Barrier Thinking in Practice

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How does an incident occur in practice?

In practice, this often doesn’t happen all at once, but step by step — due to the way we work.

Let’s watch a video that shows how we influence those barriers every day.

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Risicograaf VS HAZOP/LOPA with Risk Matrix

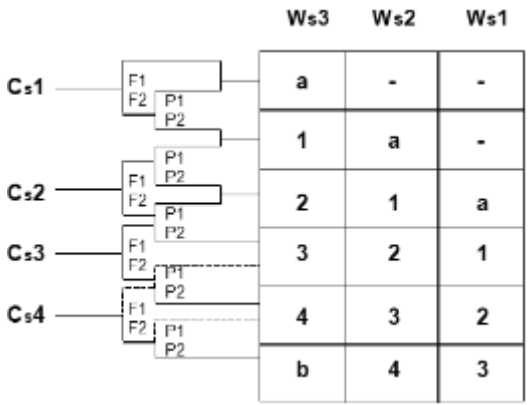
Approximately 30 scenarios were assessed with LOPA.

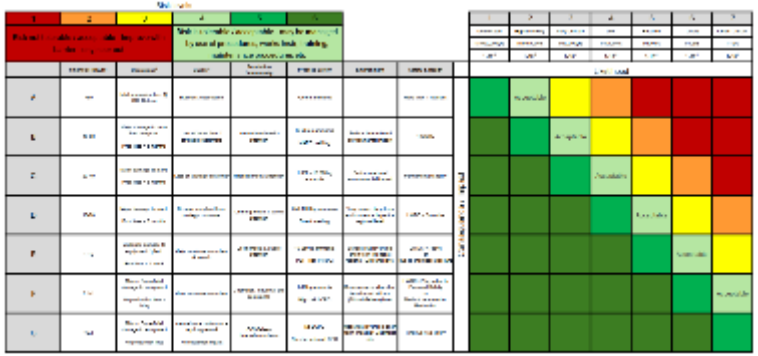
Key findings:

- A risk gap was identified in approx. 40% of scenarios.
  - ~15% involved a SIL2 gap (RRF 100).
  - ~85% involved a SIL1 gap (RRF 10).
- In approximately 65% of scenarios, more or differently allocated barriers/IPLs were needed in LOPA compared to the risk graph method.
- On average, approximately one additional barrier must be found per scenario.

Interpretation of results:

- The current methodology may underestimate risks because barriers are not systematically validated for effectiveness, independence, and auditability.
- LOPA makes risk gaps explicit, where the risk graph method sometimes leaves them implicit.
- The pilot confirms that a more structured and defensible substantiation of risk reduction is achieved with HAZOP/LOPA.





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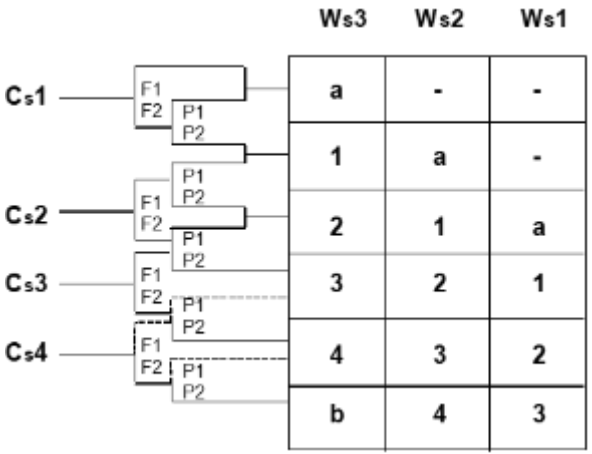


Limitations of the current methodology

- Safeguards are assigned and verified, but not explicitly assessed as barriers.
- Effectiveness is functionally assessed (does the safeguard work technically for this scenario, incl. PST, fail-safe and testing), but not explicitly translated into demonstrable risk reduction per safeguard (e.g. PFD/RRF).
- Independence is not explicitly demonstrated or documented.
- The risk graph is semi-qualitative and interpretation-sensitive, allowing teams to generate different RL/SIL outcomes.
- Not fully aligned with modern international standards (IEC 61511, CCPS), which emphasize explicit barrier management and IPL validation.

Limitations in practice

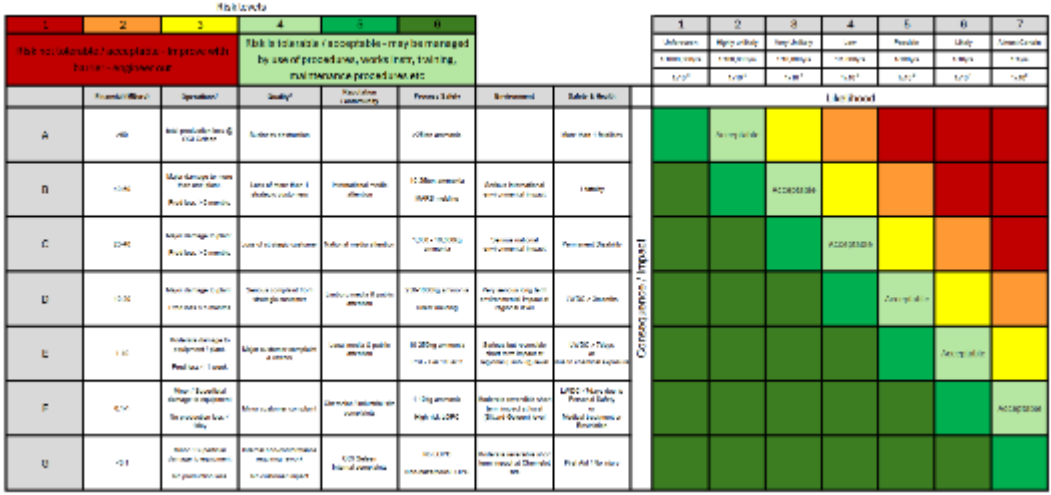
- Not all barriers are always identified, because the methodology does not explicitly require this. As a result, they are also not managed, tested, or maintained as barriers.
- The EUC assumption only works if EUC elements function reliably; in practice, this functionality is not always assured with a demonstrable maintenance and testing regime.
- In practice, mainly what is explicitly labeled as a safeguard is maintained; other functions we implicitly rely on can therefore weaken unnoticed.
- D&IV addresses high-demand situations through design guidelines, but without explicit modeling of cumulative demand on a barrier.

