



Design. Analyze. Optimize.

ELMAS Screen Captures



Availability Modelling Tools and Synergies for Collaboration Workshop

CERN 7.7.2016

Ramentor Oy
Hermiankatu 8 D
FI-33720 Tampere

Tel. +358 (0) 40 746 6585
info@ramentor.com
www.ramentor.com

Jussi-Pekka Penttinen

Outline

1. Brief Background: Ramentor Inc., ELMAS acronym
2. Basic Fault Tree – General User Interface
 - Tree structure, Root Failure/Restoration, Simulation, Risks
3. Larger Fault Tree – Data Interface
 - Results Overview, HTML Reports, Table Summary, Excel Reports
4. Advanced Features
 - Block Diagram, Data Import, Maintenance Actions
 - Dynamic Simulation, Debug Log Window
 - LHC Dynamic Model

Ramentor Inc.

- Founded in 2006 and based in Tampere, Finland
 - Personnel ~10 (Dr. & M.Sc. – Mech. & aut. eng. / Applied math. / Software dev.)
 - Privately owned and independent software and expertise company
- Background: Tampere University of Technology (TUT)
 - Finnish Technology Agency (TEKES) Competitive Reliability Programme 1996-2000
 - Probabilistic approach in reliability and maintenance management 2001-2003
 - RAM Products 2003-2005, RAM Solutions 2006-2008, RAM Efficiency 2008-2010
- Please visit for more information: www.ramentor.com

Ramentor – Experience in Industry Sectors

- Energy Industry:
 - Nuclear Power Plants, District Cooling, ...
- Process Industry :
 - Pulp & Paper Mills, Steel Industry, Mineral Processing, Medical, ...
- IT Industry:
 - Data Centers, Telecommunication, Broadband connections, ...
- Equipment Manufacturers:
 - Cranes, Elevators, Thruster Units, ...
- Education and Research Organizations:
 - Universities (technology / applied sciences), CERN, ...

Ramentor – ELMAS Users / Co-developers

Industry Service	Design for Reliability	Quality & Risk mgmt
      	     	        
Operation & Maintenance	After Sales Support Service & Warranty	Research & Education
       	      	        

ELMAS – An Acronym

Event

- Time to Failure, Distribution
- Time to Repair, Distribution
- Maintenance actions
- Break and downtime loss
- Repair Costs
- Hazards
- Usage and stress profile
- External events

Logic

- OR
- AND
- K/N-Voting
- XOR-Exclusive
- Limits
- Conditional probability
- Delays
- Throughput, fuzzy logic
- Dynamic coding

Modeling

- Fault tree
- Event tree
- Cause-consequence-tree
- Reliability block diagram
- Process diagram
- Waiting and redundancy
- Buffers
- Failure modes, RCA

Analysis

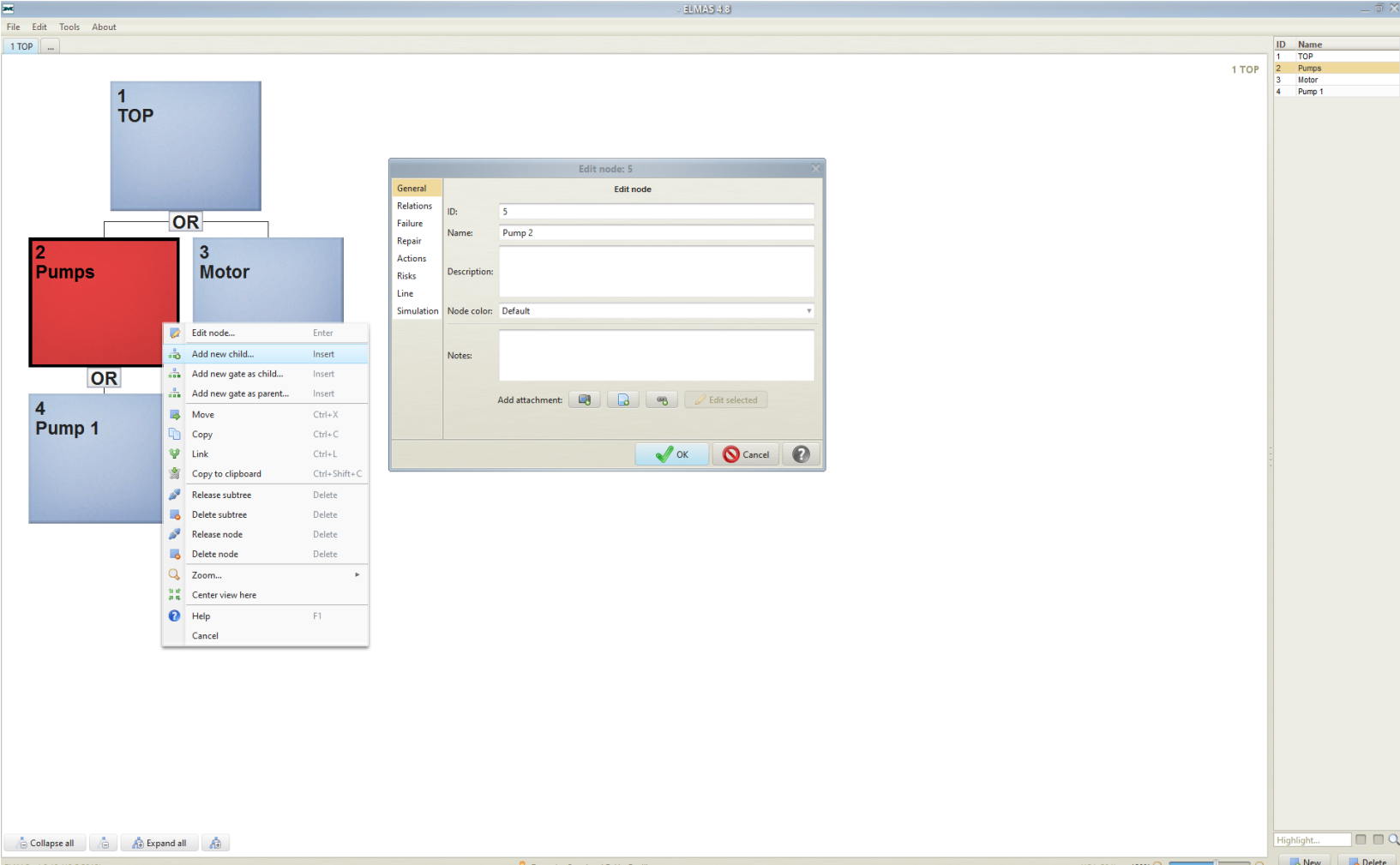
- Simulation
- Reliability, Availability
- Risk Analysis
- Importance measures
- Conditional probabilities
- Spare part consumption
- Resources
- FMEA, Classification, RCM, Decision tree, Criticality

Software

- Graphical user interface
- Excel export and import
- HTML report
- Table summary
- ERP interface
- Project versioning
- Template library
- Search
- Web start

Basic Fault Tree – General User Interface

Basic Fault Tree: Structure + Node Info



The screenshot displays the ELMAS 4.8 software interface. On the left, a fault tree diagram is shown with the following structure:

- Node 1 (TOP) is an OR gate.
- Node 2 (Pumps) is a child of Node 1.
- Node 3 (Motor) is a child of Node 1.
- Node 4 (Pump 1) is a child of Node 2.

An 'Edit node: 5' dialog box is open in the center, showing the following fields:

- Relations ID: 5
- Failure Name: Pump 2
- Repair Description:
- Actions Description:
- Risks Description:
- Line Description:
- Simulation Node color: Default
- Notes:

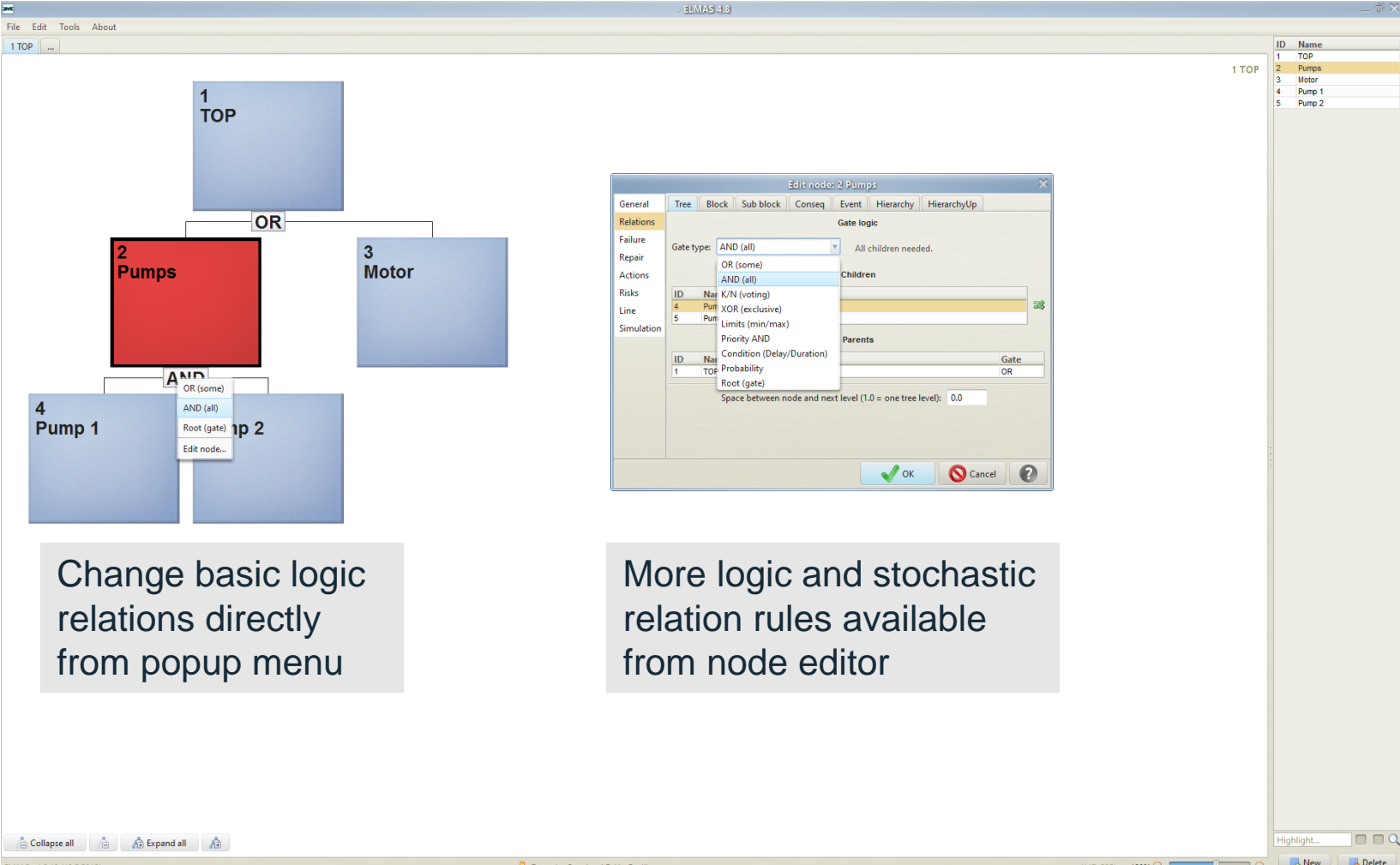
At the bottom of the dialog box, there are buttons for 'Add attachment', 'OK', 'Cancel', and a help icon.

On the right side of the software window, a table lists the nodes in the fault tree:

ID	Name
1	TOP
2	Pumps
3	Motor
4	Pump 1

The status bar at the bottom of the window shows 'ELMAS v4.8.13 (19.5.2016)', 'Ramentor Oy - Jussi-Pekka Penttinen', '(124, 204) 180%', and buttons for 'New' and 'Delete'.

