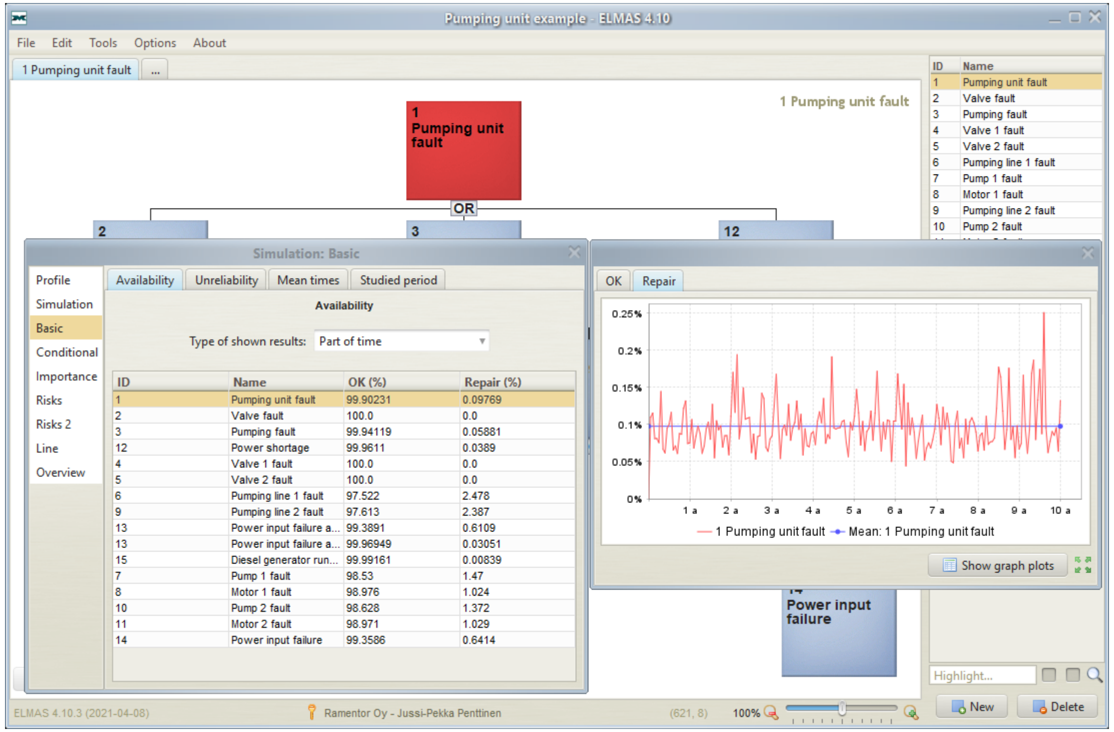
Estimate: Mean, At least (5%), At most (95%)

Mean: 365 d Dev: 299 d

ELMAS includes advanced fault tree modelling features. For comparison with other software packages, see slides 15-17 from PowerPoint Presentation - cern.ch)