Risk Management @ OCI

Advantages of this approach

- More complete and consistent risk assessment based on raw (unprotected) risk.
- Explicit barrier management and IPL validation per IEC 61511 and CCPS.
- Effectiveness, independence, and auditability of barriers become visible and demonstrable.
- Better alignment with modern industry standards and best practices.
- Better assurance through maintenance and management via explicit IPL criteria.
- Fewer interpretation differences between teams through structured risk reduction steps.
- Scenario-specific, substantiated SIL requirements based on residual risk.
- Invalid or weak barriers also become visible, leading to targeted improvement actions.

HAZOP/LOPA forms the **basis for effective barrier management**: it identifies deviations, explicitly names existing barriers, and tests their suitability as IPL.



How does an incident occur in practice?

Mentimeter - Questions / Discussion

- What small signals or deviations should be a trigger for you to intervene in time before they escalate?

- What can help us in practice to recognize risks in time and make them discussable?

- Which habits or daily actions do you think contribute most to a safe and reliable installation?

What small signals or deviations should be a trigger for you to intervene in time before they escalate?

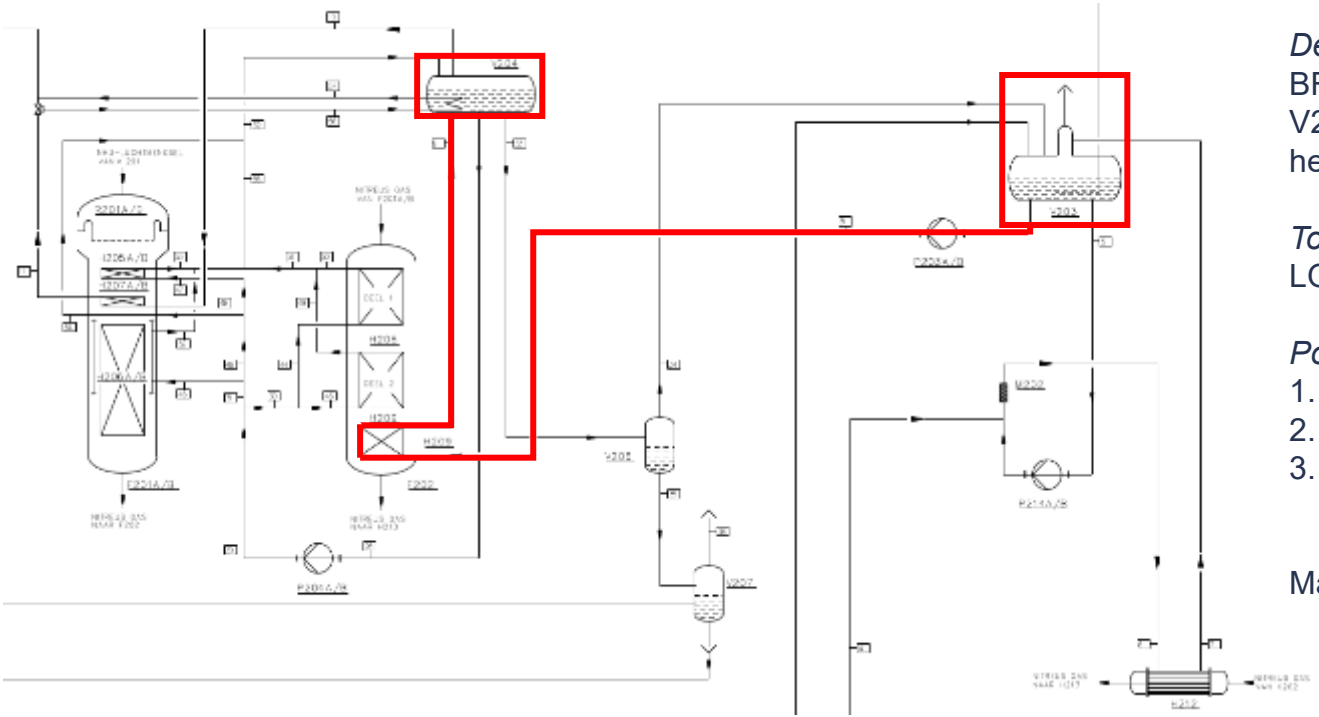
- Alarms
- Dripping
- Druk omhoog
- Leaked fluids
- Leakage or liquid on the floor
- Sound/noice
- Trends in Logboekmeldingen
- Signals from production: the last line of defence
- Kleine afwijkingen van standaard parameters
- Smell

Where did barriers fail?