Basic Fault Tree: Gate Relation



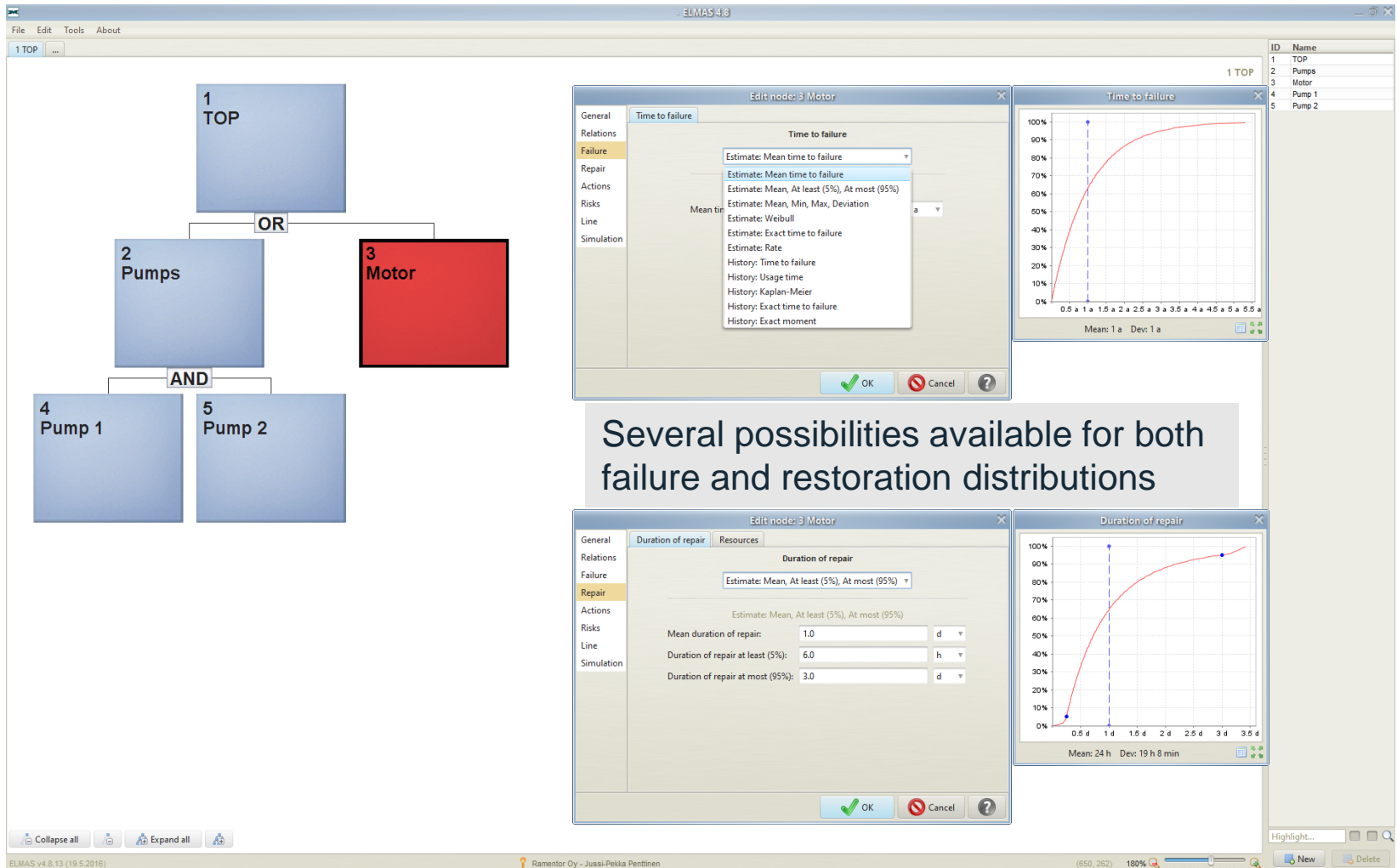
The screenshot shows the ELMAS 4.8 software interface. On the left, a fault tree diagram is displayed with nodes: 1 TOP (blue), 2 Pumps (red), 3 Motor (blue), 4 Pump 1 (blue), and 5 Pump 2 (blue). Node 2 is connected to nodes 4 and 5 via an AND gate. Node 1 is connected to nodes 2 and 3 via an OR gate. A context menu is open over node 2, showing options: OR (some), AND (all), Root (gate), and Edit node... On the right, the 'Edit node: 2 Pumps' dialog box is open, showing the 'Gate logic' tab. The 'Gate type' dropdown is set to 'AND (all)'. The 'Children' list contains nodes 4 and 5. The 'Parents' list contains node 1. A 'Space between node and next level' field is set to 0.0. At the bottom right, a table lists the nodes in the tree:

ID	Name
1	TOP
2	Pumps
3	Motor
4	Pump 1
5	Pump 2

Change basic logic relations directly from popup menu

More logic and stochastic relation rules available from node editor

Basic Fault Tree: Root Failure/Restoration



The screenshot displays the ELMAS 4.8 software interface. On the left, a fault tree diagram is shown with the following structure:

- Root node: 1 TOP
- Intermediate node: 2 Pumps (connected to TOP via an OR gate)
- Intermediate node: 3 Motor (connected to TOP via an OR gate)
- Leaf nodes: 4 Pump 1 and 5 Pump 2 (connected to Pumps via an AND gate)

Two configuration windows are open for node 3 Motor:

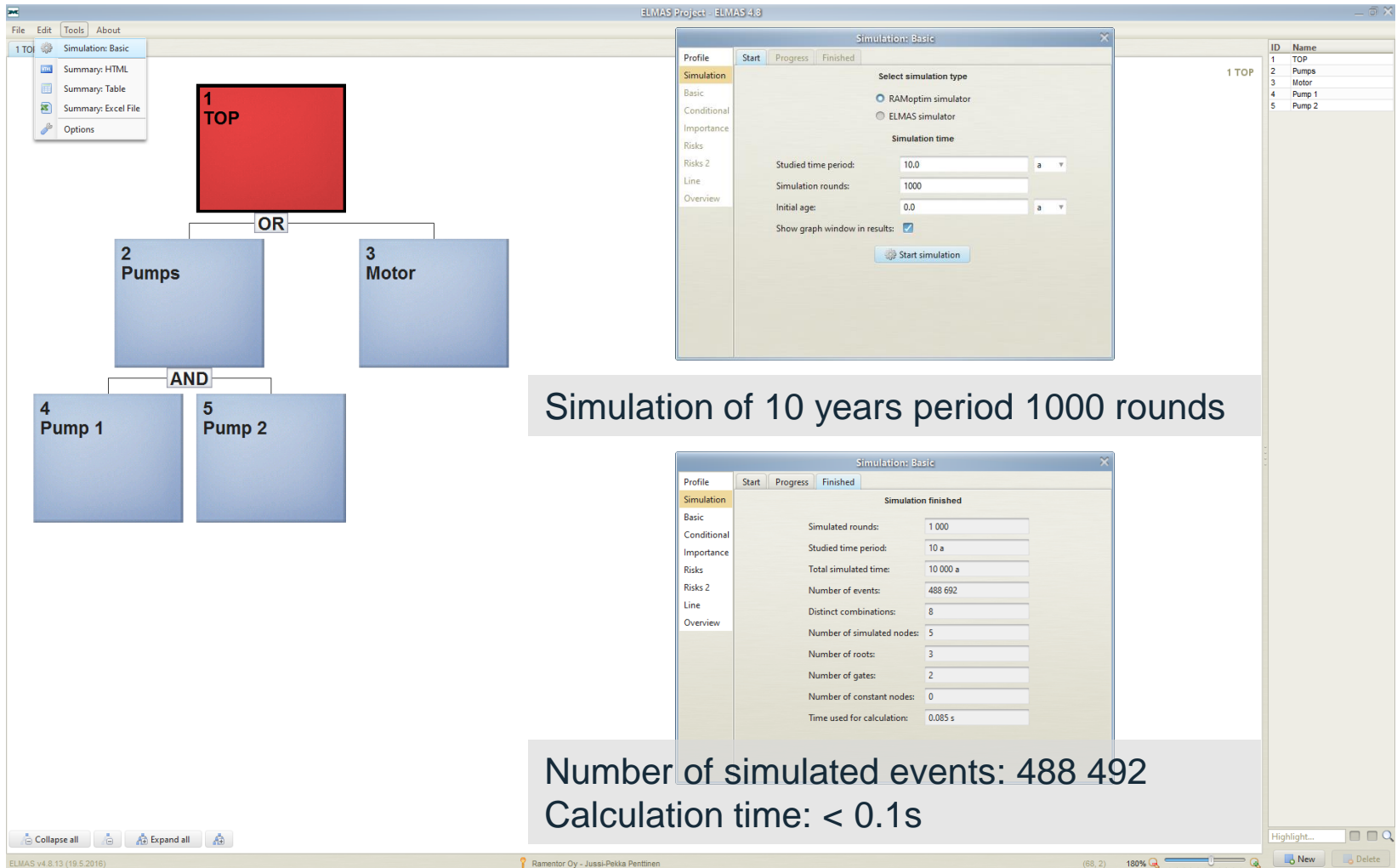
- Time to failure window:** Shows a dropdown menu for 'Estimate: Mean time to failure' with options: Estimate: Mean time to failure, Estimate: Mean, At least (5%), At most (95%), Estimate: Mean, Min, Max, Deviation, Estimate: Weibull, Estimate: Exact time to failure, Estimate: Rate, History: Time to failure, History: Usage time, History: Kaplan-Meier, History: Exact time to failure, History: Exact moment.
- Duration of repair window:** Shows a dropdown menu for 'Estimate: Mean, At least (5%), At most (95%)' with input fields for: Mean duration of repair: 1.0 d, Duration of repair at least (5%): 6.0 h, and Duration of repair at most (95%): 3.0 d.

Two graphs are also visible:

- Time to failure graph:** A cumulative distribution function (CDF) plot showing a curve starting at (0,0) and approaching 100% as time increases. The x-axis is labeled 'a' and the y-axis is labeled 'a'.
- Duration of repair graph:** A cumulative distribution function (CDF) plot showing a curve starting at (0,0) and approaching 100% as time increases. The x-axis is labeled 'd' and the y-axis is labeled 'd'.

Several possibilities available for both failure and restoration distributions

Basic Fault Tree: Stochastic Simulation



The screenshot displays the ELMAS v4.8.13 interface. On the left, a fault tree diagram is shown with the following structure:

- 1 TOP** (Red box) is connected via an **OR** gate to **2 Pumps** and **3 Motor** (Blue boxes).
- 2 Pumps** is connected via an **AND** gate to **4 Pump 1** and **5 Pump 2** (Blue boxes).

On the right, the **Simulation: Basic** dialog box is open, showing the **Start** tab. The simulation type is set to **ELMAS simulator**. The **Simulation time** parameters are:

- Studied time period: 10.0 a
- Simulation rounds: 1000
- Initial age: 0.0 a

The **Start simulation** button is visible.

Below the dialog box, a grey banner reads: **Simulation of 10 years period 1000 rounds**

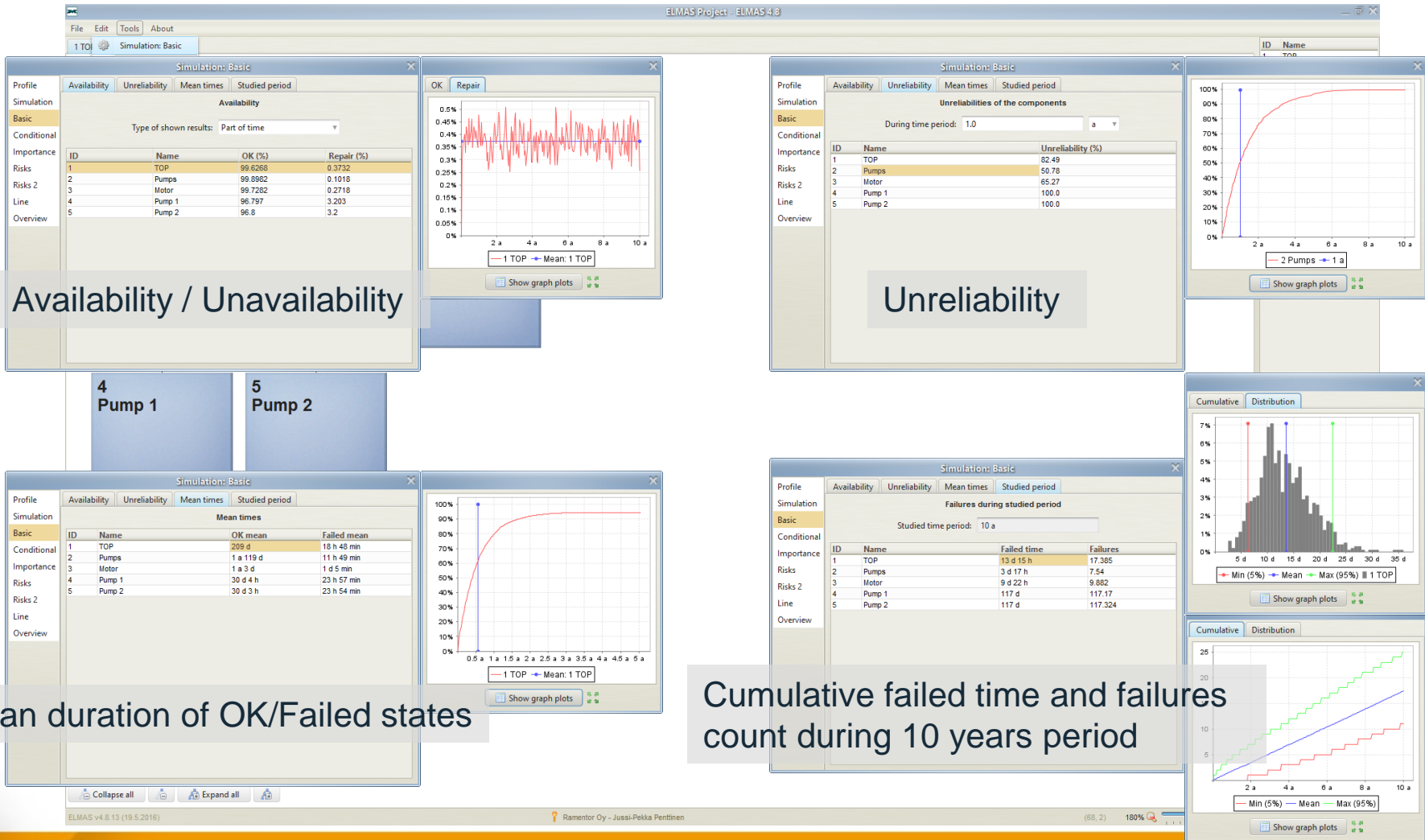
Below that, another **Simulation: Basic** dialog box is shown, displaying the **Finished** tab with the following results:

Simulation finished	
Simulated rounds:	1 000
Studied time period:	10 a
Total simulated time:	10 000 a
Number of events:	488 692
Distinct combinations:	8
Number of simulated nodes:	5
Number of roots:	3
Number of gates:	2
Number of constant nodes:	0
Time used for calculation:	0.085 s

