Fault Tree — the top-event probability, its cut sets and the event to fix first

Menu: System ▸ Fault Tree...

# Part 1 — What the function does

**What it calculates.** FTA stands for fault tree analysis. A fault tree starts from one unwanted top event - "no cooling water", "the pump set does not deliver" - and breaks it down through gates into basic events, each with a probability. You type the tree into the worksheet, one row per node, and Fault Tree calculates:

| Result | What it tells you |
|---|---|
| The exact top-event probability | The chance of the top event, calculated exactly through the gates |
| The rare-event approximation | The sum of the minimal cut set probabilities, with its gap to the exact value |
| The minimal cut sets | Each smallest combination of basic events that causes the top event, with its probability and its share of the top event |
| Fussell–Vesely (FV) importance | For each basic event, the share of top-event risk that flows through it - the repair-priority list |
| Which single fix buys the most | For each cut set, the new top-event probability if its events could not fail, recalculated in full |

Three gate types are available: and (all inputs fail), or (any input fails) and vote:k (at least k of the inputs fail). An and gate multiplies its input probabilities; an or gate gives $1 - \Pi(1 - q)$.

**From which data.** The worksheet, four columns, one row per node: the name; for a gate, its type and its inputs (names separated by commas); for a basic event, its probability q, strictly between 0 and 1. Names are case-sensitive.

**When an engineer uses it.** When the way the top event happens can be described as a logic tree of independent basic events with fixed probabilities.

**When not to use it.**

| Situation | Use instead |
|---|---|
| One basic event appears under two gates (a shared cause) | Not calculated in version 1.0.0: model the shared cause as its own branch |
| You think in blocks and success paths rather than failures | Draw a reliability block diagram: System ▸ RBD Canvas (chapter 4.1) |
| You want probabilities that change with time, repairs or preventive maintenance | System ▸ RAM Simulation... (chapter 4.5) |
| You want to rank failure modes by scores or by criticality | System ▸ FMEA / Criticality... (chapter 4.7) |

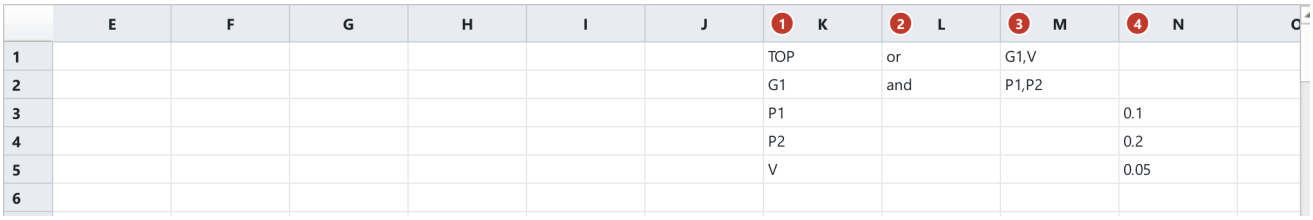
# Part 2 — The example's input data

*Setting.* Cooling water is lost (TOP) if both pumps fail (gate G1) or the outlet valve V fails. Pump P1 fails on demand with probability 0.1, pump P2 with 0.2, the valve with 0.05.

| Name | Gate type | Inputs | Probability |
|---|---|---|---|
| TOP | or | G1,V | |
| G1 | and | P1,P2 | |
| P1 | | | 0.1 |
| P2 | | | 0.2 |
| V | | | 0.05 |

| Input | Value |
|---|---|
| Top gate name | TOP |
| File in the worked-example zip | 4-Fault-Tree/Example-1.csv - the five rows in four columns |

The data in the worksheet, as the pictures of Part 3 show it (columns K to N):



| | E | F | G | H | I | J | ① K | ② L | ③ M | ④ N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | TOP | or | G1,V | | |
| 2 | | | | | | | G1 | and | P1,P2 | | |
| 3 | | | | | | | P1 | | | 0.1 | |
| 4 | | | | | | | P2 | | | 0.2 | |
| 5 | | | | | | | V | | | 0.05 | |
| 6 | | | | | | | | | | | |