Decisions and actions can weaken or strengthen barriers

Let’s watch a video that shows how different people play a role in strengthening or weakening barriers.

HAZOP node: BFW supply Nitric Acid plant



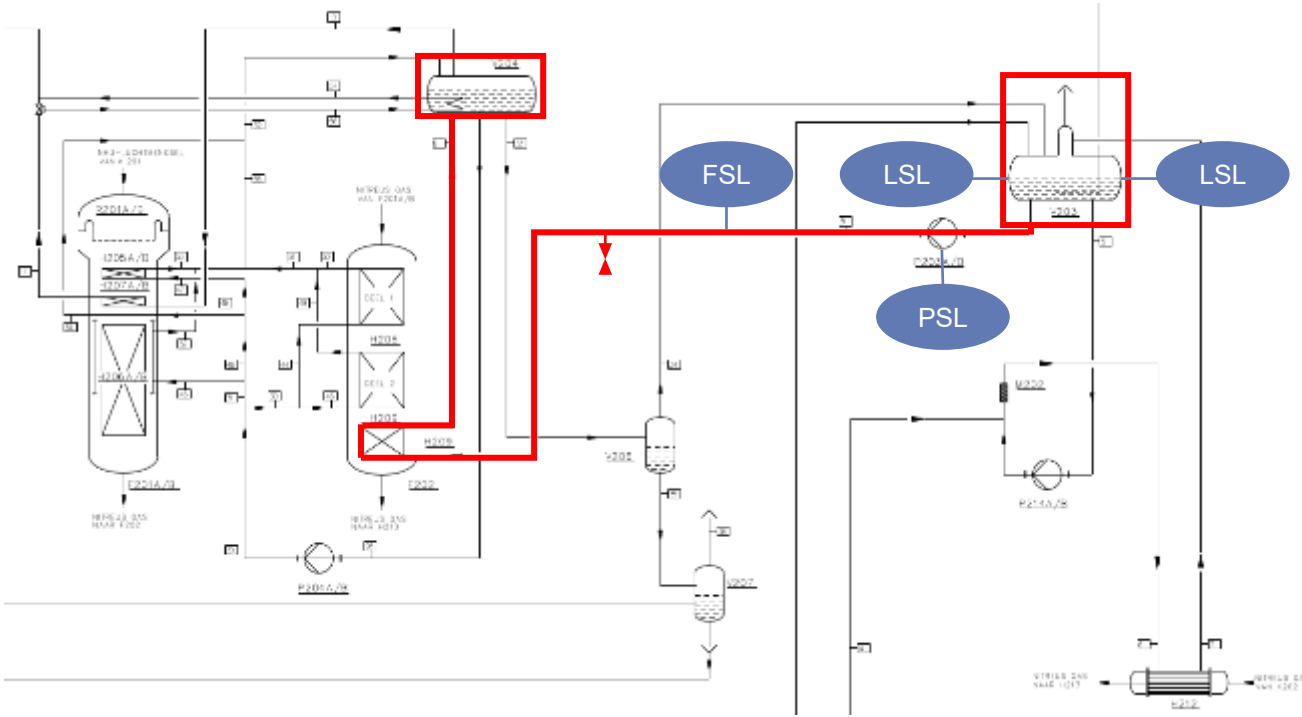
Design intent:
BFW supply from low pressure deaerator V203 to steam drum V204 via waste heat boiler H202.

Top Event:
LOC of NOx gasses

Possible consequences:
1. Safety: 1 fatality
2. Financial: 20-40mil Euro
3. Environment: Moderate, reversible impact at plant level

Main cause: Low/No Flow

HAZOP node: BFW supply Nitric Acid plant



Criteria for Effective Barriers

When is a barrier valid?

Not every measure or instrument automatically counts as a barrier. Only when these criteria are met:

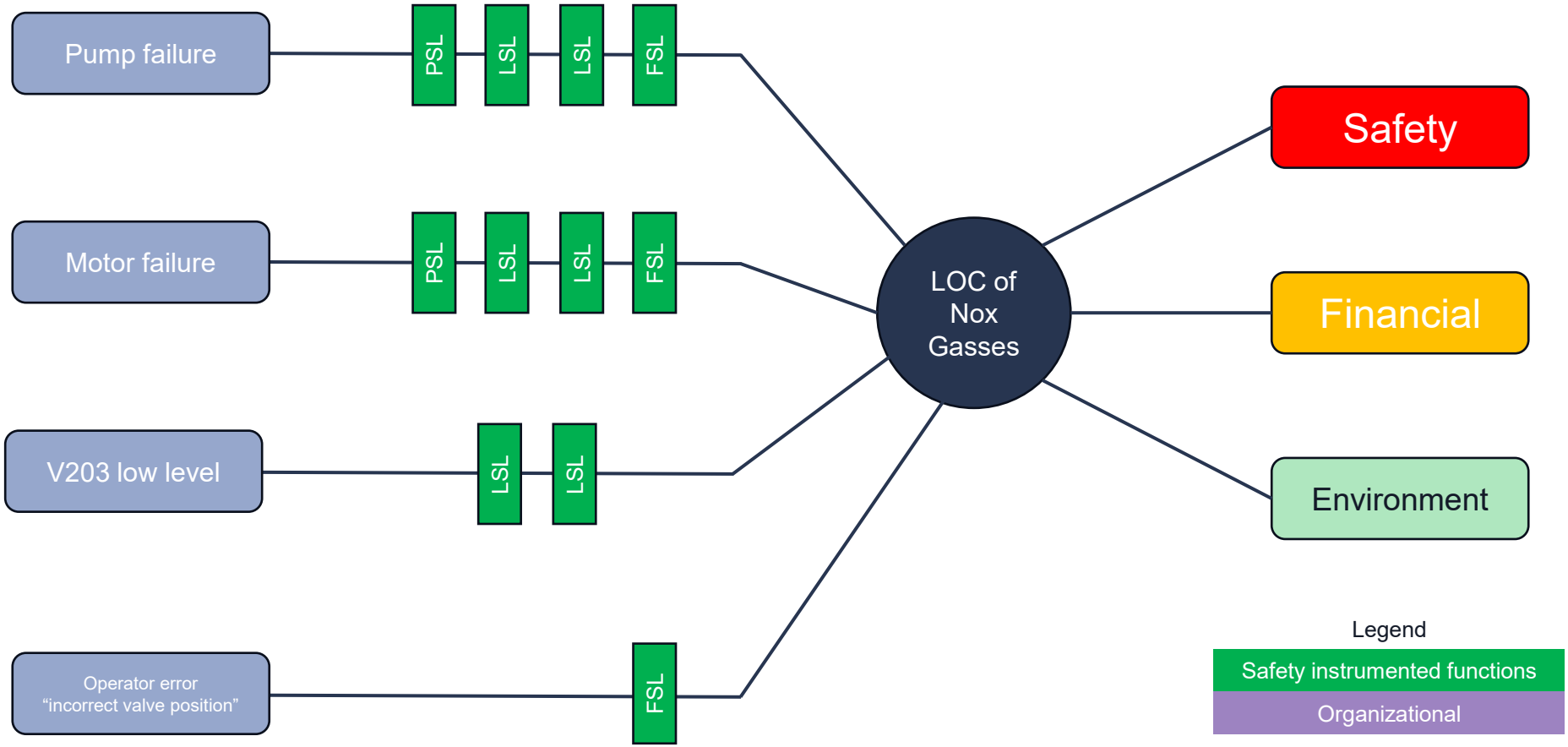
- **Effectiveness:** The barrier must be demonstrably capable of preventing the hazardous event or limiting its consequences.
    - Based on design, function, or demonstrable operational experience.
    - Works reliably under the conditions for which it was designed.
- **Independence:** The barrier must be functionally independent of the initiating cause and of other barriers.
    - No common failure modes (common cause failures).
    - No dependency on the same instrument, system (e.g. PLC/DCS) or the same operator action.
- **Auditability:** The barrier must be inspectable, testable and maintainable.
    - Regular verification that the barrier is present and functional.
    - Documented maintenance and test results.
    - Deviations are detected and corrected in a timely manner.

Criteria for Effective Barriers

How do the barrier types fit these criteria?

- **Engineering barriers**
  - ✓ Often effective
  - ✓ Often independent
  - ✓ Easy to test and document
  - → ***Usually valid as a barrier***
- **Procedural barriers**
  - ! Dependent on human action (e.g. operator action on alarm)
  - ! Variable reliability
  - ! Difficult to fully audit
  - → ***Often not valid as a primary barrier***
- **Organizational barriers**
  - ✓ Important for maintaining safety
  - ! No direct protection during an incident
  - → ***Supporting, but not a direct barrier***
- **Mitigating barriers**
  - ✓ Can be valid if they are engineered and testable (sprinklers, containment)
  - ! Less predictable with human-dependent measures
  - → ***Sometimes valid, depending on design and auditability***