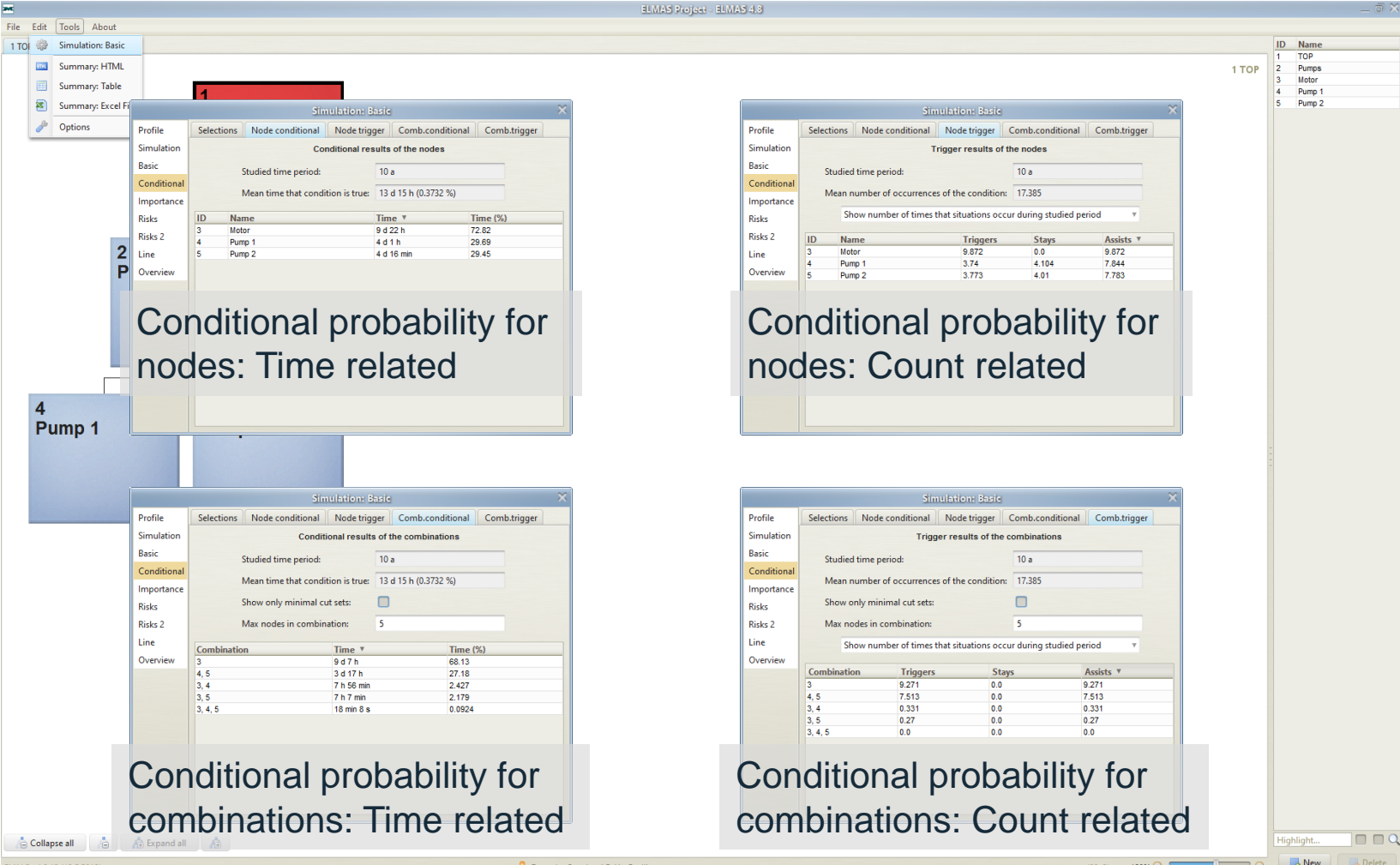
Below this dialog box, a grey banner reads: **Number of simulated events: 488 492**
Calculation time: < 0.1s

The bottom status bar of the software shows: **ELMAS v4.8.13 (19.5.2016)**, **Ramentor Oy - Jussi-Pekka Penttinen**, **(88, 2)**, **180%**, and **New Delete** buttons.

Basic Fault Tree: Basic Analysis Results



Basic Fault Tree: Conditional Results



The screenshot displays the ELMAS 4.8 software interface with four simulation result windows. The main window shows a fault tree diagram with nodes 1, 2, 3, 4, and 5. The simulation results are as follows:

Conditional results of the nodes (Time related):

ID	Name	Time	Time (%)
3	Motor	9 d 22 h	72.82
4	Pump 1	4 d 1 h	29.69
5	Pump 2	4 d 16 min	29.45

Trigger results of the nodes (Count related):

ID	Name	Triggers	Stays	Assists
3	Motor	9.872	0.0	9.872
4	Pump 1	3.74	4.104	7.844
5	Pump 2	3.773	4.01	7.783

Conditional results of the combinations (Time related):

Combination	Time	Time (%)
3	9 d 7 h	68.13
4, 5	3 d 17 h	27.18
3, 4	7 h 56 min	2.427
3, 5	7 h 7 min	2.179
3, 4, 5	18 min 8 s	0.0924

Trigger results of the combinations (Count related):

Combination	Triggers	Stays	Assists
3	9.271	0.0	9.271
4, 5	7.513	0.0	7.513
3, 4	0.331	0.0	0.331
3, 5	0.27	0.0	0.27
3, 4, 5	0.0	0.0	0.0

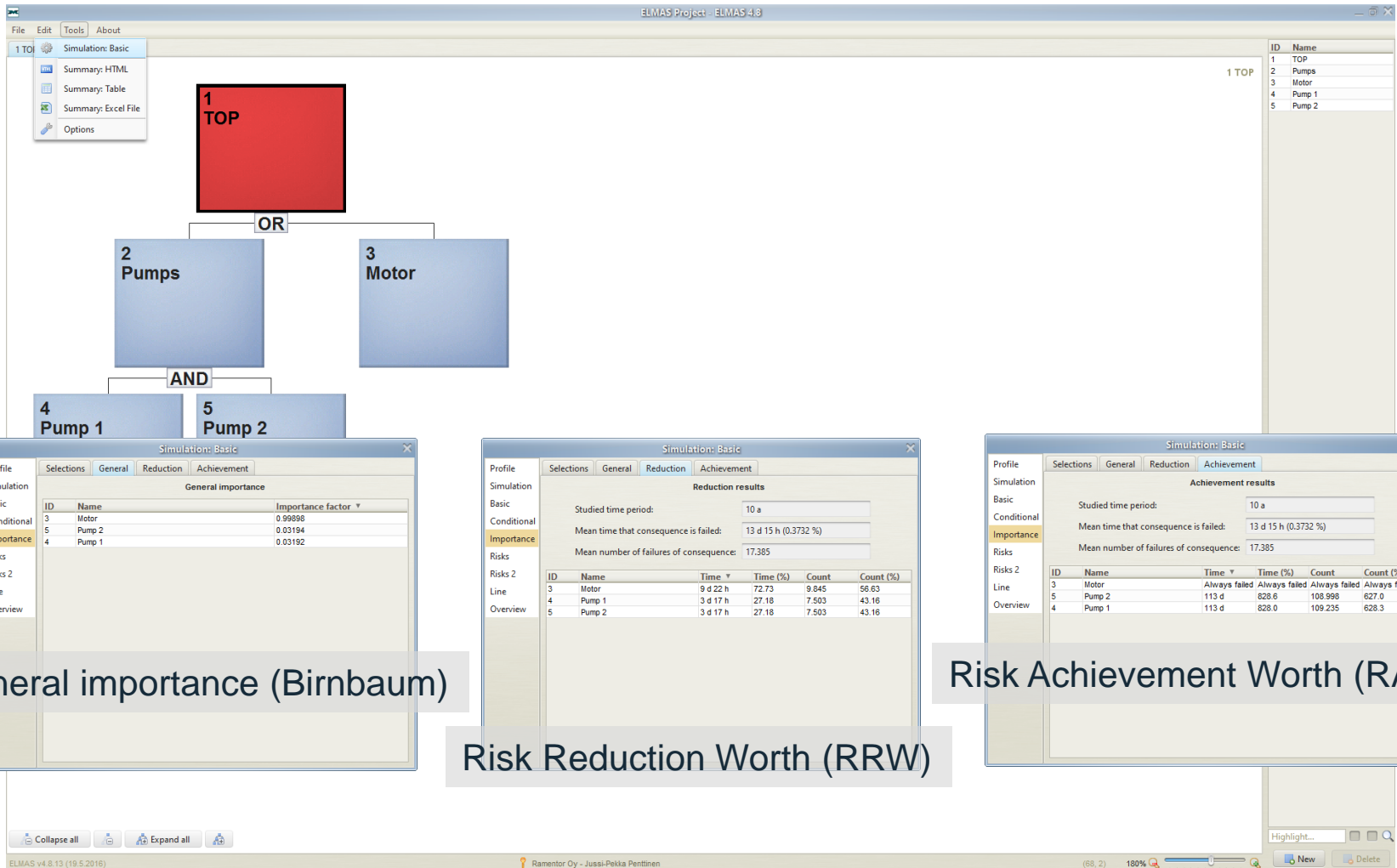
Conditional probability for nodes: Time related

Conditional probability for nodes: Count related

Conditional probability for combinations: Time related

Conditional probability for combinations: Count related

Basic Fault Tree: Importance Measures



The screenshot displays the ELMAS 4.8 software interface. At the top, a fault tree diagram shows a top event '1 TOP' (red box) connected via an 'OR' gate to two intermediate events: '2 Pumps' and '3 Motor' (blue boxes). The '2 Pumps' event is further connected via an 'AND' gate to two bottom events: '4 Pump 1' and '5 Pump 2' (blue boxes). A table on the right side of the main window lists the events:

ID	Name
1	TOP
2	Pumps
3	Motor
4	Pump 1
5	Pump 2

Three simulation result windows are overlaid on the main interface:

- General importance (Birnbbaum):** Shows the 'General importance' tab with a table of importance factors for each event.
- Risk Reduction Worth (RRW):** Shows the 'Reduction results' tab with a table of risk reduction metrics.
- Risk Achievement Worth (RAW):** Shows the 'Achievement' tab with a table of risk achievement metrics.

General importance (Birnbbaum)

Risk Reduction Worth (RRW)

Risk Achievement Worth (RAW)

Basic Fault Tree: Break and Downtime Cost

The screenshot displays the ELMAS Project - ELMAS 4.8 software interface. On the left, a fault tree diagram is shown with the following structure:

- 1 TOP** (Red box) is connected via an **OR** gate to:
 - 2 Pumps** (Blue box)
 - 3 Motor** (Blue box)
- 2 Pumps** is connected via an **AND** gate to:
 - 4 Pump 1** (Blue box)
 - 5 Pump 2** (Blue box)

Two configuration windows are overlaid on the right side of the interface:

Top Window: Edit node: 1 TOP - Break

- Tab: Break
- Field: Break cost: 10000.0 €
- Text overlay: Break cost

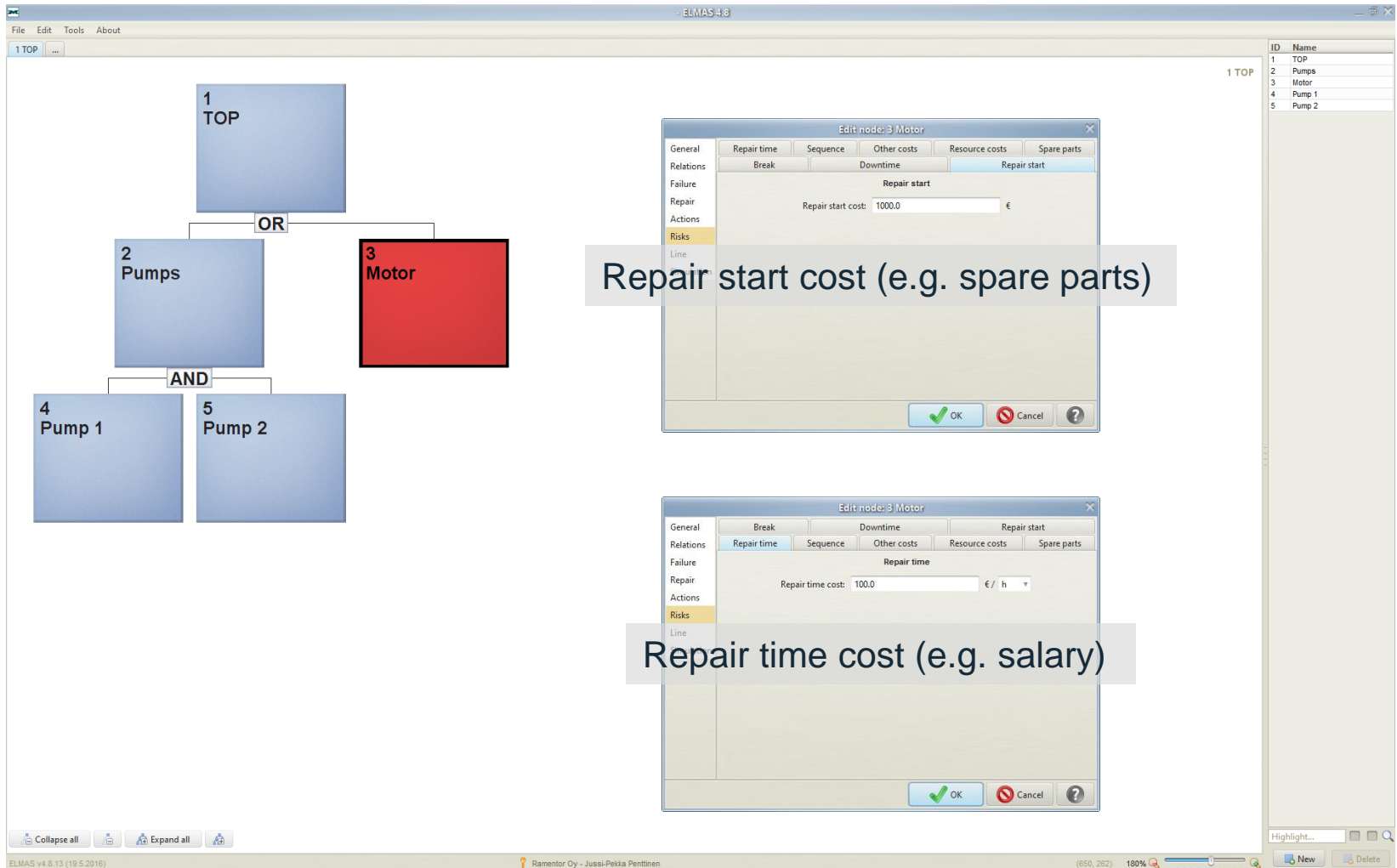
Bottom Window: Edit node: 1 TOP - Downtime