EVENT LOGIC MODELLING AND ANALYSIS SOFTWARE

ELMAS 4.9 – Stochastic simulation

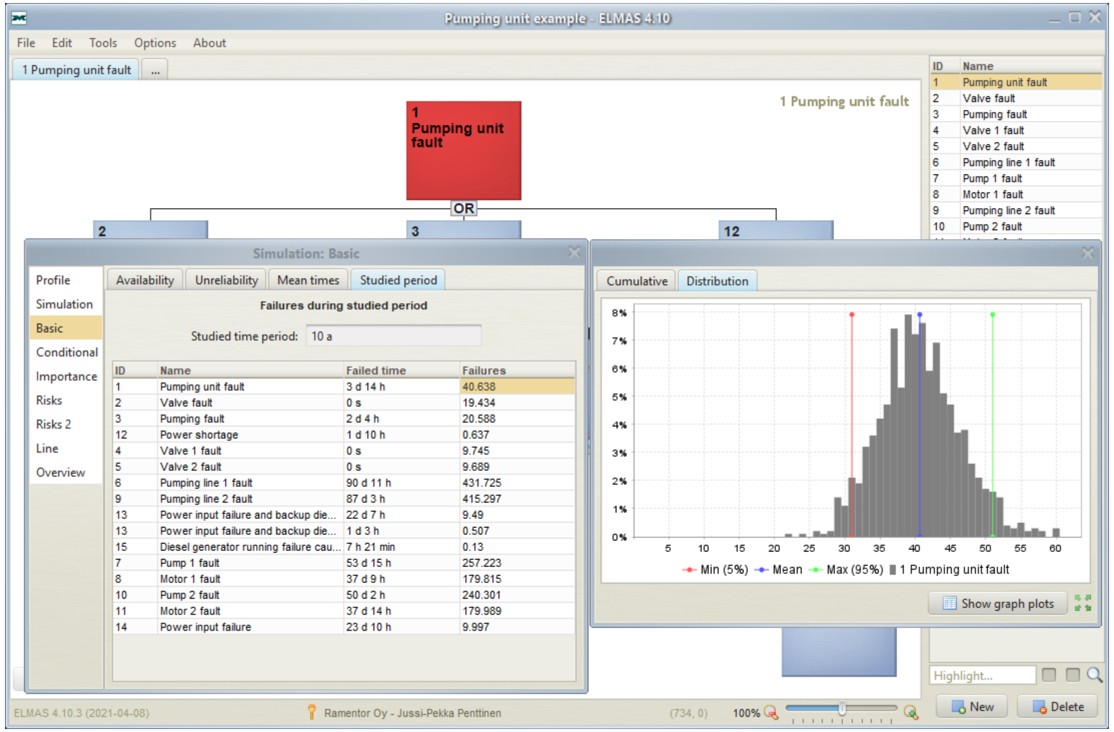


ID	Name
1	Pumping unit fault
2	Valve fault
3	Pumping fault
4	Valve 1 fault
5	Valve 2 fault
6	Pumping line 1 fault
7	Pump 1 fault
8	Motor 1 fault
9	Pumping line 2 fault
10	Pump 2 fault

Availability

Type of shown results: Part of time

ID	Name	OK (%)	Repair (%)
1	Pumping unit fault	99.90231	0.09769
2	Valve fault	100.0	0.0
3	Pumping fault	99.94119	0.05881
12	Power shortage	99.9611	0.0389
4	Valve 1 fault	100.0	0.0
5	Valve 2 fault	100.0	0.0
6	Pumping line 1 fault	97.522	2.478
9	Pumping line 2 fault	97.613	2.387
13	Power input failure a...	99.3891	0.6109
13	Power input failure a...	99.96949	0.03051
15	Diesel generator run...	99.99161	0.00839
7	Pump 1 fault	98.53	1.47
8	Motor 1 fault	98.976	1.024
10	Pump 2 fault	98.628	1.372
11	Motor 2 fault	98.971	1.029
14	Power input failure	99.3586	0.6414



ID	Name
1	Pumping unit fault
2	Valve fault
3	Pumping fault
4	Valve 1 fault
5	Valve 2 fault
6	Pumping line 1 fault
7	Pump 1 fault
8	Motor 1 fault
9	Pumping line 2 fault
10	Pump 2 fault

Failures during studied period

Studied time period: 10 a

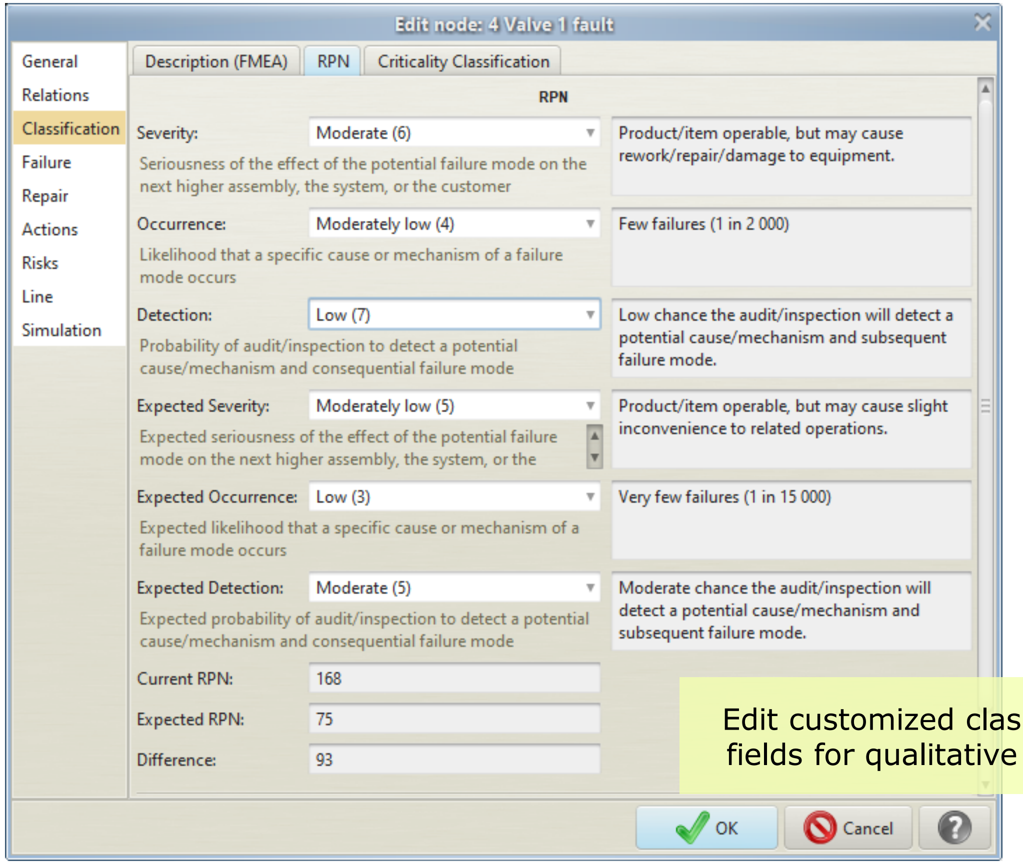
ID	Name	Failed time	Failures
1	Pumping unit fault	3 d 14 h	40.638
2	Valve fault	0 s	19.434
3	Pumping fault	2 d 4 h	20.588
12	Power shortage	1 d 10 h	0.637
4	Valve 1 fault	0 s	9.745
5	Valve 2 fault	0 s	9.689
6	Pumping line 1 fault	90 d 11 h	431.725
9	Pumping line 2 fault	87 d 3 h	415.297
13	Power input failure and backup die...	22 d 7 h	9.49
13	Power input failure and backup die...	1 d 3 h	0.507
15	Diesel generator running failure cau...	7 h 21 min	0.13
7	Pump 1 fault	53 d 15 h	257.223
8	Motor 1 fault	37 d 9 h	179.815
10	Pump 2 fault	50 d 2 h	240.301
11	Motor 2 fault	37 d 14 h	179.989
14	Power input failure	23 d 10 h	9.997