HAZOP node: BFW supply Nitric Acid plant, Bow-Tie



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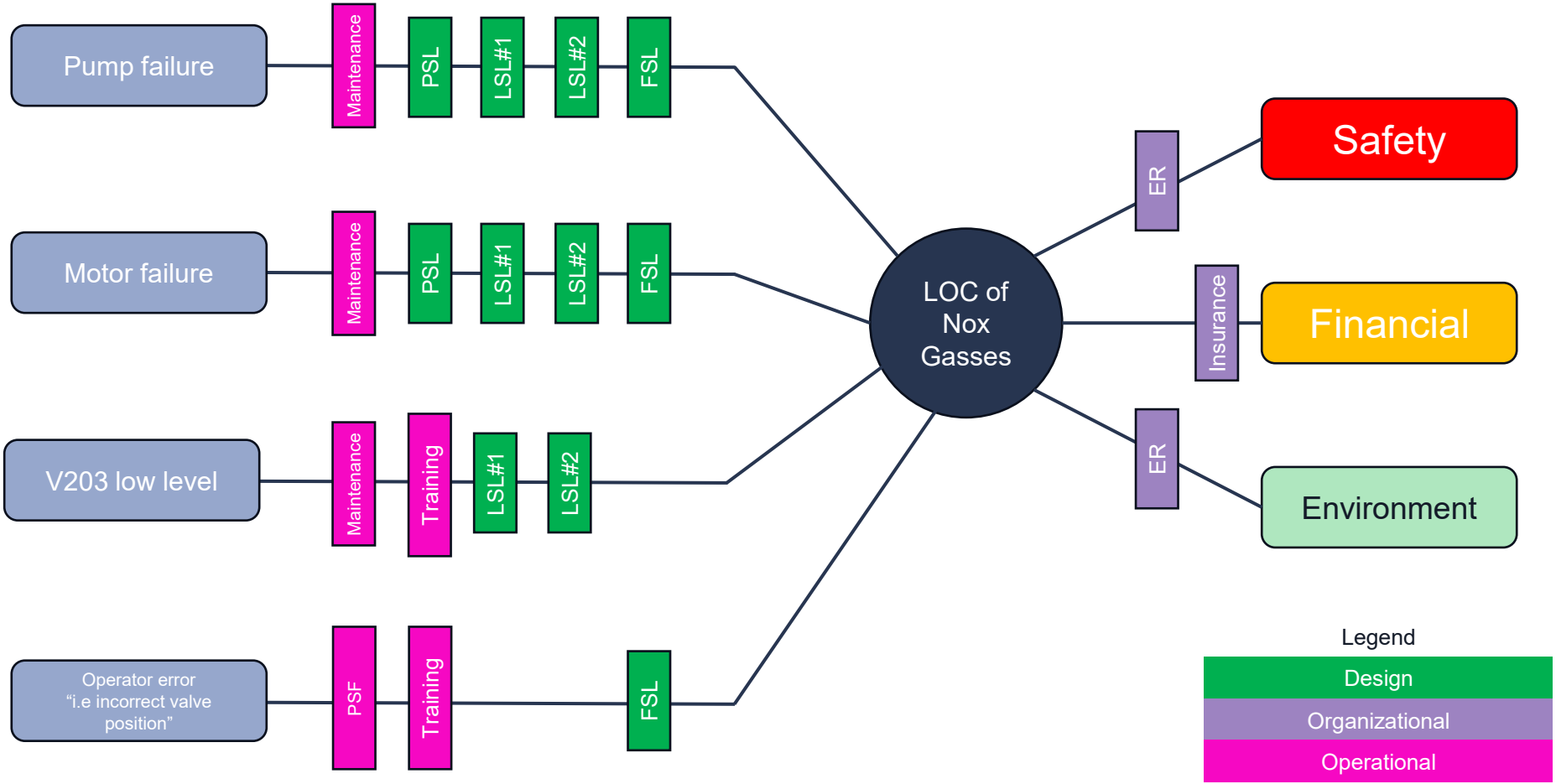
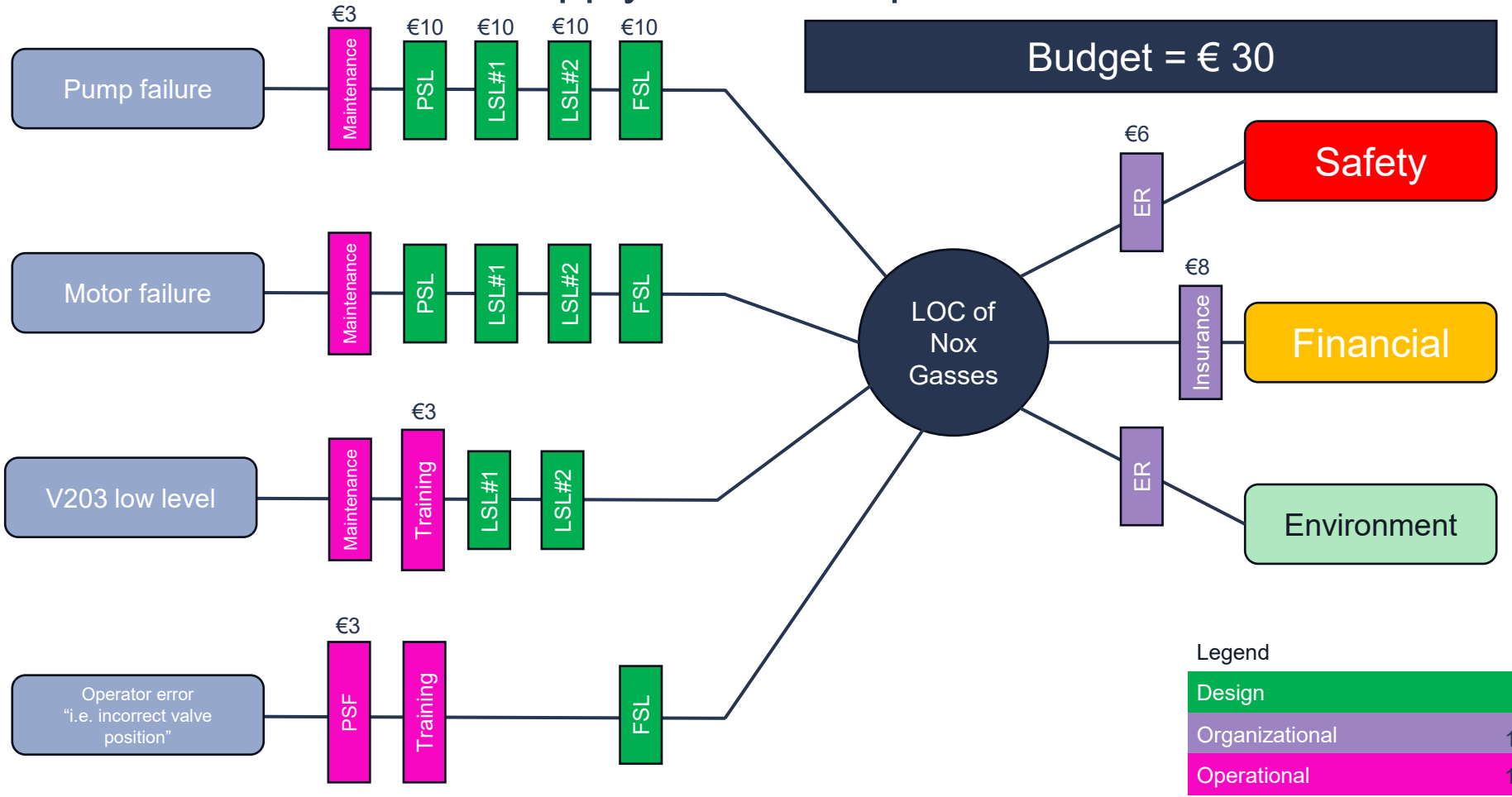