- Tab: Downtime
- Field: Downtime cost: 1000 € / h
- Text overlay: Downtime cost

The right sidebar contains a table with the following data:

ID	Name
1	TOP
2	Pumps
3	Motor
4	Pump 1
5	Pump 2

Basic Fault Tree: Repair Start and Time



The screenshot displays the ELMAS 4.8 software interface. On the left, a fault tree diagram is shown with the following structure:

- Node 1 (TOP) is connected via an OR gate to Node 2 (Pumps) and Node 3 (Motor).
- Node 2 (Pumps) is connected via an AND gate to Node 4 (Pump 1) and Node 5 (Pump 2).
- Node 3 (Motor) is highlighted in red.

Two configuration windows for Node 3 (Motor) are shown:

- The top window is titled "Edit node: 3 Motor" and shows the "Repair start" tab. The "Repair start cost" is set to 1000.0 €.
- The bottom window is titled "Edit node: 3 Motor" and shows the "Repair time" tab. The "Repair time cost" is set to 100.0 €/h.

Annotations in grey boxes point to these values:

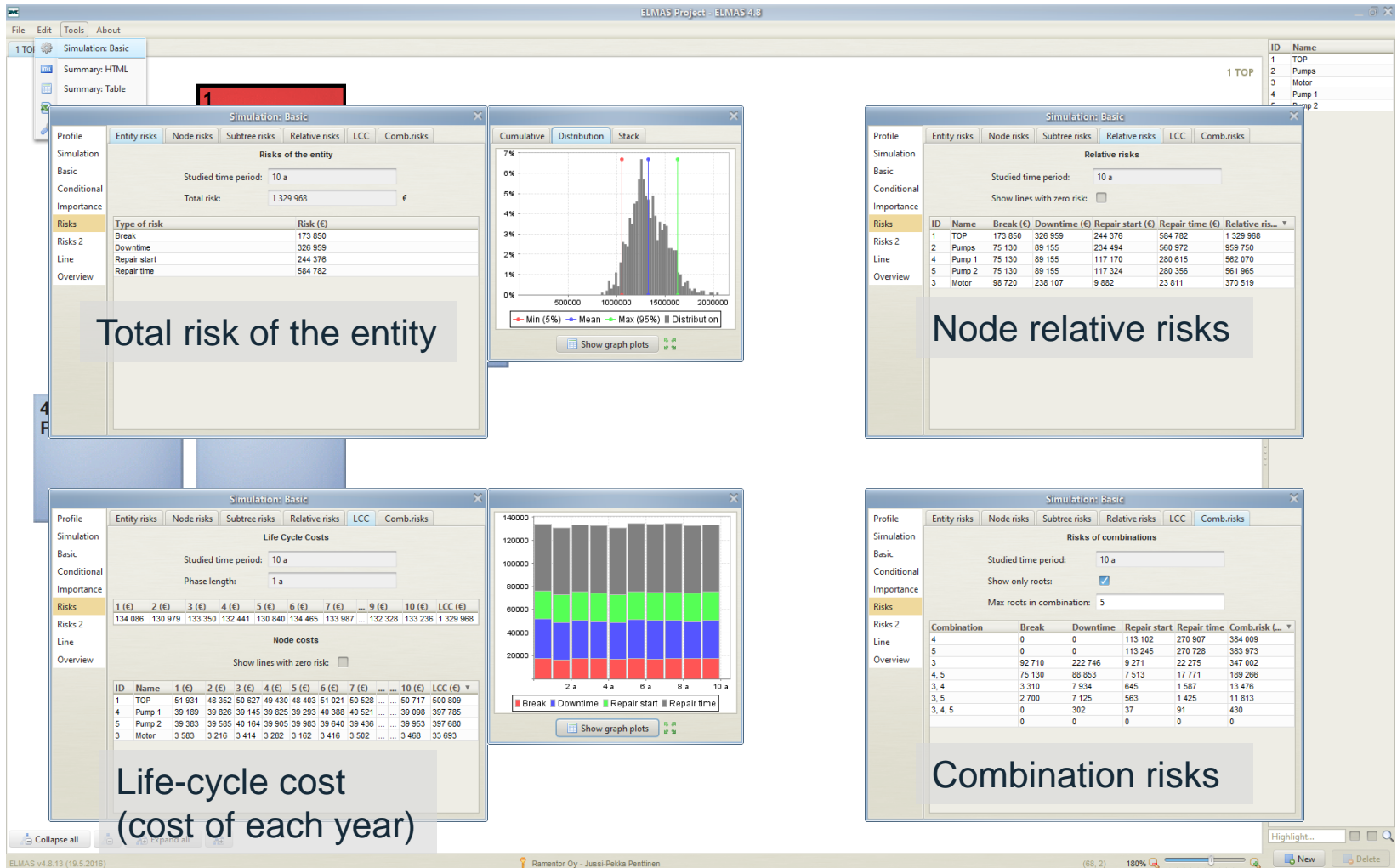
- "Repair start cost (e.g. spare parts)" points to the 1000.0 € value.
- "Repair time cost (e.g. salary)" points to the 100.0 €/h value.

The software interface includes a menu bar (File, Edit, Tools, About), a toolbar, and a right-hand pane with a table listing nodes:

ID	Name
1	TOP
2	Pumps
3	Motor
4	Pump 1
5	Pump 2

At the bottom of the window, the status bar shows "ELMAS v4.8.13 (19.5.2016)", "Ramentor Oy - Jussi-Pekka Penttinen", and system information like "(650, 262) 180%".

Basic Fault Tree: Risk Results



The screenshot displays the ELMAS 4.8 software interface with four simulation result windows open. The main window shows the simulation profile for 'Simulation: Basic' with a studied time period of 10 years. The total risk of the entity is 1,329,968 €. The node relative risks window shows the relative risks for various components. The life-cycle cost window shows the cost of each year, with a total cost of 1,329,968 €. The combination risks window shows the risks of combinations, with a maximum of 5 roots in combination.

Total risk of the entity

Type of risk	Risk (€)
Break	173 850
Risks 2	328 959
Line	244 376
Overview	584 782

Node relative risks

ID	Name	Break (€)	Downtime (€)	Repair start (€)	Repair time (€)	Relative risk
1	TOP	173 850	328 959	244 376	584 782	1 329 968
2	Pumps	75 130	89 155	234 494	569 972	959 750
4	Pump 1	75 130	89 155	117 170	280 615	562 070
5	Pump 2	75 130	89 155	117 324	280 356	561 965
3	Motor	98 720	238 107	9 882	23 811	370 519

Life-cycle cost (cost of each year)

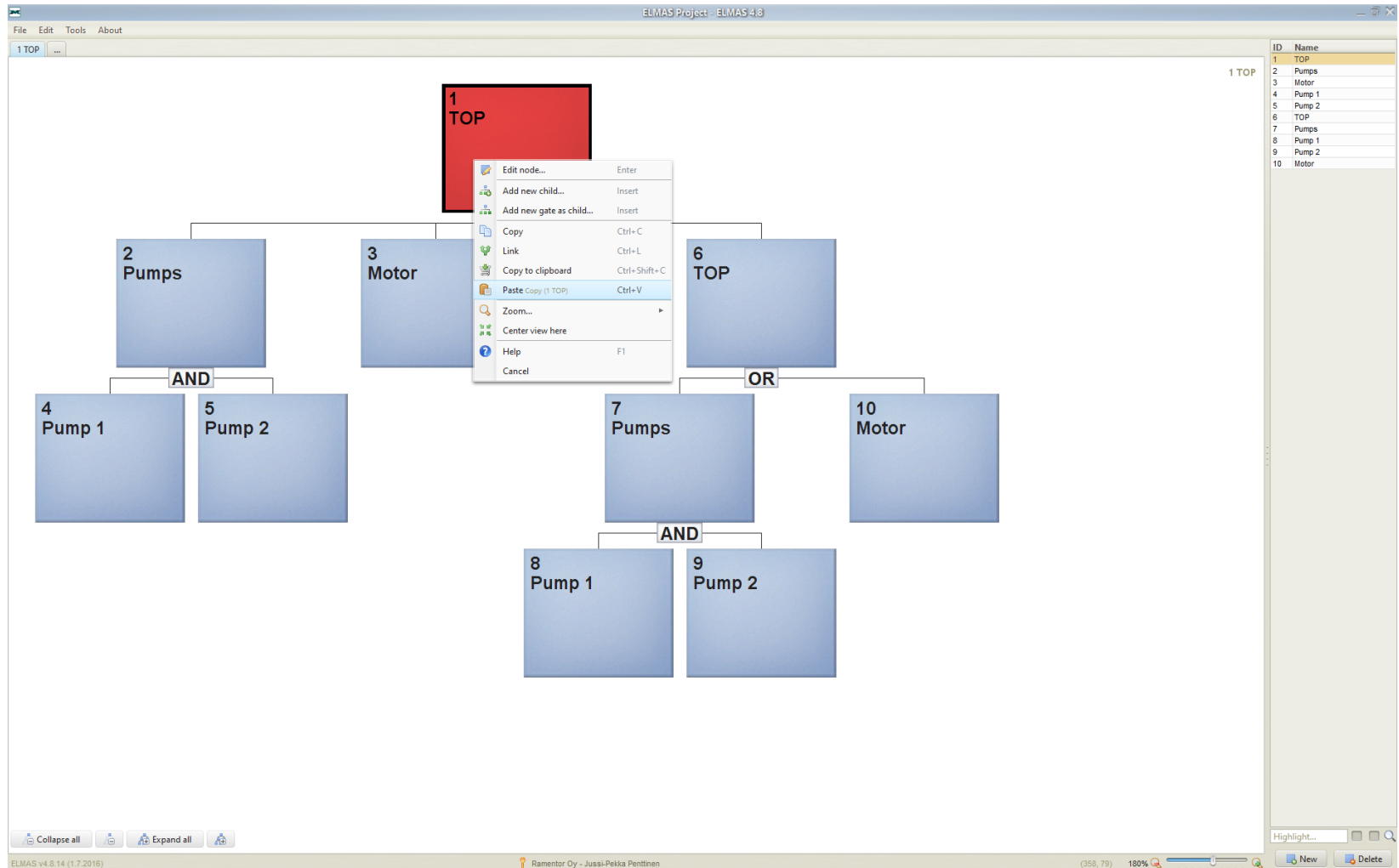
ID	Name	1 (€)	2 (€)	3 (€)	4 (€)	5 (€)	6 (€)	7 (€)	8 (€)	9 (€)	10 (€)	LCC (€)
1	TOP	51 931	48 352	50 627	49 430	48 403	51 021	50 528	...	50 717	500 809	1 329 968
4	Pump 1	39 189	39 828	39 145	39 625	39 283	40 388	40 521	...	39 098	397 785	3 963
5	Pump 2	39 383	39 586	40 164	39 905	39 983	39 640	39 436	...	39 963	397 680	3 468
3	Motor	3 583	3 216	3 414	3 282	3 162	3 416	3 502	...	3 468	33 693	336 933