ELMAS includes an efficient simulation algorithm. For example, ELMAS calculation time 2.1 seconds vs. Isograph ~35 minutes (see slide 12 from PowerPoint Presentation - cern.ch)

AFRY
ÅF PÖYRY

EVENT LOGIC MODELLING AND ANALYSIS SOFTWARE

ELMAS 4.9 – Customizable criticality classification



RPN

Severity: Moderate (6)
Seriousness of the effect of the potential failure mode on the next higher assembly, the system, or the customer
Product/item operable, but may cause rework/repair/damage to equipment.

Occurrence: Moderately low (4)
Likelihood that a specific cause or mechanism of a failure mode occurs
Few failures (1 in 2 000)

Detection: Low (7)
Probability of audit/inspection to detect a potential cause/mechanism and consequential failure mode
Low chance the audit/inspection will detect a potential cause/mechanism and subsequent failure mode.

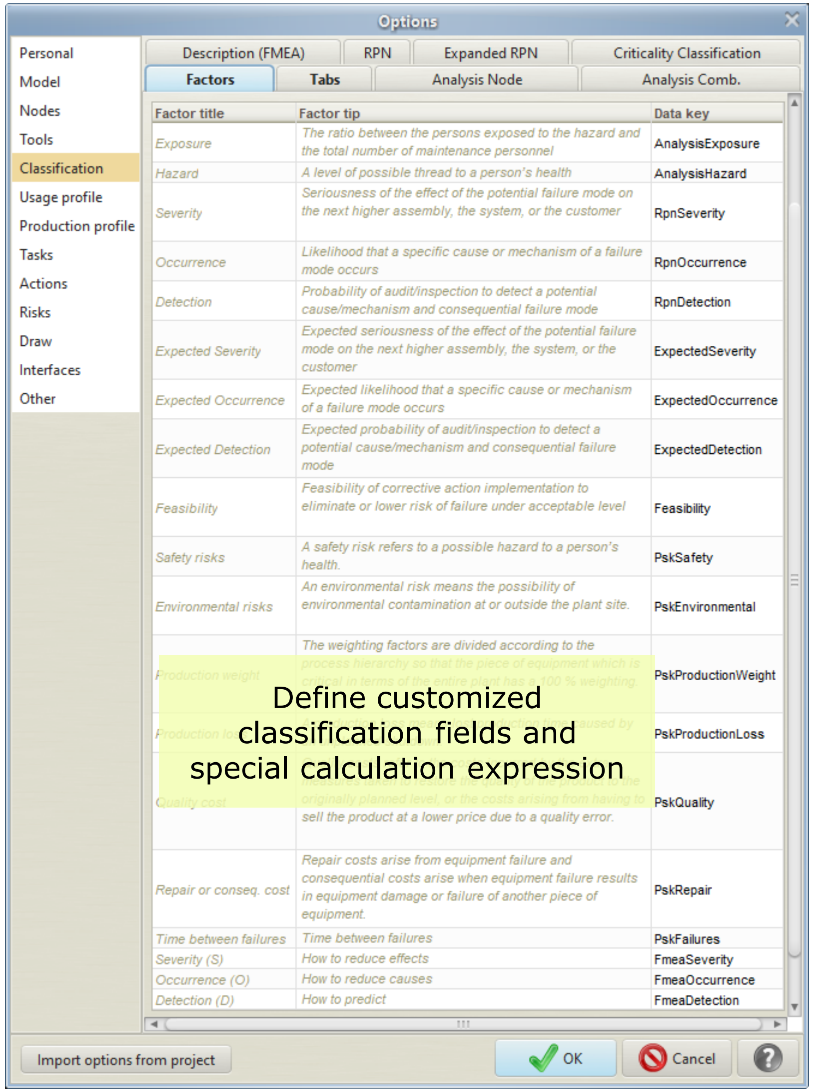
Expected Severity: Moderately low (5)
Expected seriousness of the effect of the potential failure mode on the next higher assembly, the system, or the
Product/item operable, but may cause slight inconvenience to related operations.