HAZOP node: BFW supply Nitric Acid plant



HAZOP node: BFW supply Nitric Acid plant – real life test

Are you feeling lucky?

In which barriers would you invest?

1. PSL
2. LSL#1
3. LSL#2
4. FSL
5. Maintenance
6. Training
7. PSF (Process safety fundamentals)
8. ER (Emergency response)
9. Insurance

In which barriers would you invest?

14 PSL

9 FSL

8 Proces Safety fundamentals

6 LSL#1

15 maintenance

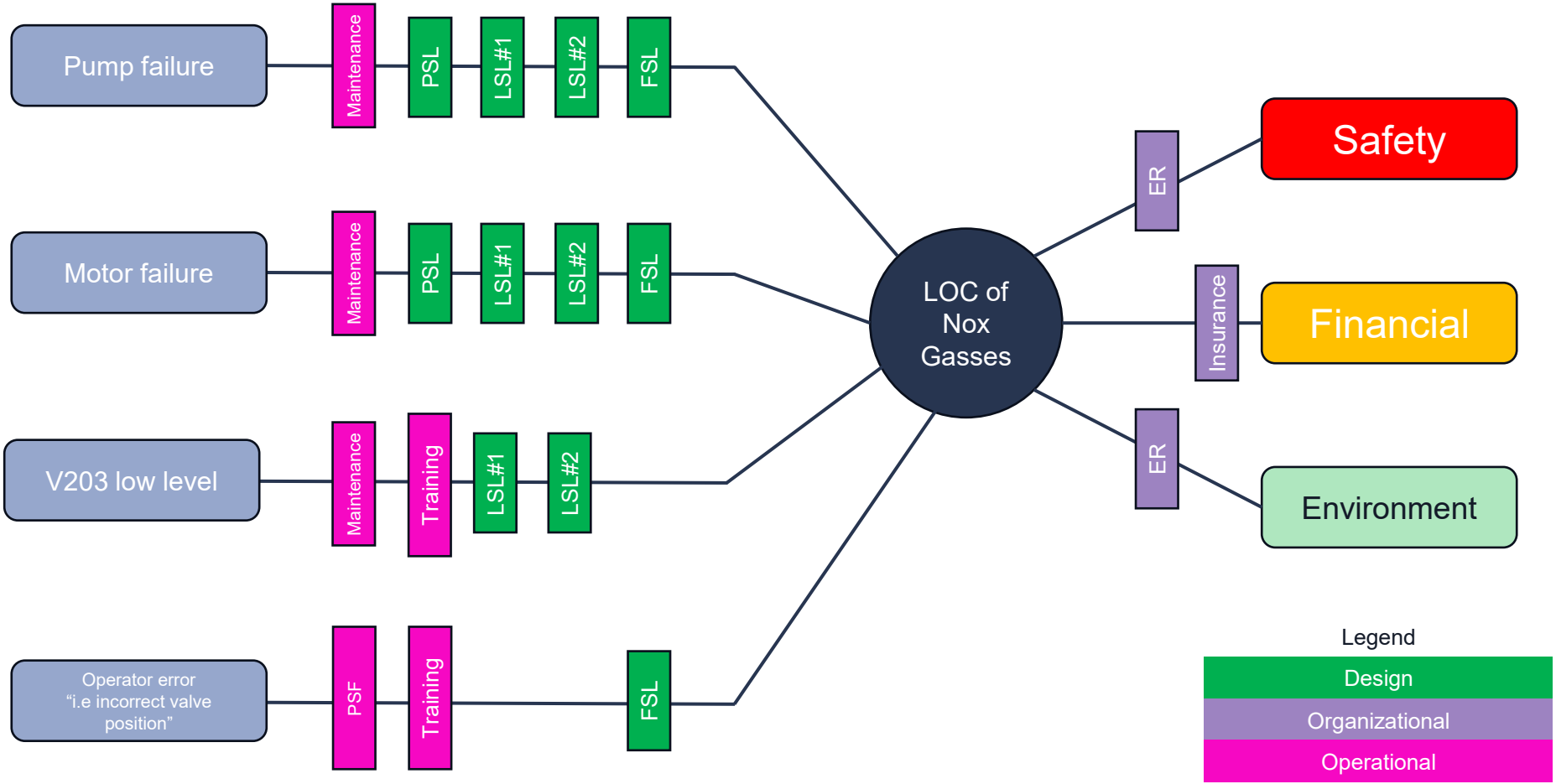
7 Emergency Resönse

4 LSL#2

12 training

0 Insurance

HAZOP node: BFW supply Nitric Acid plant, Bow-Tie



HAZOP node: BFW supply Nitric Acid plant – real life test

Are you feeling lucky?