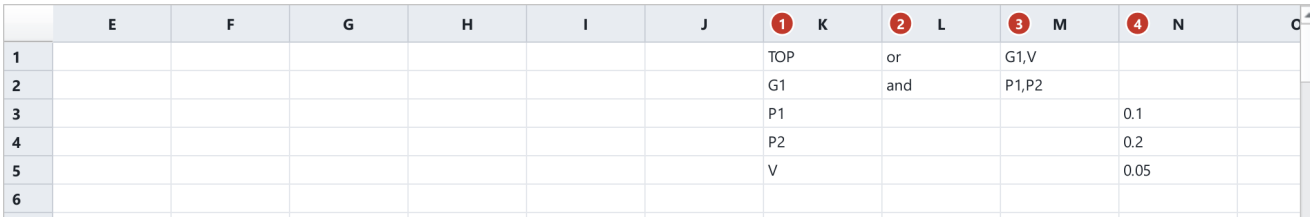
The example data in the worksheet

- ① Column K: Name column (5 values)
- ② Column L: Gate type column (2 values)
- ③ Column M: Inputs column (2 values)
- ④ Column N: Probability column (3 values)

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# Part 3 — How to use it, step by step

1. **Put the tree into the worksheet.** Import 4-Fault-Tree/Example-1.csv with File ▸ Import Data (Excel / CSV / JSON)..., or type the five rows into four columns. The pictures of this chapter show them in columns K to N.

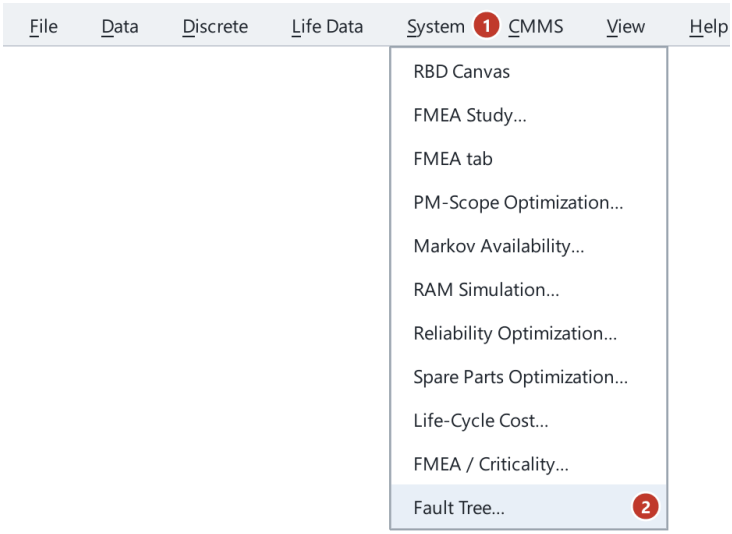


| | E | F | G | H | I | J | ① K | ② L | ③ M | ④ N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | TOP | or | G1,V | | |
| 2 | | | | | | | G1 | and | P1,P2 | | |
| 3 | | | | | | | P1 | | | 0.1 | |
| 4 | | | | | | | P2 | | | 0.2 | |
| 5 | | | | | | | V | | | 0.05 | |
| 6 | | | | | | | | | | | |

Step 1 — the tree in the worksheet

- ① Column K: Name column (5 values)
- ② Column L: Gate type column (2 values)
- ③ Column M: Inputs column (2 values)
- ④ Column N: Probability column (3 values)

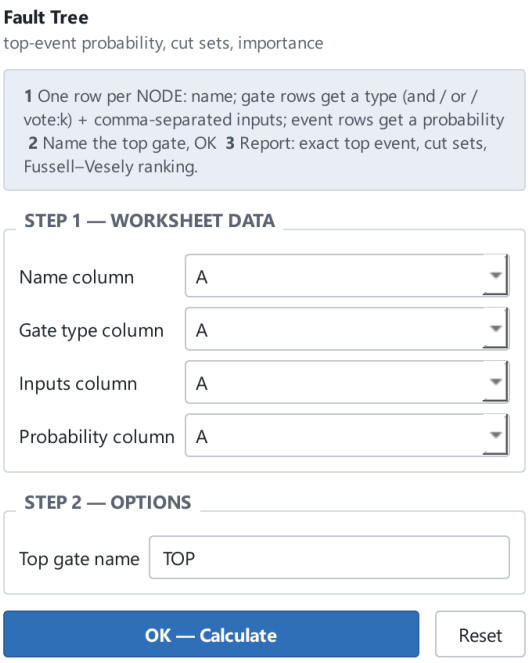
2. **Choose System ▸ Fault Tree...** in the menu bar. The form Fault Tree opens in the left panel.