Expected Occurrence: Low (3)
Expected likelihood that a specific cause or mechanism of a failure mode occurs
Very few failures (1 in 15 000)

Expected Detection: Moderate (5)
Expected probability of audit/inspection to detect a potential cause/mechanism and consequential failure mode
Moderate chance the audit/inspection will detect a potential cause/mechanism and subsequent failure mode.

Current RPN: 168
Expected RPN: 75
Difference: 93

Edit customized classification fields for qualitative analysis

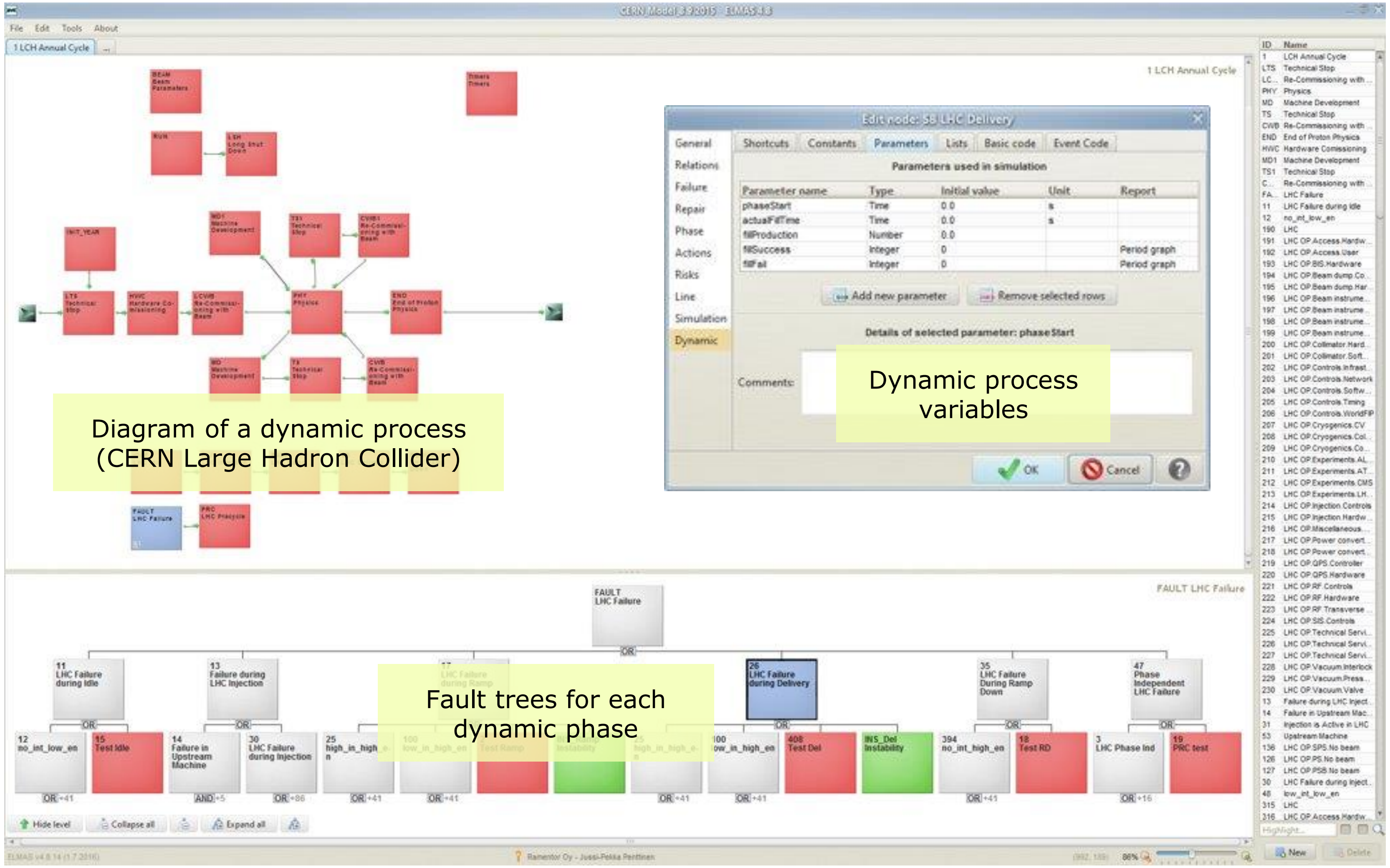


Factor title	Factor tip	Data key
Exposure	The ratio between the persons exposed to the hazard and the total number of maintenance personnel	AnalysisExposure
Hazard	A level of possible thread to a person's health	AnalysisHazard
Severity	Seriousness of the effect of the potential failure mode on the next higher assembly, the system, or the customer	RpnSeverity
Occurrence	Likelihood that a specific cause or mechanism of a failure mode occurs	RpnOccurrence
Detection	Probability of audit/inspection to detect a potential cause/mechanism and consequential failure mode	RpnDetection
Expected Severity	Expected seriousness of the effect of the potential failure mode on the next higher assembly, the system, or the customer	ExpectedSeverity
Expected Occurrence	Expected likelihood that a specific cause or mechanism of a failure mode occurs	ExpectedOccurrence
Expected Detection	Expected probability of audit/inspection to detect a potential cause/mechanism and consequential failure mode	ExpectedDetection
Feasibility	Feasibility of corrective action implementation to eliminate or lower risk of failure under acceptable level	Feasibility
Safety risks	A safety risk refers to a possible hazard to a person's health.	PskSafety