Which of the scenarios are more likely to occur?

1. Budget cuts – inadequite maintenance, hardware barriers ineffective
2. Poor process safety culture – identified during insurance audit
3. High employee turnover
4. Loss of experienced operators

Which of the scenarios are more likely to occur?

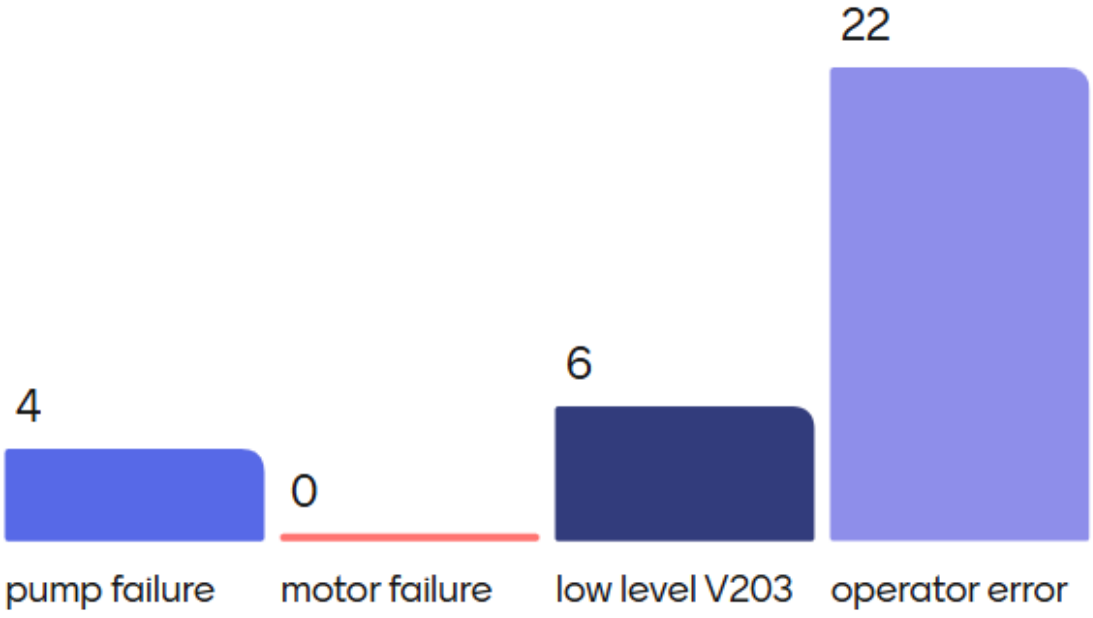
HAZOP node: BFW supply Nitric Acid plant – real life test

Are you feeling lucky?

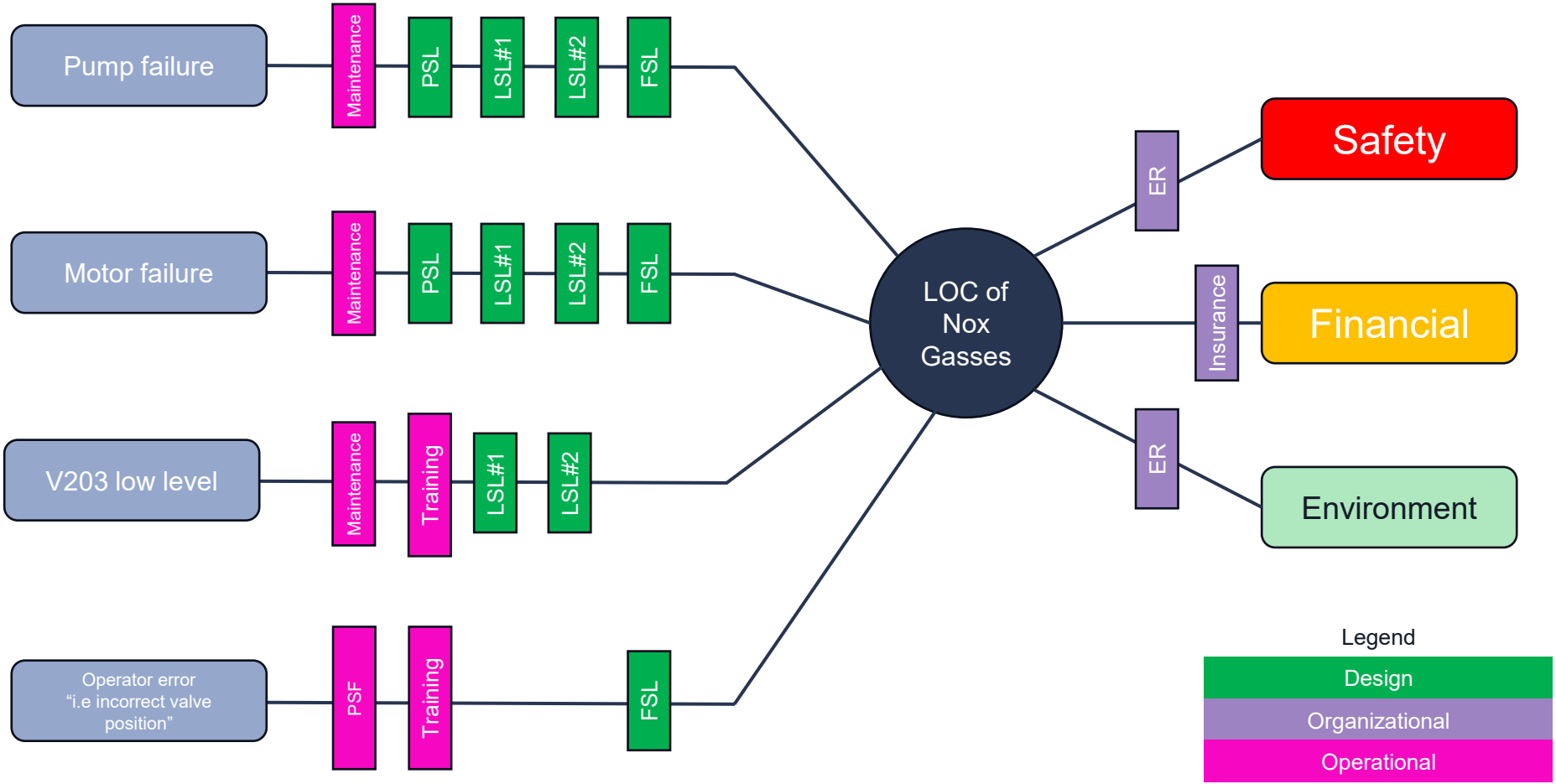
Which of the scenarios are more likely to occur?