Step 2 — the menu path

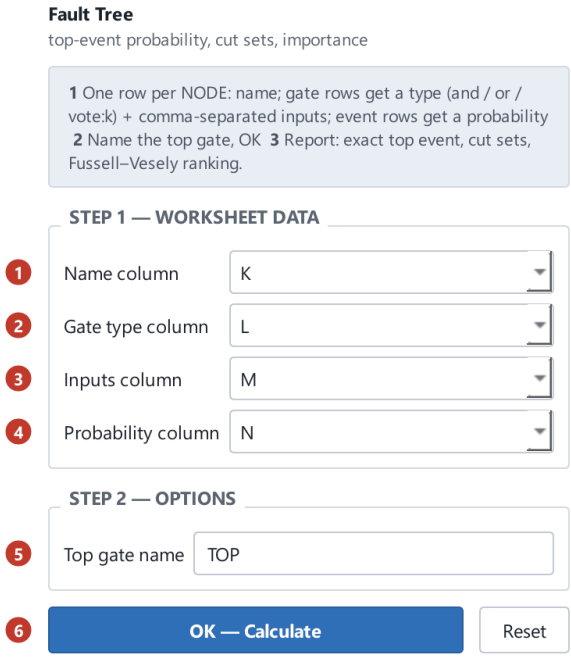
- ① System: the menu.
- ② Fault Tree...: the entry to click.

The form as it opens, before any box is set:




Step 2 — the form as it opens

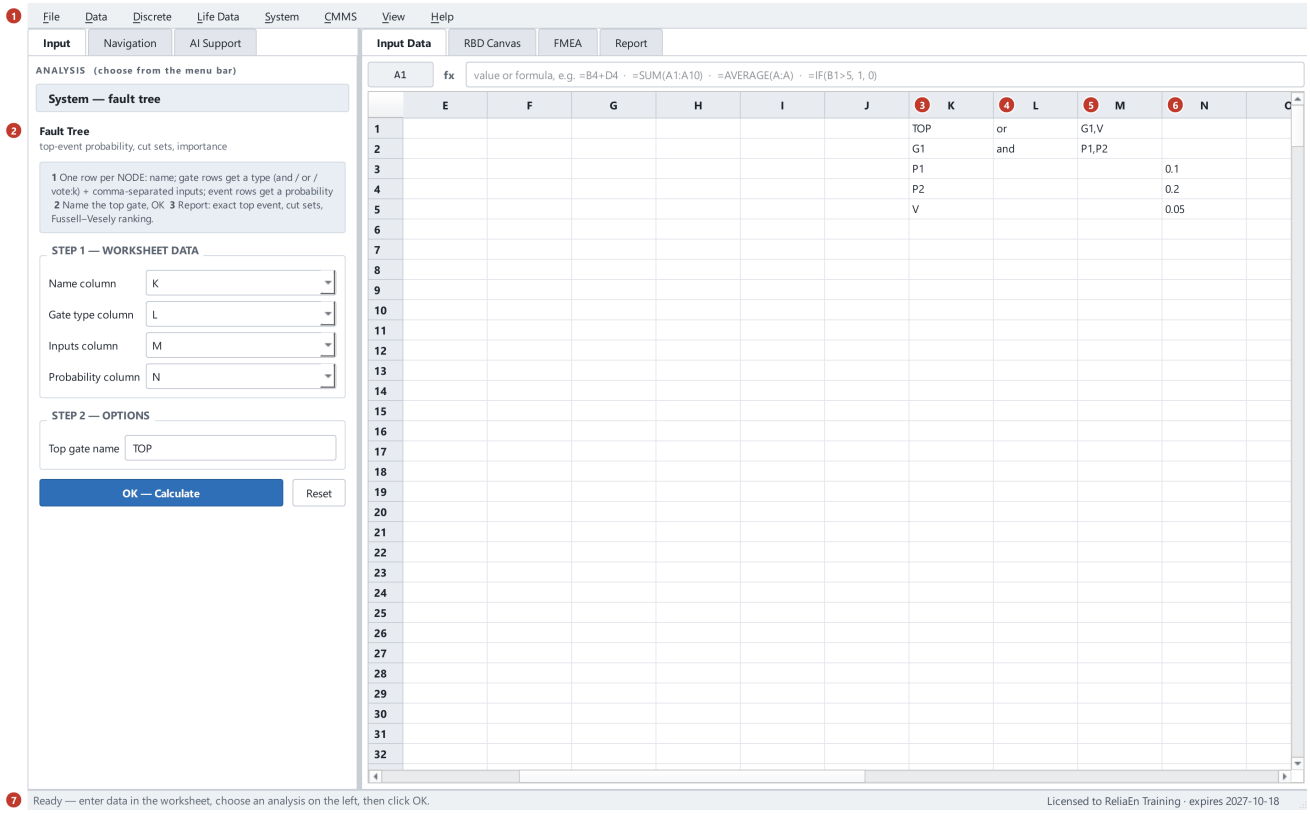
Steps 3 to 7 set the form, marked ① to ⑤; ⑥ is the button of step 8:




Steps 3 to 7 — the form set for this example

3. ① **In Name column, choose K.** The four columns must all differ.
4. ② **In Gate type column, choose L.**
5. ③ **In Inputs column, choose M.**
6. ④ **In Probability column, choose N.**
7. ⑤ **Check that Top gate name reads TOP.**

8. **Click OK — Calculate** at the foot of the form (② in the picture below). ReliaEn checks the tree, calculates it and shows the report.

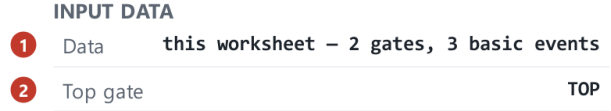



Step 8 — the window just before OK

- ① The menu bar: File, Data, Discrete, Life Data, System, CMMS, View, Help.
- ② The analysis form, set as in steps 3 to 7; OK — Calculate at its foot.
- ③ Column K: Name column (5 values)
- ④ Column L: Gate type column (2 values)
- ⑤ Column M: Inputs column (2 values)
- ⑥ Column N: Probability column (3 values)
- ⑦ The status bar: Ready — enter data in the worksheet, choose an analysis on the left, then click OK., Licensed to ReliaEn Training · expires 2027-10-18.

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# Part 4 — The report, card by card




Input data

- ① Data this worksheet — 2 gates, 3 basic events. The gates and basic events ReliaEn read from the worksheet.
- ② Top gate TOP. The gate the calculation starts from.

RESULTS

| | | |
|---|---|---|
| 1 | Top-event probability (EXACT) | 0.069 |
| 2 | Rare-event approximation | 0.07 (over by 0.001 — the exact number is the answer) |
| 3 | Minimal cut sets | 2 |
| 4 | Most important event (Fussell–Vesely) | V (FV = 0.7246) |

Results

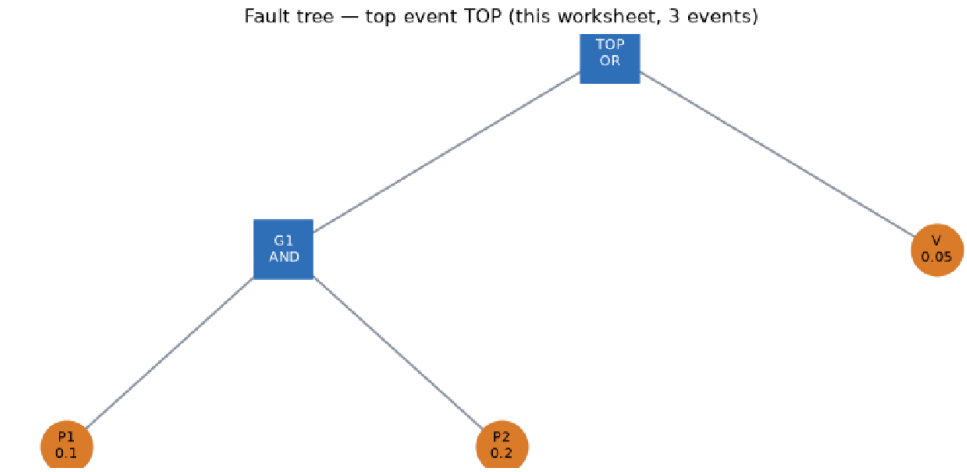
- ① Top-event probability (EXACT) 0.069. The chance of the top event, calculated exactly through the gates.
- ② Rare-event approximation 0.07 (over by 0.001 — the exact number is the answer). The sum of the cut set probabilities and how far it lies above the exact value.
- ③ Minimal cut sets 2. How many smallest combinations of failures cause the top event.
- ④ Most important event (Fussell–Vesely) V (FV = 0.7246). The basic event with the largest share of the risk.