Environmental risks	An environmental risk means the possibility of environmental contamination at or outside the plant site.	PskEnvironmental
Production weight	The weighting factors are divided according to the process hierarchy so that the piece of equipment which is critical in terms of the entire plant has a 100 % weighting.	PskProductionWeight
Production loss	A production loss means lost production time caused by an unplanned shutdown.	PskProductionLoss
Quality cost	[illegible] measures taken to restore the quality of the product to the originally planned level, or the costs arising from having to sell the product at a lower price due to a quality error.	PskQuality
Repair or conseq. cost	Repair costs arise from equipment failure and consequential costs arise when equipment failure results in equipment damage or failure of another piece of equipment.	PskRepair
Time between failures	Time between failures	PskFailures
Severity (S)	How to reduce effects	FmeaSeverity
Occurrence (O)	How to reduce causes	FmeaOccurrence
Detection (D)	How to predict	FmeaDetection

Define customized classification fields and special calculation expression

EVENT LOGIC MODELLING AND ANALYSIS SOFTWARE

ELMAS – Dynamic modeling



Edit node: SB LHC Delivery

General / Relations / Failure / Repair / Phase / Actions / Risks / Line / Simulation / Dynamic

Shortcuts | Constants | Parameters | Lists | Basic code | Event Code

Parameters used in simulation

Parameter name	Type	Initial value	Unit	Report
phaseStart	Time	0.0	s	
actualFillTime	Time	0.0	s	
fillProduction	Number	0.0		
fillSuccess	Integer	0		Period graph
fillFail	Integer	0		Period graph

Add new parameter | Remove selected rows

Details of selected parameter: phaseStart

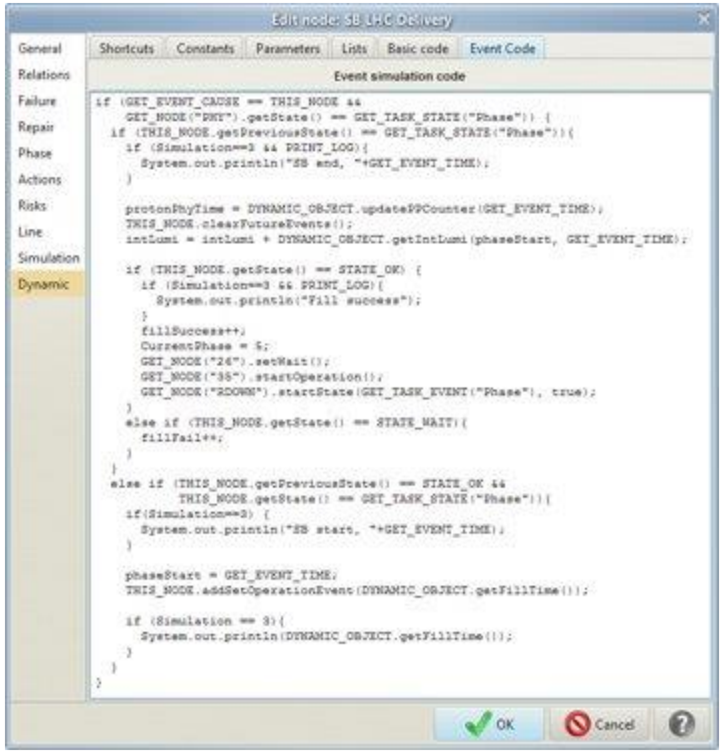
Comments:

OK | Cancel

Diagram of a dynamic process (CERN Large Hadron Collider)