Combination risks

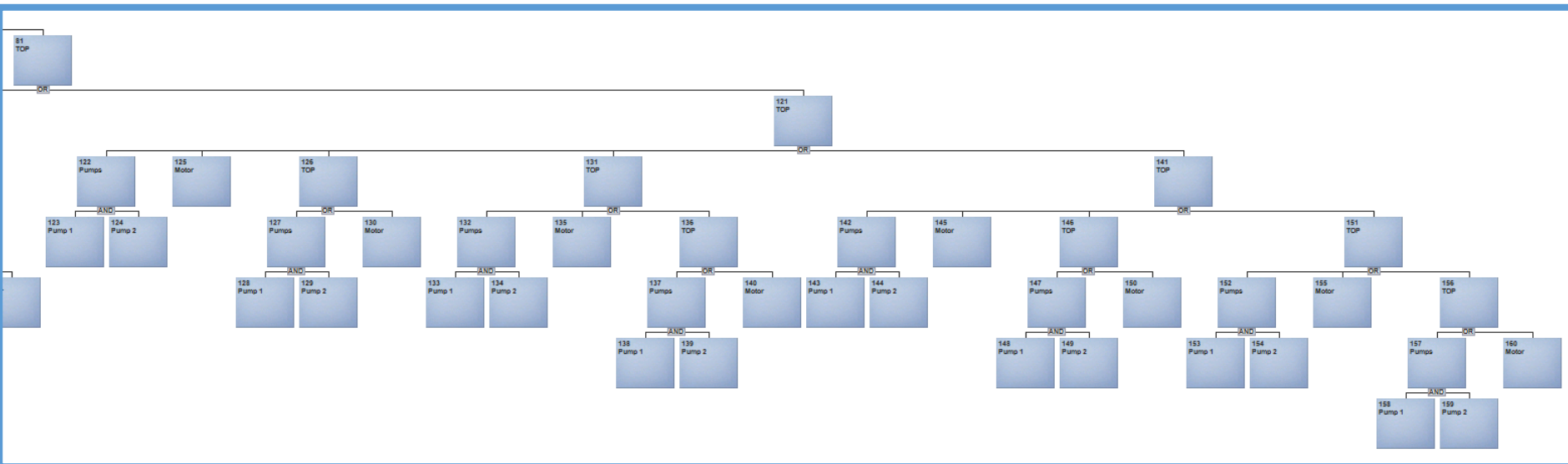
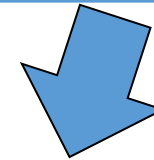
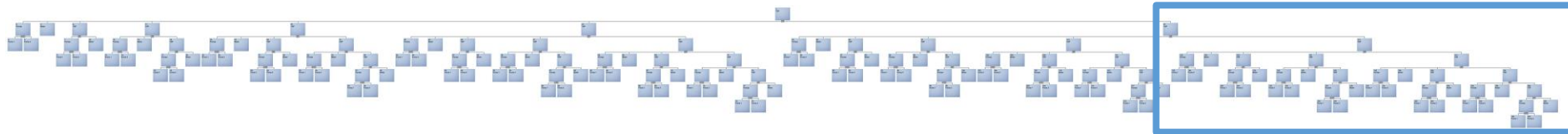
Combination	Break	Downtime	Repair start	Repair time	Comb.risk (€)
4	0	0	113 102	270 907	384 009
5	0	0	113 245	270 728	383 973
4, 5	92 710	222 746	9 271	22 275	347 002
3	75 130	88 853	7 513	17 771	189 266
3, 4	3 310	7 934	645	1 587	13 478
3, 5	2 700	7 125	563	1 425	11 613
3, 4, 5	0	302	37	91	430
3	0	0	0	0	0

Larger fault tree – Data Interface

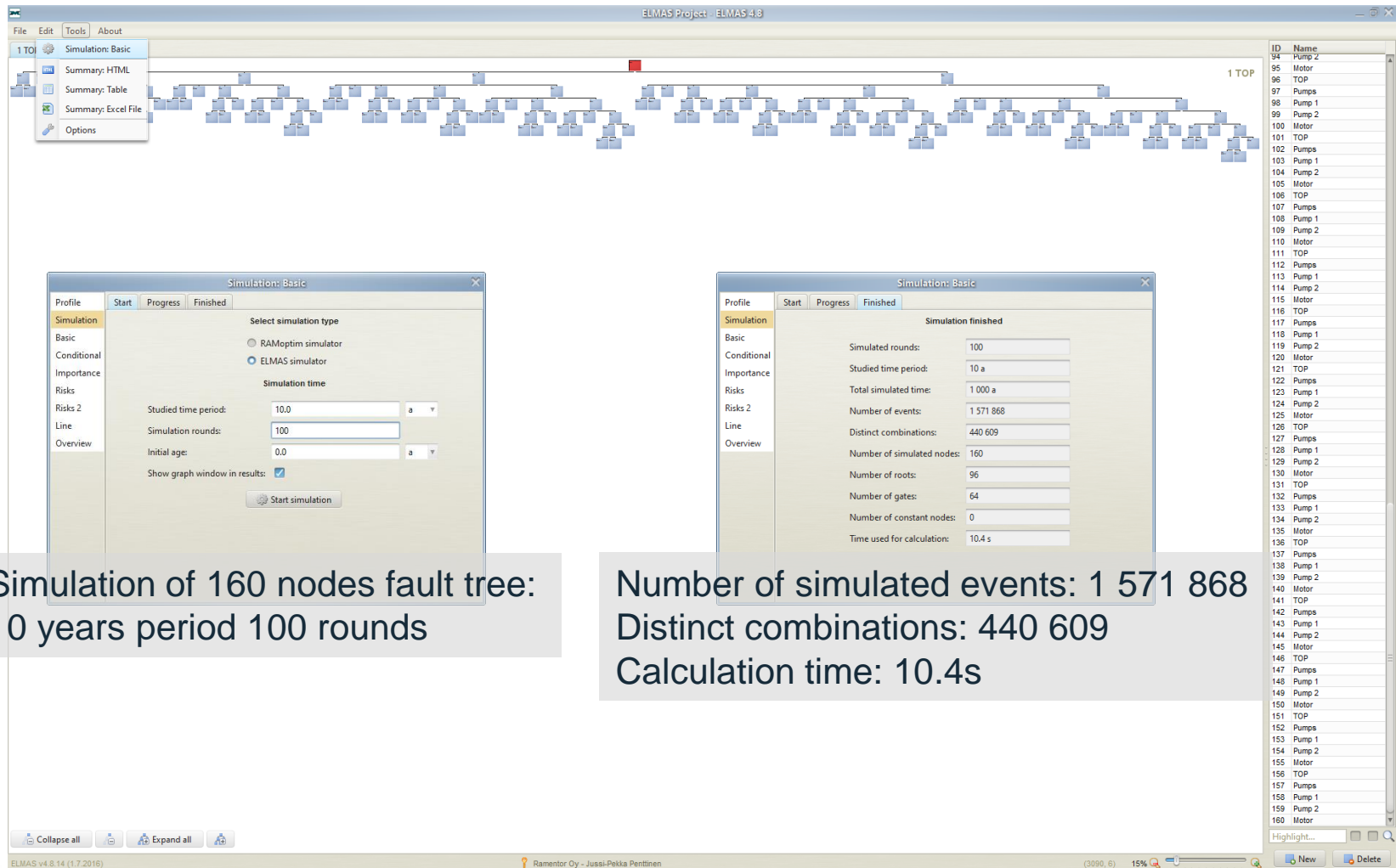
Larger Fault Tree: Copy-Paste Subtree



Larger Fault Tree: Repeat Until 160 Nodes



Larger Fault Tree: Simulation



The screenshot shows the ELMAS Project - ELMAS 4.8 interface. The main window displays a large fault tree diagram with a '1 TO' event at the top. A 'Simulation: Basic' dialog box is open, showing simulation parameters. A second 'Simulation: Basic' dialog box shows the results of the simulation.

Simulation: Basic (Left Dialog)

- Profile: Simulation
- Start: Start
- Progress: Progress
- Finished: Finished
- Select simulation type:
 - RAMOptim simulator
 - ELMAS simulator
- Simulation time:
 - Studied time period: 10.0 a
 - Simulation rounds: 100
 - Initial age: 0.0 a
 - Show graph window in results:
 - Start simulation

Simulation: Basic (Right Dialog)

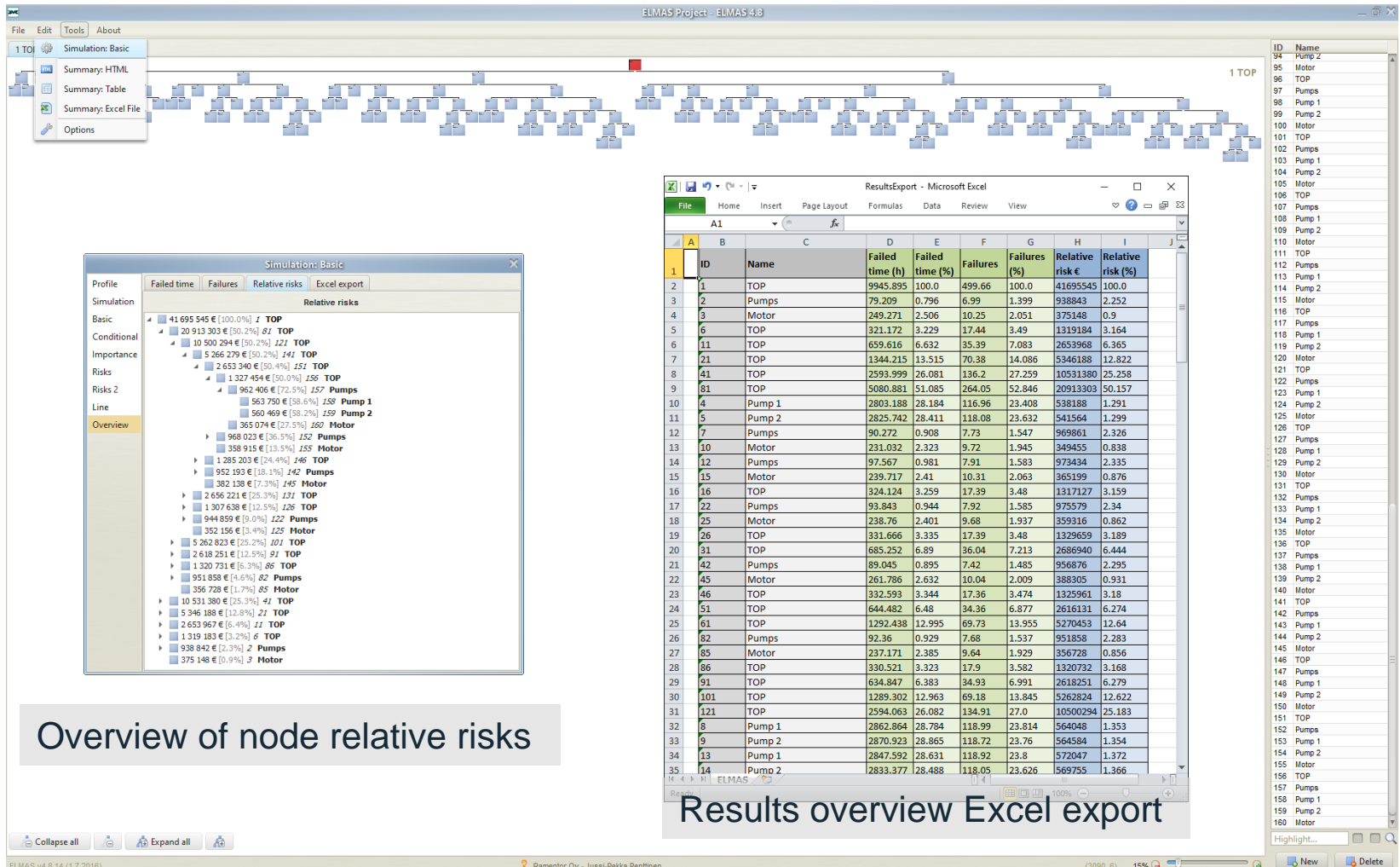
- Profile: Simulation
- Start: Start
- Progress: Progress
- Finished: Finished
- Simulation finished
- Basic: Simulated rounds: 100
- Conditional: Studied time period: 10 a
- Importance: Total simulated time: 1 000 a
- Risks: Number of events: 1 571 868
- Risks 2: Distinct combinations: 440 609
- Line: Number of simulated nodes: 160
- Overview: Number of roots: 96
- Number of gates: 64
- Number of constant nodes: 0
- Time used for calculation: 10.4 s

**Simulation of 160 nodes fault tree:
10 years period 100 rounds**

**Number of simulated events: 1 571 868
Distinct combinations: 440 609
Calculation time: 10.4s**

ELMAS v4.8.14 (1.7.2015) | Ramentor Oy - Jussi-Pekka Penttinen | (3090, 6) 15% | New Delete

Larger Fault Tree: Results Overview



The screenshot displays the ELMAS 4.8 software interface. The main window shows a complex fault tree diagram. A 'Simulation: Basic' window is open, showing a tree of simulation results with columns for 'Failed time', 'Failures', 'Relative risks', and 'Excel export'. A 'ResultsExport - Microsoft Excel' window is also open, showing a table of results.