INTERPRETATION

1. Each cut set is a smallest combination of failures that brings the top event; Fussell–Vesely is the share of top-event risk flowing through each basic event — the repair-priority list. The exact and approximate top probabilities are both printed; the gap grows with event probabilities.

Interpretation

- ① Each cut set is a smallest combination of failures that brings the top event; Fussell–Vesely is the share of top-event risk flowing through each basic event — the repair-priority list. The exact and approximate top probabilities are both printed; the gap grows with event probabilities.




Interactive Plot

Plot

- The tree as typed in the worksheet: the top gate, the gates below it and the basic events.

**MINIMAL CUT SETS (THIS WORKSHEET — 2 GATES, 3 BASIC EVENTS)**

1 Shares use the exact top probability; they exceed 100% jointly because cuts overlap (that overlap is exactly what the rare-event approximation ignores).

| 2 Cut set | 3 Probability | 4 Share of top |
|---|---|---|
| 5 V | 0.05 | 72.5% |
| 6 P1 · P2 | 0.02 | 29.0% |

Minimal cut sets (this worksheet — 2 gates, 3 basic events)

- ① Shares use the exact top probability; they exceed 100% jointly because cuts overlap (that overlap is exactly what the rare-event approximation ignores).
- ② Cut set
- ③ Probability
- ④ Share of top
- ⑤ V · 0.05 · 72.5%
- ⑥ P1 · P2 · 0.02 · 29.0%

**FUSSELL–VESELY IMPORTANCE (THIS WORKSHEET — 2 GATES, 3 BASIC EVENTS)**

1 FV(e) = P(some cut containing e fails)/P(top) — fix the top of this list first.

| Basic event | FV |
|---|---|
| 2 V | 0.7246 |
| 3 P1 | 0.2899 |
| 4 P2 | 0.2899 |

Fussell–Vesely importance (this worksheet — 2 gates, 3 basic events)

- ① FV(e) = P(some cut containing e fails)/P(top) — fix the top of this list first.
- ② V · 0.7246
- ③ P1 · 0.2899
- ④ P2 · 0.2899

**WHICH SINGLE FIX BUYS THE MOST? (THIS WORKSHEET — 2 GATES, 3 BASIC EVENTS)**

1 ★ fixing V takes the top event 0.069 → 0.02 — the largest reduction. Each row is a full re-analysis with those events made unfailable, not an approximation.

| 2 Cut set fixed | 3 New top event | 4 Reduction | 5 Share removed |
|---|---|---|---|
| 6 V ★ | 0.02 | 0.049 | 71.0% |
| 7 P1 · P2 | 0.05 | 0.019 | 27.5% |

Which single fix buys the most? (this worksheet — 2 gates, 3 basic events)

- ① ★ fixing V takes the top event 0.069 → 0.02 — the largest reduction. Each row is a full re-analysis with those events made unfailable, not an approximation.
- ② Cut set fixed
- ③ New top event
- ④ Reduction
- ⑤ Share removed
- ⑥ V ★ · 0.02 · 0.049 · 71.0%
- ⑦ P1 · P2 · 0.05 · 0.019 · 27.5%

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# Part 5 — How to interpret the results

**How likely the cooling water is lost.** 0.069 per demand, exactly: the pump pair fails together with probability 0.1 × 0.2 = 0.02, and TOP = 1 − (1 − 0.02)(1 − 0.05) = 0.069. Use this number. The rare-event approximation, 0.02 + 0.05 = 0.07, lies 0.001 above it because it counts the case where the pumps and the valve fail together twice.

**Where the risk comes from.** Two minimal cut sets: the valve alone, and the two pumps together. The valve is a single point of failure.

**What to fix first.** The valve. Its Fussell–Vesely importance is 0.7246 (0.05 / 0.069) against 0.2899 for each pump. Making the valve unable to fail takes the top event from 0.069 to 0.02 - 71.0% of the risk removed; perfect pumps would take it only to 0.05 (27.5%). A second valve in parallel would do more than better pumps.

**Why the shares add to more than 100%.** 72.5% + 29.0% = 101.5%: the shares use the exact top probability and the cut sets overlap - the overlap the rare-event approximation ignores.

**What the result is not.** The probabilities are fixed per demand: no time, no repair. For a system whose parts age or are repaired, draw it on the RBD canvas and simulate it with System ▸ RAM Simulation….