Dynamic process variables

Fault trees for each dynamic phase



Edit node: SB LHC Delivery

Shortcuts | Constants | Parameters | Lists | Basic code | Event Code

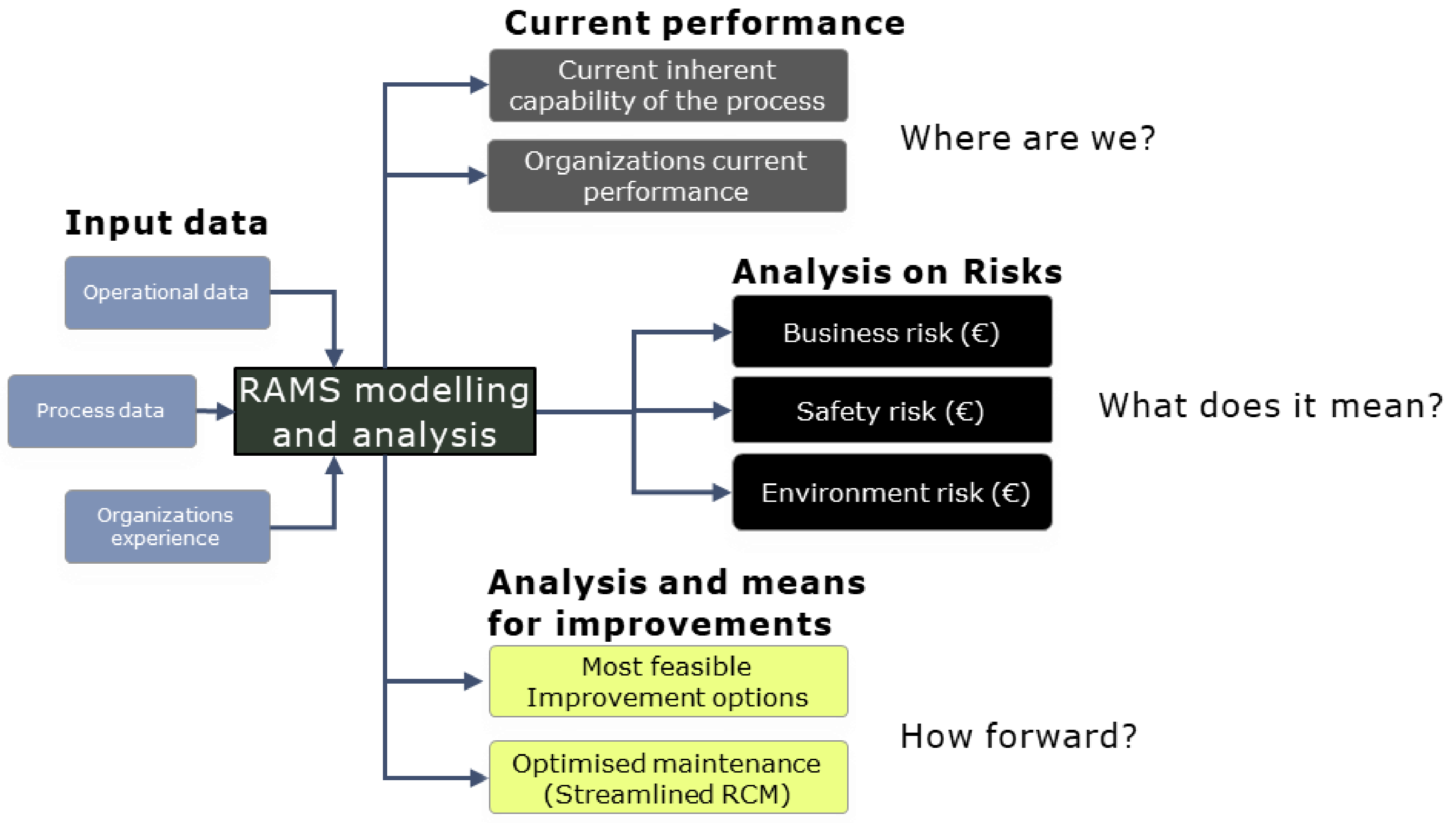
Event simulation code

```
if (GET_EVENT_CAUSE == THIS_NODE &&
    GET_NODE("PHY").getState() == GET_TASK_STATE("Phase")) {
  if (THIS_NODE.getPreviousState() == GET_TASK_STATE("Phase")){
    if (Simulation==3 && PRINT_LOG){
      System.out.println("SB end, "+GET_EVENT_TIME);
    }

    protonPhyTime = DYNAMIC_OBJECT.updatePPCounter(GET_EVENT_TIME);
    THIS_NODE.clearFutureEvents();
    intLumi = intLumi + DYNAMIC_OBJECT.getIntLumi(phaseStart, GET_EVENT_TIME);

    if (THIS_NODE.getState() == STATE_OK) {
      if (Simulation==3 && PRINT_LOG){
        System.out.println("Fill success");
      }
      fillSuccess++;
      CurrentPhase = 5;
      GET_NODE("26").setWait();
      GET_NODE("35").startOperation();
      GET_NODE("RDOWN").startState(GET_TASK_EVENT("Phase"), true);
    }
    else if (THIS_NODE.getState() == STATE_WAIT){
      fillFail++;
    }
  }
  else if (THIS_NODE.getPreviousState() == STATE_OK &&
           THIS_NODE.getState() == GET_TASK_STATE("Phase")){
    if(Simulation==3) {
      System.out.println("SB start, "+GET_EVENT_TIME);
    }

    phaseStart = GET_EVENT_TIME;
    THIS_NODE.addSetOperationEvent(DYNAMIC_OBJECT.getFillTime());

    if (Simulation == 3){
      System.out.println(DYNAMIC_OBJECT.getFillTime());
    }
  }
}
```

OK | Cancel

Custom process simulation code

RAMS Analysis outcome



Current performance

Current inherent capability of the process

Organizations current performance

Where are we?