ID	Name	Failed time (h)	Failed time (%)	Failures	Failures (%)	Relative risk €	Relative risk (%)
1	TOP	9945.895	100.0	499.66	100.0	41695545	100.0
2	Pumps	79.209	0.796	6.99	1.399	938843	2.252
3	Motor	249.271	2.506	10.25	2.051	375148	0.9
4	TOP	321.172	3.229	17.44	3.49	1319184	3.164
5	TOP	659.616	6.632	35.39	7.083	2653968	6.365
6	TOP	1344.215	13.515	70.38	14.086	5346188	12.822
7	TOP	2593.999	26.081	136.2	27.259	10531380	25.258
8	TOP	5080.881	51.085	264.05	52.846	20913303	50.157
9	Pump 1	2803.188	28.184	116.96	23.408	538188	1.291
10	Pump 2	2825.742	28.411	118.08	23.632	541564	1.299
11	Pumps	90.272	0.908	7.73	1.547	969861	2.326
12	Motor	231.032	2.323	9.72	1.945	349455	0.838
13	Pumps	97.567	0.981	7.91	1.583	973434	2.335
14	Motor	239.717	2.41	10.31	2.063	365199	0.876
15	TOP	324.124	3.259	17.39	3.48	1317127	3.159
16	Pumps	93.843	0.944	7.92	1.585	975579	2.34
17	Motor	238.76	2.401	9.68	1.937	359316	0.862
18	TOP	331.666	3.335	17.39	3.48	1329659	3.189
19	TOP	685.252	6.89	36.04	7.213	2686940	6.444
20	Pumps	89.045	0.895	7.42	1.485	956876	2.295
21	Motor	261.786	2.632	10.04	2.009	388305	0.931
22	TOP	332.593	3.344	17.36	3.474	1325961	3.18
23	TOP	644.482	6.48	34.36	6.877	2616131	6.274
24	TOP	1292.438	12.995	69.73	13.955	5270453	12.64
25	Pumps	92.36	0.929	7.68	1.537	951858	2.283
26	Motor	237.171	2.385	9.64	1.929	356728	0.856
27	TOP	330.521	3.323	17.9	3.582	1320732	3.168
28	TOP	634.847	6.383	34.93	6.991	2618251	6.279
29	TOP	1289.302	12.963	69.18	13.845	5262824	12.622
30	TOP	2594.063	26.082	134.91	27.0	10500294	25.183
31	Pump 1	2862.864	28.784	118.99	23.814	564048	1.353
32	Pump 2	2870.923	28.865	118.72	23.76	564584	1.354
33	Pump 1	2847.592	28.631	118.92	23.8	572047	1.372
34	Pump 2	2833.377	28.488	118.05	23.626	569755	1.366

Overview of node relative risks

Results overview Excel export

Larger Fault Tree: HTML Summary

ELMAS HTML Summary
✕ +

←

file:///C:/Users/username/ELMAS/temp/ELMAS-ELMAS-Project/index.htm

↻

🔍

Search

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ELMAS Project

- [-] [OR] 1 TOP
 - [-] [AND] 2 Pumps
 - [-] 4 Pump 1
 - [-] 5 Pump 2
 - [-] 3 Motor
- [-] [OR] 6 TOP
 - [-] [AND] 7 Pumps
 - [-] 8 Pump 1
 - [-] 9 Pump 2
 - [-] 10 Motor
- [-] [OR] 11 TOP
 - [-] [AND] 12 Pumps
 - [-] 13 Pump 1
 - [-] 14 Pump 2
 - [-] 15 Motor
- [-] [OR] 16 TOP
 - [-] [AND] 17 Pumps
 - [-] 18 Pump 1
 - [-] 19 Pump 2
 - [-] 20 Motor
- [-] [OR] 21 TOP
- [-] [OR] 41 TOP
- [-] [OR] 81 TOP

Expand/Collapse: Expand All ▼ Refresh

5 Pump 2

General

ID:	5
Name:	Pump 2

Relations

Tree

Parents:	2 Pumps [AND]
----------	---------------

Failure

Time to failure

Mean time to failure:	30.0 d
-----------------------	--------

Repair

Duration of repair:

Mean duration of repair:	1.0 d
--------------------------	-------

Risks

Repair start

Repair start cost:	1000.0 €
--------------------	----------

Repair time

Repair time cost:	100.0 € / h
-------------------	-------------

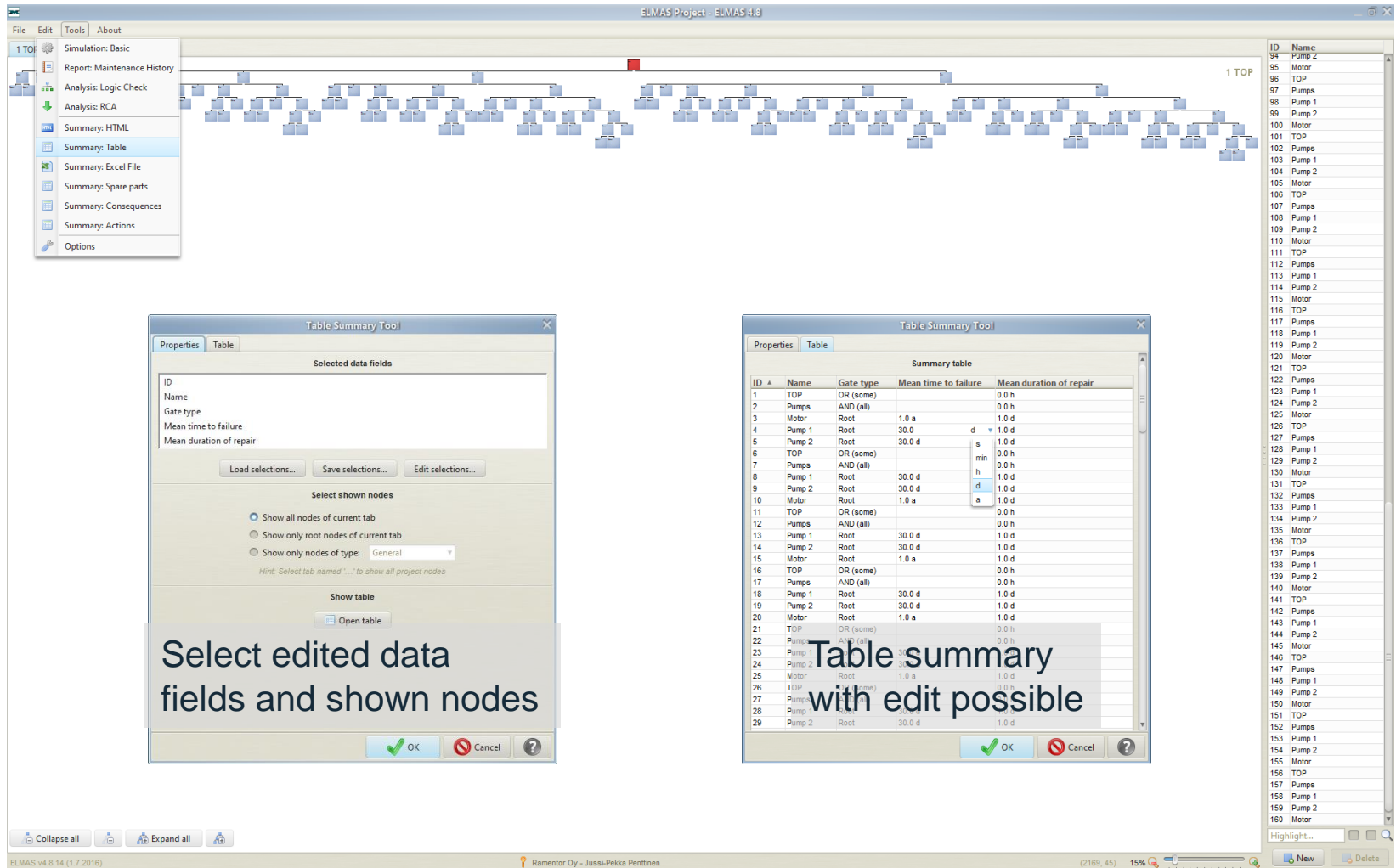
Copyright © Ramentor Oy (www.ramentor.com)

file:///C:/Users/jussi/ELMAS/temp/ELMAS-ELMAS-Project/Nodes/Node-5.htm

Tree structure

Node data fields

Larger Fault Tree: Table Summary



The screenshot shows the ELMAS Project - ELMAS 4.8 interface. A large fault tree is displayed in the center, with a menu on the left and a component list on the right. Two 'Table Summary Tool' windows are overlaid on the bottom half of the screen.

Table Summary Tool - Left Window:

Properties | Table

Selected data fields

ID
Name
Gate type
Mean time to failure
Mean duration of repair

Load selections... Save selections... Edit selections...

Select shown nodes

Show all nodes of current tab
 Show only root nodes of current tab
 Show only nodes of type: General

Hint: Select tab named "...to show all project nodes"

Show table

Open table

Select edited data fields and shown nodes

OK Cancel ?

Table Summary Tool - Right Window:

Properties | Table

Summary table

ID	Name	Gate type	Mean time to failure	Mean duration of repair
1	TOP	OR (some)		0.0 h
2	Pumps	AND (all)		0.0 h
3	Motor	Root	1.0 a	1.0 d
4	Pump 1	Root	30.0 d	1.0 d
5	Pump 2	Root	30.0 d	1.0 d
6	TOP	OR (some)		0.0 h
7	Pumps	AND (all)		0.0 h
8	Pump 1	Root	30.0 d	1.0 d
9	Pump 2	Root	30.0 d	1.0 d
10	Motor	Root	1.0 a	1.0 d
11	TOP	OR (some)		0.0 h
12	Pumps	AND (all)		0.0 h
13	Pump 1	Root	30.0 d	1.0 d
14	Pump 2	Root	30.0 d	1.0 d
15	Motor	Root	1.0 a	1.0 d
16	TOP	OR (some)		0.0 h
17	Pumps	AND (all)		0.0 h
18	Pump 1	Root	30.0 d	1.0 d
19	Pump 2	Root	30.0 d	1.0 d
20	Motor	Root	1.0 a	1.0 d
21	TOP	OR (some)		0.0 h
22	Pumps	AND (all)		0.0 h
23	Pump 1	Root	30.0 d	1.0 d
24	Pump 2	Root	30.0 d	1.0 d
25	Motor	Root	1.0 a	1.0 d
26	TOP	OR (some)		0.0 h
27	Pumps	AND (all)		0.0 h
28	Pump 1	Root	30.0 d	1.0 d
29	Pump 2	Root	30.0 d	1.0 d

Table summary with edit possible

OK Cancel ?

Larger Fault Tree: Excel Summary

test - Microsoft Excel

File Home Insert Page Layout Formulas Data Review View

A1 fx 1 TOP

#	ID	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8	Level #	ID	Name	Gate type	Mean time to failure	Mean duration of repair
1	1	TOP								1	1	TOP	OR (some)		0.0 h
2	2		Pumps							2	2	Pumps	AND (all)		0.0 h
3	4			Pump 1						3	4	Pump 1	Root	30.0 d	1.0 d
4	5			Pump 2						3	5	Pump 2	Root	30.0 d	1.0 d
5	3		Motor							2	3	Motor	Root	1.0 a	1.0 d
6	6		TOP							2	6	TOP	OR (some)		0.0 h
7	7			Pumps						3	7	Pumps	AND (all)		0.0 h
8	8				Pump 1					4	8	Pump 1	Root	30.0 d	1.0 d
9	9				Pump 2					4	9	Pump 2	Root	30.0 d	1.0 d
10	10			Motor						3	10	Motor	Root	1.0 a	1.0 d
11	11		TOP							2	11	TOP	OR (some)		0.0 h
12	12			Pumps						3	12	Pumps	AND (all)		0.0 h
13	13				Pump 1					4	13	Pump 1	Root	30.0 d	1.0 d
14	14				Pump 2					4	14	Pump 2	Root	30.0 d	1.0 d
15	15			Motor						3	15	Motor	Root	1.0 a	1.0 d
16	16		TOP							3	16	TOP	OR (some)		0.0 h
17	17			Pumps						4	17	Pumps	AND (all)		0.0 h
18	18					Pump 1				5	18	Pump 1	Root	30.0 d	1.0 d
19	19					Pump 2				5	19	Pump 2	Root	30.0 d	1.0 d
20	20				Motor					4	20	Motor	Root	1.0 a	1.0 d
21	21		TOP							2	21	TOP	OR (some)		0.0 h
22	22			Pumps						3	22	Pumps	AND (all)		0.0 h
23	23				Pump 1					4	23	Pump 1	Root	30.0 d	1.0 d
24	24				Pump 2					4	24	Pump 2	Root	30.0 d	1.0 d
25	25			Motor						3	25	Motor	Root	1.0 a	1.0 d
26	26		TOP							3	26	TOP	OR (some)		0.0 h
27	27			Pumps						4	27	Pumps	AND (all)		0.0 h
28	28					Pump 1				5	28	Pump 1	Root	30.0 d	1.0 d
29	29					Pump 2				5	29	Pump 2	Root	30.0 d	1.0 d
30	30			Motor						4	30	Motor	Root	1.0 a	1.0 d
31	31		TOP							3	31	TOP	OR (some)		0.0 h
32	32			Pumps						4	32	Pumps	AND (all)		0.0 h

Info Structure - 1 TOP ELMAS Project / 1 TOP / 2 Pumps / 3 Motor / 4 Pump 1 / 5 Pump 2 / 6 Motor