Input data

Operational data

Process data

Organizations experience

RAMS modelling and analysis

Analysis on Risks

Business risk (€)

Safety risk (€)

Environment risk (€)

What does it mean?

Analysis and means for improvements

Most feasible Improvement options

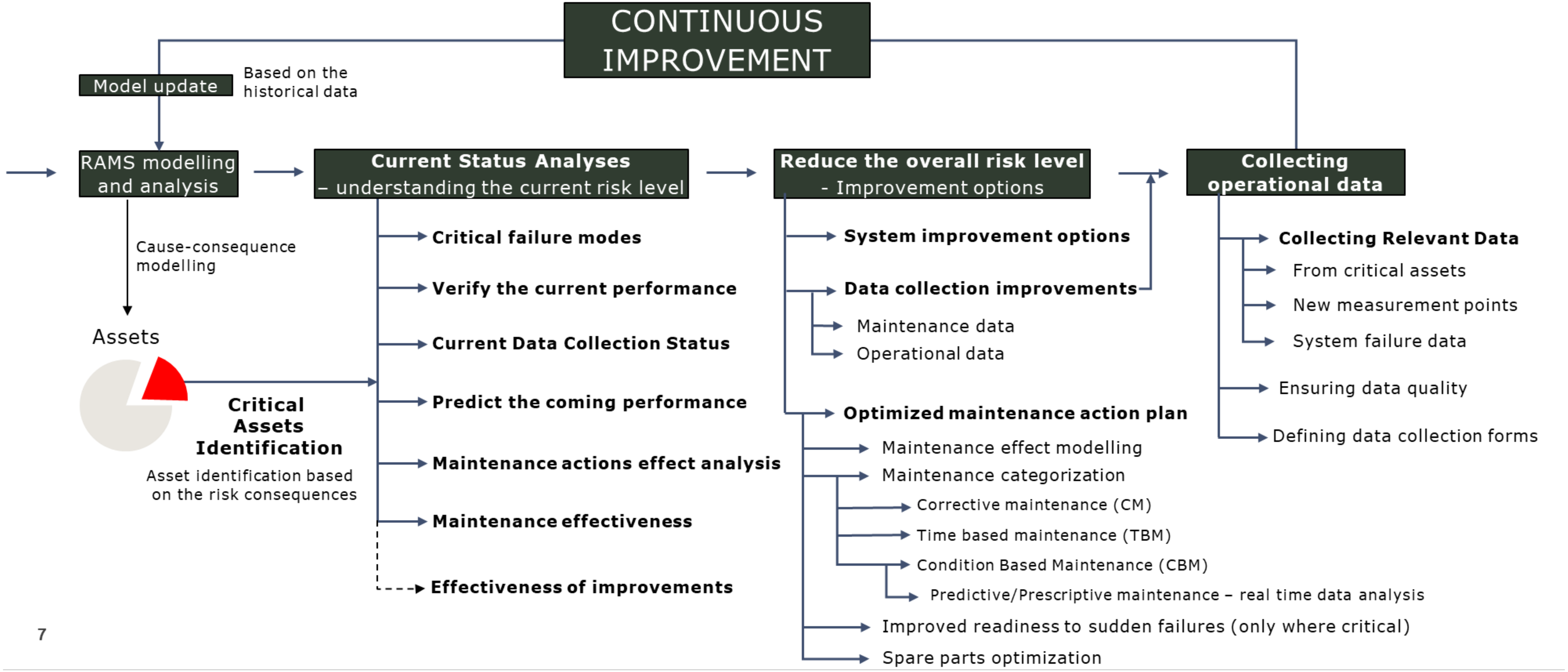
Optimised maintenance (Streamlined RCM)

How forward?

RAMS Analysis key benefits:

- Modeling visualizing large and complex systems
- Utilization of existing failure data and employee expert knowledge for optimization of the system
- Prediction of costs and resources through the whole life cycle
- Overall optimization (cost/benefit) of Reliability, Availability, Maintainability and Safety (RAMS) – potentially already at the design stage
- Focusing of data gathering and operative IT-systems use, e.g. condition monitoring and diagnostic systems

RAMS Analysis substance



CONTINUOUS IMPROVEMENT

Model update Based on the historical data

RAMS modelling and analysis
- Cause-consequence modelling
- Assets
- **Critical Assets Identification**
  - Asset identification based on the risk consequences