Ready

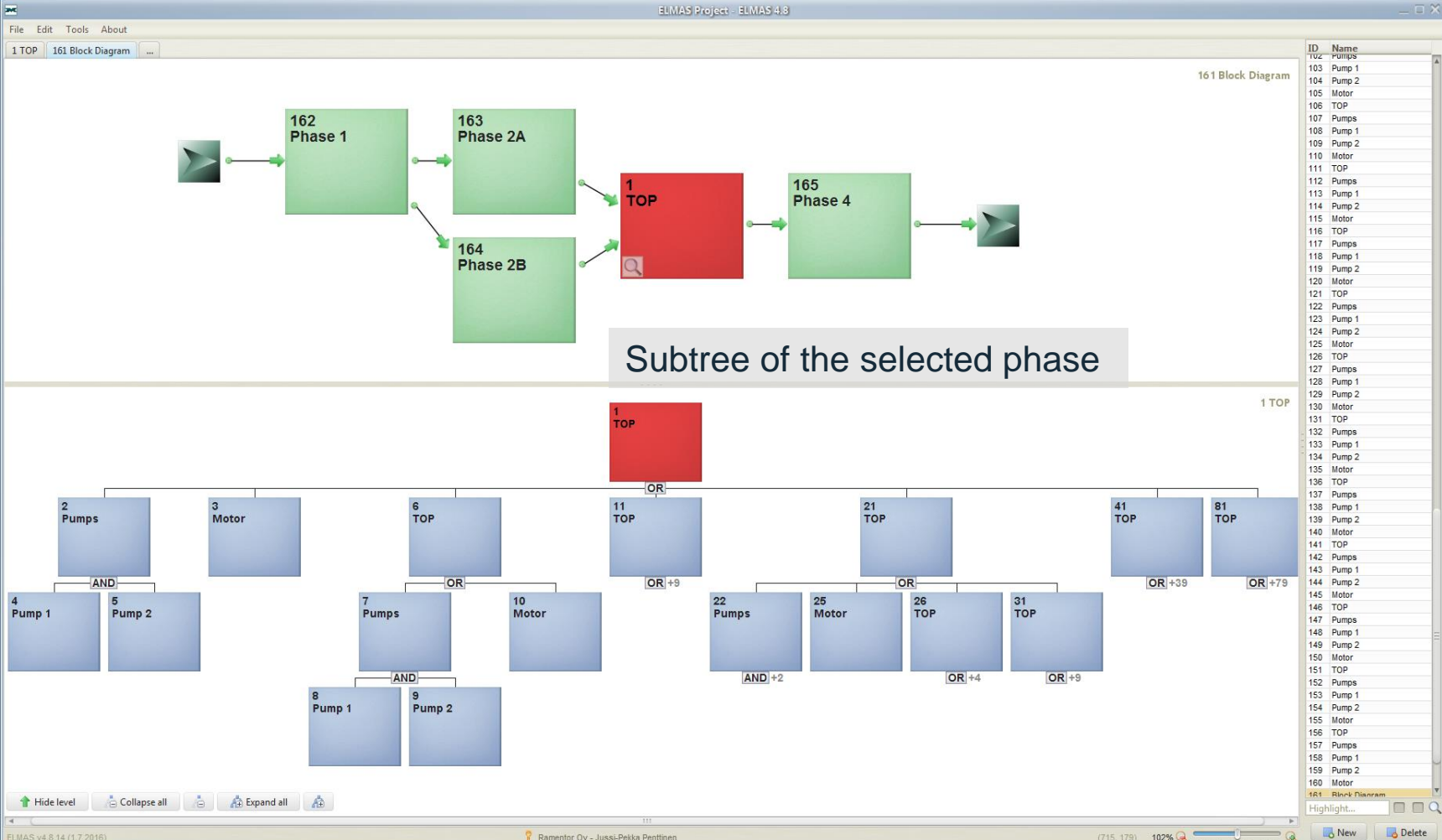
Tree structure

Selected data fields

All data fields in a node sheet

Advanced Features

Advanced Features: Block Diagram



The screenshot displays the ELMAS Project - ELMAS 4.8 interface. The main workspace shows a block diagram with the following components and connections:

- 162 Phase 1** (green box) receives input from a source and connects to **163 Phase 2A** and **164 Phase 2B** (green boxes).
- 163 Phase 2A** and **164 Phase 2B** both connect to **1 TOP** (red box).
- 1 TOP** connects to **165 Phase 4** (green box), which then connects to a final output source.

A callout box labeled "Subtree of the selected phase" shows a hierarchical tree structure for the selected **1 TOP** block:

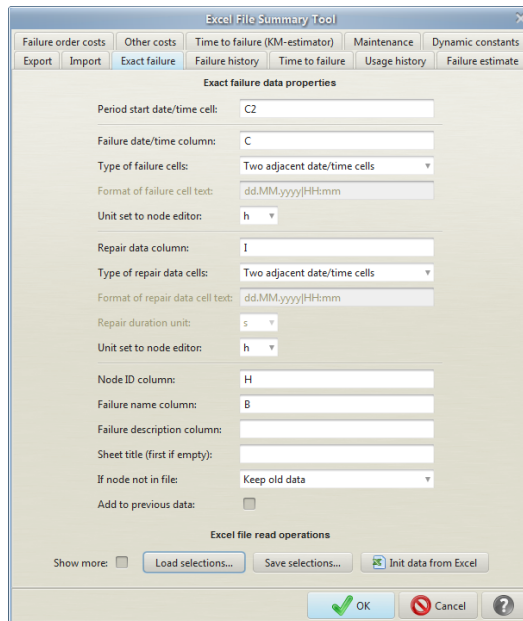
- 1 TOP** (red box) is the root.
- It branches into **2 Pumps**, **3 Motor**, **6 TOP**, **11 TOP**, **21 TOP**, **41 TOP**, and **81 TOP** (all blue boxes).
- 2 Pumps** branches into **4 Pump 1** and **5 Pump 2** (connected by an AND gate).
- 6 TOP** branches into **7 Pumps** and **10 Motor** (connected by an OR gate).
- 7 Pumps** branches into **8 Pump 1** and **9 Pump 2** (connected by an AND gate).
- 11 TOP** branches into **22 Pumps**, **25 Motor**, **26 TOP**, and **31 TOP** (connected by an OR gate).
- 22 Pumps** branches into **23 Pumps** and **24 Pumps** (connected by an AND gate).
- 26 TOP** branches into **27 TOP** and **28 TOP** (connected by an OR gate).
- 41 TOP** branches into **42 Pumps** and **43 Pump 1** (connected by an OR gate).
- 81 TOP** branches into **82 Pumps** and **83 Pump 2** (connected by an OR gate).

The right-hand pane shows a list of components with columns for ID and Name. The bottom status bar indicates "ELMAS v4.8.14 (1.7.2016)" and "Ramentor Oy - Jussi-Pekka Penttinen".

Advanced Features: Data Import

Several import types in own tabs

Machine ID is used to find correct ELMAS model node



Excel File Summary Tool

Failure order costs | Other costs | Time to failure (KM-estimator) | Maintenance | Dynamic constants

Export | Import | Exact failure | Failure history | Time to failure | Usage history | Failure estimate

Exact failure data properties

Period start date/time cell: C2

Failure date/time column: C

Type of failure cells: Two adjacent date/time cells

Format of failure cell text: dd.MM.yyyy|H:mm

Unit set to node editor: h

Repair data column: I

Type of repair data cells: Two adjacent date/time cells

Format of repair data cell text: dd.MM.yyyy|H:mm

Repair duration unit: s

Unit set to node editor: h

Node ID column: H

Failure name column: B

Failure description column:

Sheet title (first if empty):

If node not in file: Keep old data

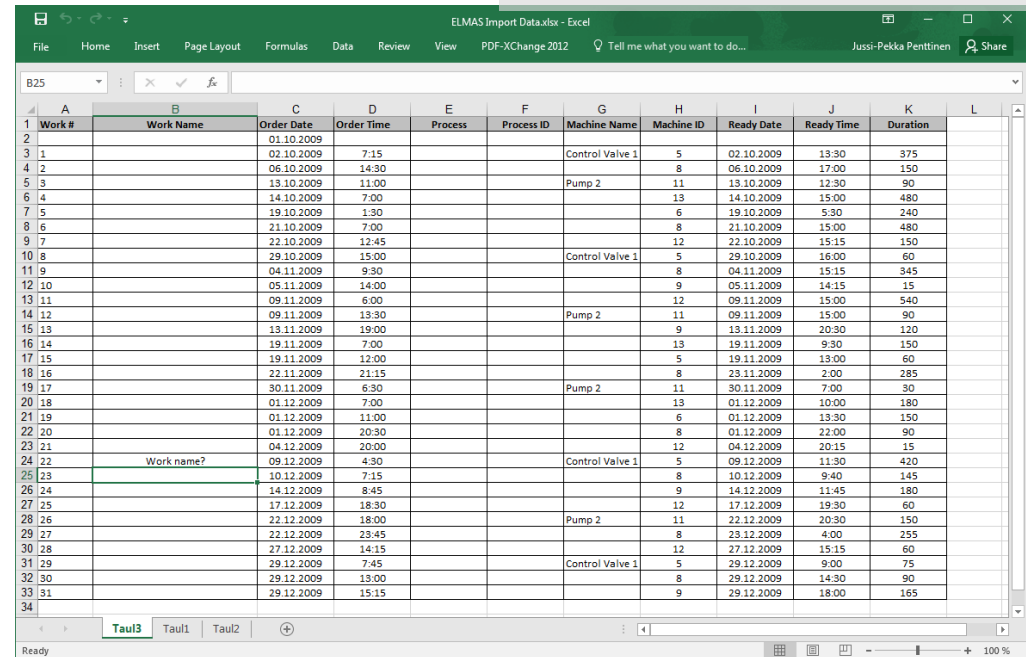
Add to previous data:

Excel file read operations

Show more: Load selections... Save selections... Init data from Excel

OK Cancel ?

Select from ELMAS which type of Excel is imported and the format data cells used in ELMAS

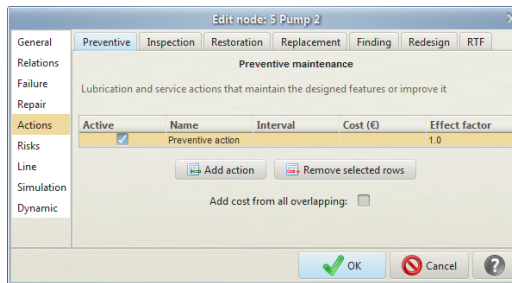


ELMAS Import Data.xlsx - Excel

Work #	Work Name	Order Date	Order Time	Process	Process ID	Machine Name	Machine ID	Ready Date	Ready Time	Duration
1		01.10.2009								
2		02.10.2009	7:15			Control Valve 1	5	02.10.2009	13:30	375
3		06.10.2009	14:30				8	06.10.2009	17:00	150
4		13.10.2009	11:00			Pump 2	11	13.10.2009	12:30	90
5		14.10.2009	7:00				13	14.10.2009	15:00	480
6		19.10.2009	1:30				6	19.10.2009	5:30	240
7		21.10.2009	7:00				8	21.10.2009	15:00	480
8		22.10.2009	12:45				12	22.10.2009	15:15	150
9		29.10.2009	15:00			Control Valve 1	5	29.10.2009	16:00	60
10		04.11.2009	9:30				8	04.11.2009	15:15	345
11		05.11.2009	14:00				9	05.11.2009	14:15	15
12		09.11.2009	6:00				12	09.11.2009	15:00	540
13		09.11.2009	13:30			Pump 2	11	09.11.2009	15:00	90
14		13.11.2009	19:00				9	13.11.2009	20:30	120
15		19.11.2009	7:00				13	19.11.2009	9:30	150
16		19.11.2009	12:00				5	19.11.2009	13:00	60
17		22.11.2009	21:15				8	23.11.2009	2:00	285
18		30.11.2009	6:30			Pump 2	11	30.11.2009	7:00	30
19		01.12.2009	7:00				13	01.12.2009	10:00	180
20		01.12.2009	11:00				6	01.12.2009	13:30	150
21		01.12.2009	20:30				8	01.12.2009	22:00	90
22		04.12.2009	20:00				12	04.12.2009	20:15	15
23		09.12.2009	4:30			Control Valve 1	5	09.12.2009	11:30	420
24	Work name?	10.12.2009	7:15				8	10.12.2009	9:40	145
25		14.12.2009	8:45				9	14.12.2009	11:45	180
26		17.12.2009	18:30				12	17.12.2009	19:30	60
27		22.12.2009	18:00			Pump 2	11	22.12.2009	20:30	150
28		22.12.2009	23:45				8	23.12.2009	4:00	255
29		27.12.2009	14:15				12	27.12.2009	15:15	60
30		29.12.2009	7:45			Control Valve 1	5	29.12.2009	9:00	75
31		29.12.2009	13:00				8	29.12.2009	14:30	90
32		29.12.2009	15:15				9	29.12.2009	18:00	165

Example Excel sheet with work orders as rows

Advanced Features: Maintenance Actions



Preventive maintenance

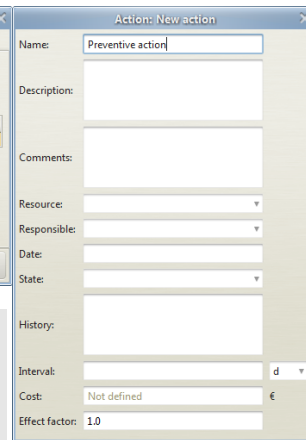
Lubrication and service actions that maintain the designed features or improve it

Active	Name	Interval	Cost (€)	Effect factor
<input checked="" type="checkbox"/>	Preventive action			1.0

Buttons: Add action, Remove selected rows

Add cost from all overlapping:

Preventive maintenance:
Improve condition by effect factor



Action: New action

Name: Preventive action

Description:

Comments:

Resource:

Responsible:

Date:

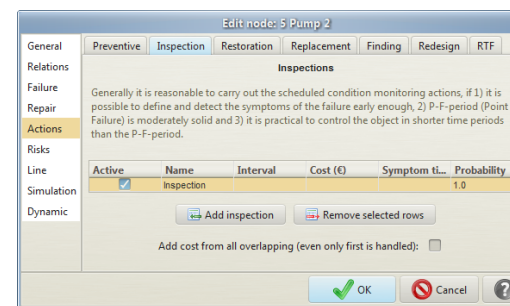
State:

History:

Interval: d

Cost: Not defined €

Effect factor: 1.0



Inspections

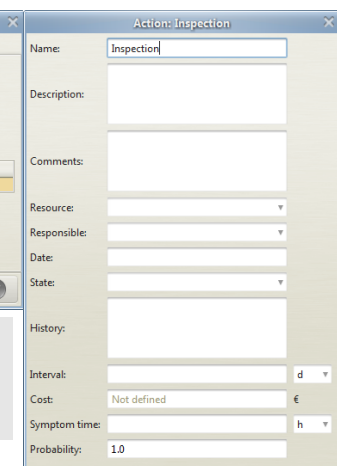
Generally it is reasonable to carry out the scheduled condition monitoring actions, if 1) it is possible to define and detect the symptoms of the failure early enough, 2) P-F-period (Point Failure) is moderately solid and 3) it is practical to control the object in shorter time periods than the P-F-period.