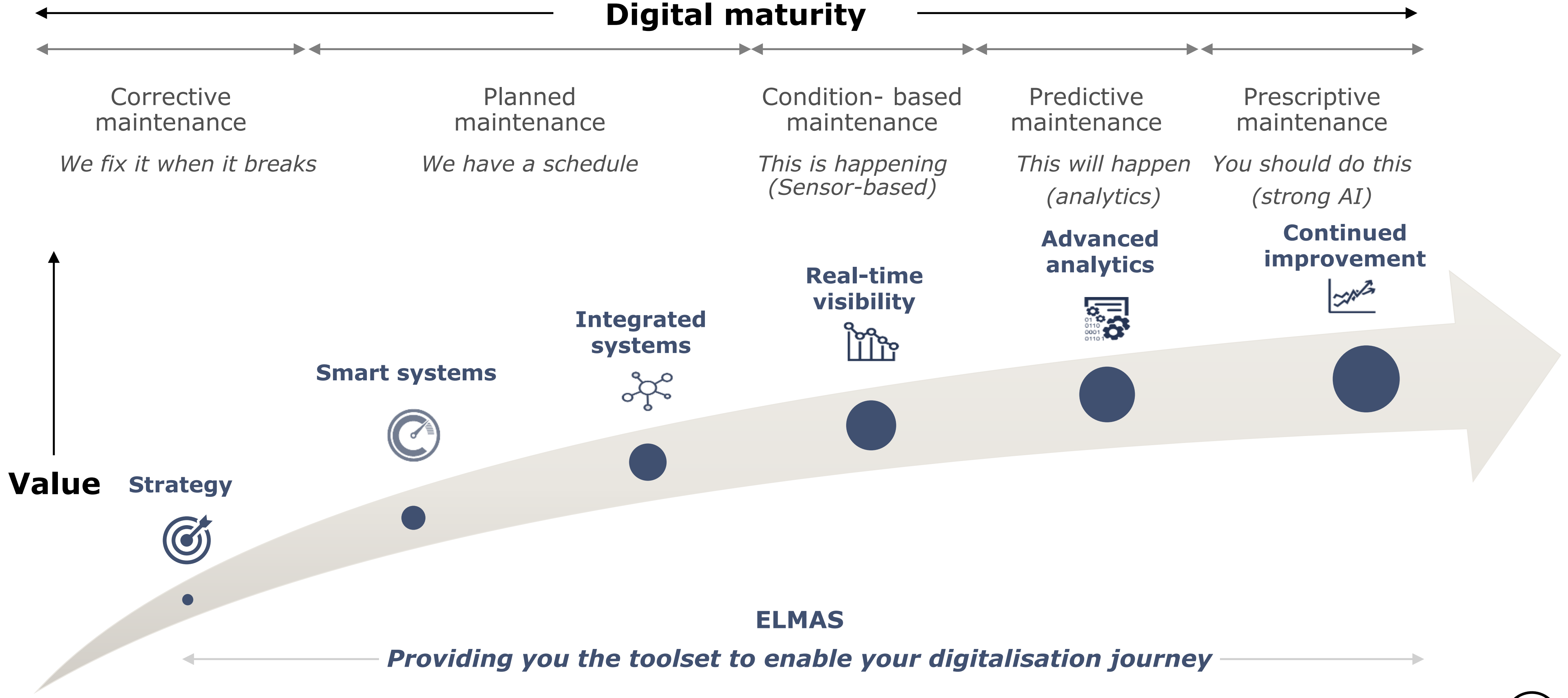
Current Status Analyses – understanding the current risk level
- **Critical failure modes**
- **Verify the current performance**
- **Current Data Collection Status**
- **Predict the coming performance**
- **Maintenance actions effect analysis**
- **Maintenance effectiveness**
- **Effectiveness of improvements**

Reduce the overall risk level - Improvement options
- **System improvement options**
- **Data collection improvements**
  - Maintenance data
  - Operational data
- **Optimized maintenance action plan**
  - Maintenance effect modelling
  - Maintenance categorization
    - Corrective maintenance (CM)
    - Time based maintenance (TBM)
    - Condition Based Maintenance (CBM)
      - Predictive/Prescriptive maintenance – real time data analysis
  - Improved readiness to sudden failures (only where critical)
  - Spare parts optimization

Collecting operational data
- **Collecting Relevant Data**
  - From critical assets
  - New measurement points
  - System failure data
- Ensuring data quality
- Defining data collection forms

WHY ELMAS IS NEEDED?

Top industry companies strives to win the race in the digitalization journey to optimize their operations and gain competitive advantage



Digital maturity

Corrective maintenance

We fix it when it breaks

Planned maintenance

We have a schedule

Condition- based maintenance

This is happening (Sensor-based)

Predictive maintenance

This will happen (analytics)

Prescriptive maintenance

You should do this (strong AI)

Value

Strategy

Smart systems

Integrated systems

Real-time visibility

Advanced analytics

Continued improvement

ELMAS

Providing you the toolset to enable your digitalisation journey

Making Future