Active	Name	Interval	Cost (€)	Symptom ti...	Probability
<input checked="" type="checkbox"/>	Inspection			1.0	1.0

Buttons: Add inspection, Remove selected rows

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

Inspection:
Detect and fix symptom



Action: Inspection

Name: Inspection

Description:

Comments:

Resource:

Responsible:

Date:

State:

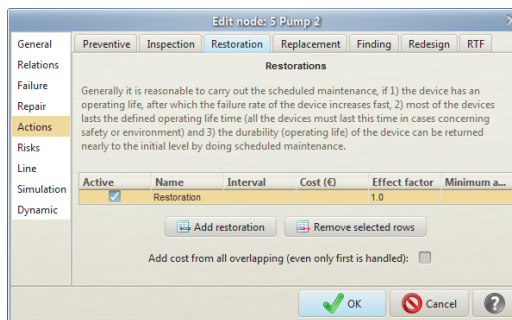
History:

Interval: d

Cost: Not defined €

Symptom time: h

Probability: 1.0



Restorations

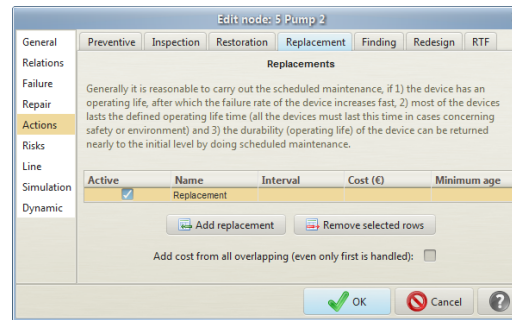
Generally it is reasonable to carry out the scheduled maintenance, if 1) the device has an operating life, after which the failure rate of the device increases fast, 2) most of the devices lasts the defined operating life time (all the devices must last this time in cases concerning safety or environment) and 3) the durability (operating life) of the device can be returned nearly to the initial level by doing scheduled maintenance.

Active	Name	Interval	Cost (€)	Effect factor	Minimum a...
<input checked="" type="checkbox"/>	Restoration			1.0	

Buttons: Add restoration, Remove selected rows

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

Restoration:
Improve age by effect factor



Replacements

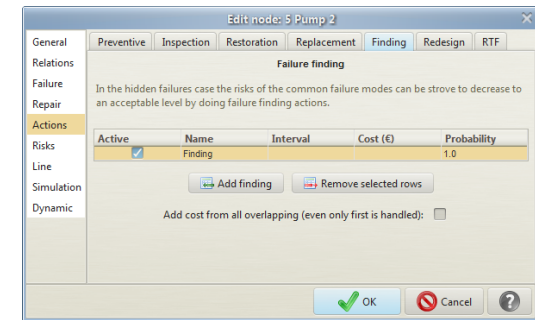
Generally it is reasonable to carry out the scheduled maintenance, if 1) the device has an operating life, after which the failure rate of the device increases fast, 2) most of the devices lasts the defined operating life time (all the devices must last this time in cases concerning safety or environment) and 3) the durability (operating life) of the device can be returned nearly to the initial level by doing scheduled maintenance.

Active	Name	Interval	Cost (€)	Minimum age
<input checked="" type="checkbox"/>	Replacement			

Buttons: Add replacement, Remove selected rows

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

Replacement:
Improve as good as new



Failure finding

In the hidden failures case the risks of the common failure modes can be strove to decrease to an acceptable level by doing failure finding actions.

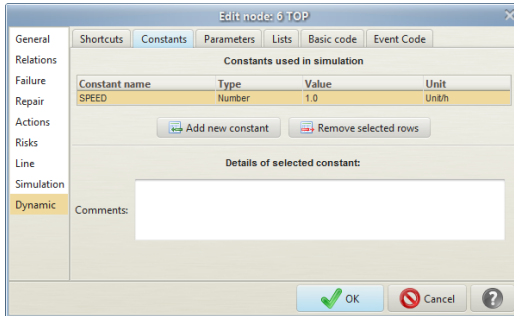
Active	Name	Interval	Cost (€)	Probability
<input checked="" type="checkbox"/>	Finding			1.0

Buttons: Add finding, Remove selected rows

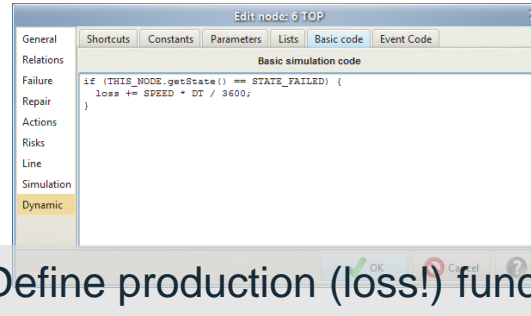
Add cost from all overlapping (even only first is handled):

Finding:
Find and fix hidden failure

Advanced Features: Dynamic simulation



Define constant: SPEED
(production speed units/h)



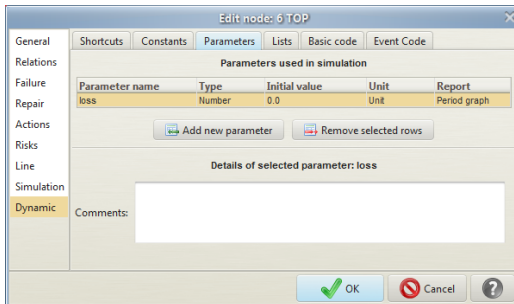
Define production (loss!) function:

```

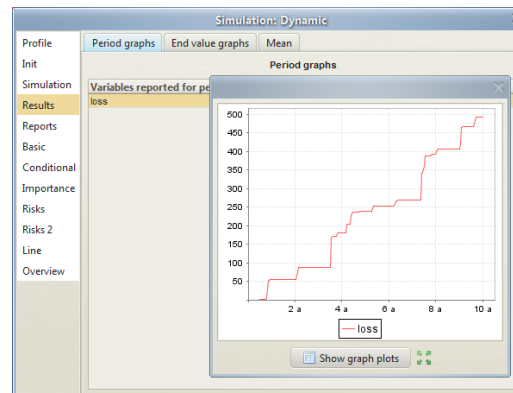
if (THIS_NODE.getState() == STATE_FAILED) {
    loss += SPEED * DT / 3600;
}
    
```

In addition to each simulation step it is also possible to add code for each simulation event

(DT = simulation step length in seconds)

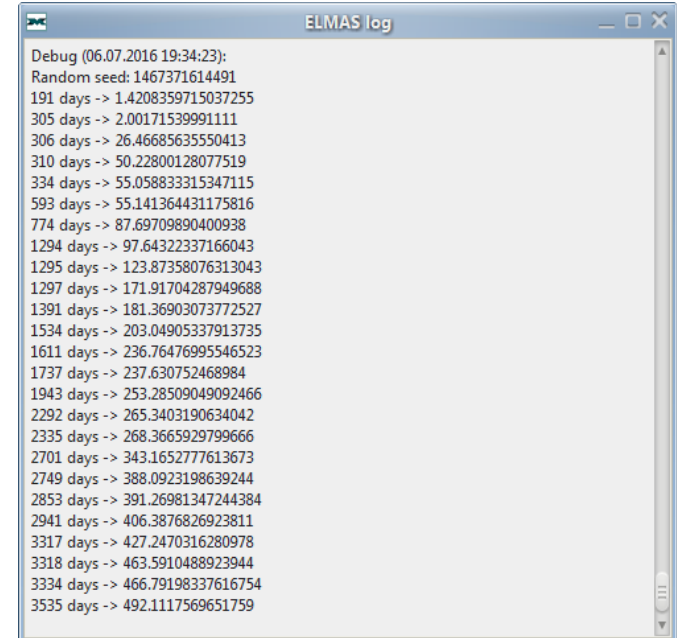
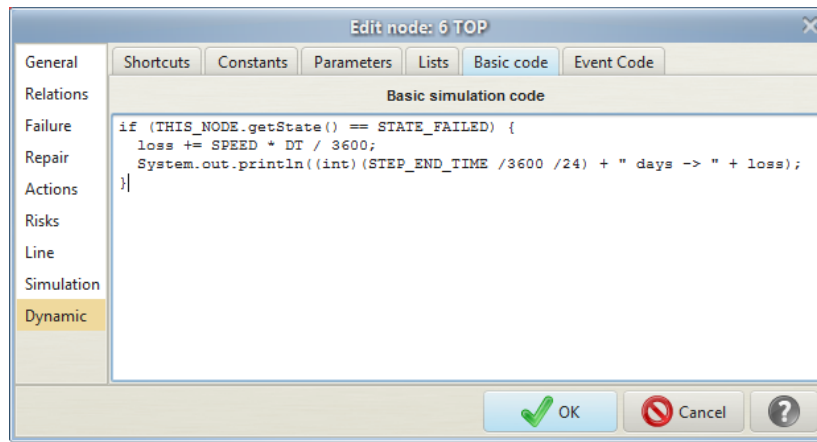


Define parameter: loss
(cumulative value added when component is failed)



Dynamic simulation results for the parameter

Advanced Features: Debug Log Window



Print debug log for example after each event (current time in days + current loss):

```
(int) (STEP_END_TIME / 3600 / 24) + " days -> " + loss
```

(STEP_END_TIME = simulation step end time in seconds)

Advanced Features: LHC Dynamic Model

The screenshot displays the ELMAS 4.8 software interface for modeling the LHC dynamic system. It is divided into several key sections:

- State Transition Diagram (Top Left):** A flowchart showing various states of the LHC system, such as 'BEAM Parameters', 'LHC Long Shut Down', 'MD1 Machine Development', 'PH1 Physics', 'END End of Proton Physics', 'LTS Technical Stop', 'HWC Hardware Commissioning', 'LCVIB Re-Commissioning with Beam', 'TS Technical Stop', 'CWB Re-Commissioning with Beam', 'MD Machine Development', 'PH2 Technical Stop', 'CWB Re-Commissioning with Beam', 'IDLE LHC Idle', 'INJ LHC Injection', 'RAMP LHC Ramp', 'RD LHC Delivery', 'RDOWN LHC Ramp Down', 'FAULT LHC Failure', and 'PRC LHC Precipos'. Arrows indicate the transitions between these states.
- Parameters Table (Top Center):** A table titled 'Parameters used in simulation' with columns for Parameter name, Type, Initial value, Unit, and Report.

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
- Custom parameters (Top Right):** A text area for defining custom parameters, with the heading 'Custom parameters' overlaid on the image.
- Event simulation code (Middle Right):** A code editor window titled 'Edit node: SB LHC Delivery' containing C++-like code for event simulation.


```

      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());
          }
      }
      
```
- Fault trees for each phase (Bottom):** A hierarchical fault tree diagram showing the decomposition of system failures. The top event is 'FAULT LHC Failure', which branches into '11 LHC Failure during Idle', '13 Failure during LHC Injection', '17 LHC Failure during Ramp', '18 LHC Failure during Delivery', '19 LHC Failure during Ramp Down', and '47 Phase Independent LHC Failure'. Each event is further decomposed into basic events (e.g., '12 no_int_low_en', '15 Test Idle', '14 Failure in Upstream Machine', '30 LHC Failure during Injection', '25 high_in_high_en', '100 low_in_high_en', '2 Test Ramp', 'INS_Ramp Instability', '25 high_in_high_en', '100 low_in_high_en', '408 Test Del', 'INS_Del Instability', '394 no_int_high_en', '18 Test RD', '3 LHC Phase Ind', '19 PRC test') connected by OR and AND gates.
 - 11 LHC Failure during Idle (OR gate)
 - 12 no_int_low_en (OR gate)
 - OR+41
 - 15 Test Idle (OR gate)
 - AND+5
 - 13 Failure during LHC Injection (OR gate)
 - 14 Failure in Upstream Machine (OR gate)
 - OR+86
 - 30 LHC Failure during Injection (OR gate)
 - OR+41
 - 17 LHC Failure during Ramp (OR gate)
 - 25 high_in_high_en (OR gate)
 - OR+41
 - 100 low_in_high_en (OR gate)
 - OR+41
 - 18 LHC Failure during Delivery (OR gate)
 - 2 Test Ramp (OR gate)
 - OR+41
 - INS_Ramp Instability (OR gate)
 - OR+41
 - 25 high_in_high_en (OR gate)
 - OR+41
 - 100 low_in_high_en (OR gate)
 - OR+41
 - 19 LHC Failure during Ramp Down (OR gate)
 - 408 Test Del (OR gate)
 - OR+41
 - INS_Del Instability (OR gate)
 - OR+41
 - 394 no_int_high_en (OR gate)
 - OR+41
 - 18 Test RD (OR gate)
 - OR+41
 - 47 Phase Independent LHC Failure (OR gate)
 - 3 LHC Phase Ind (OR gate)
 - OR+16
 - 19 PRC test (OR gate)
 - OR+16

Ramentor Oy