1. Pump failure
2. Motor failure
3. V203 low level
4. Operator error

Which of the scenarios are more likely to occur?



HAZOP node: BFW supply Nitric Acid plant, result



HAZOP node: BFW supply Nitric Acid plant, Barriers on Risk Matrix

Risk levels

1	2	3	4	5	6
Risk not tolerable / acceptable - improve with barrier - engineer out			Risk is tolerable / acceptable - may be managed by use of procedures, works instr, training, maintenance procedures etc		

	Financial (MEuro)	Operations	Quality	Reputation / community	Process Safety	Environment	Safety & Health
A	>50	Total production loss @ OCI Geleen	Business destruction		>25ton instantaneous LOPC		More than 1 fatalities
B	40-50	Major damage to more than one plant Prod loss > 6 months	Loss of more than 1 strategic customers	International media attention	10-25 ton ammoniak MARS melding	Serious international environmental impact	1 fatality
C	20-40	Major damage to plant Prod loss < 6 months	Loss of strategic customer	National media attention	1,000 - 10,000kg ammoniak	Serious national environmental impact	Permanent Disability
D	10-20	Major damage to plant Prod loss < 6 months	Serious complaint from strategic customer	Local media & public attention Significant SHE incident	250-1000kg ammoniak Direct melding	Very serious long term environmental impact at regional level	LWDC > 3months
E	1-10	Moderate damage to equipment / plant Prod loss < 1 week	Major customer complaint & rework	Lansing media & public attention Reportable SHE incident	10-250kg ammoniak [illegible]	Serious but reversible short term impact at regional (Limburg) level	LWDC < 7days or due to chemical exposure
F	0.1-1	Minor / Superficial damage to equipment No product or loss < 1day	Minor customer complaint	Chemelot / Industrial site complaints	1-10kg ammoniak High risk LOPC	Moderate reversible short term impact at local (Sittard-Geleen) level	LWDC <7days due to Personal Safety or Medical treatment or Restriction
G	<0.1	Minor / Superficial damage to equipment No production loss	Internal non-conformance requiring rework No customer impact	OCI Geleen internal complaints	No LOPC Non-hazardous LOPC	Moderate reversible short term impact at Chemelot site	First Aid / No injury

1	2		4		6	7
Unforeseen	Highly unlikely	Very Unl	Low	Fixed	Likely	Almost Certain
1/1000,000yrs	1/100,000yrs	1/10,000yrs	1/1,000yrs	1/100yrs	1/10yrs	1/1yrs
1x10-6	1x10-5	1x10-4	1x10-3	1x10-2	1x10-1	1x10-0

Likelihood

Consequence / Impact

HAZOP node: BFW supply Nitric Acid plant

Scenario: Failure of 1 of the BFW pumps during normal full load nitric acid production

New plant

Maintenance priority	P0	P1	P2
PSL2678 / 1x pump	⬟	◆	▲
FSL2605	⬟	◆	✓
LSL2602	⬟	✓	✓
LSL2603	✓	✓	✓

Risk levels

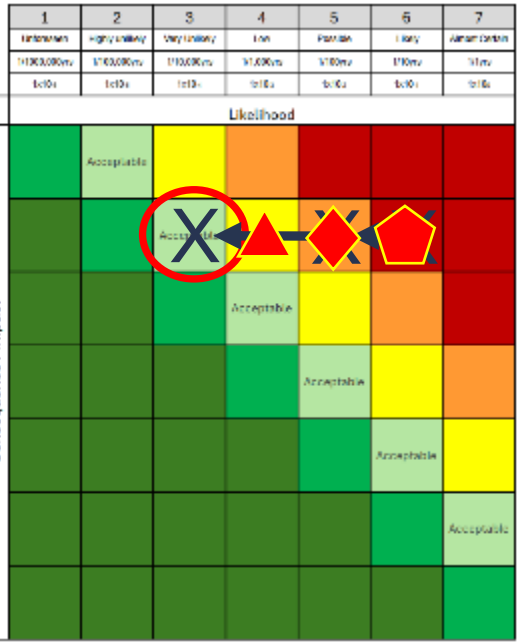
1	2	3	4	5	6
Risk not tolerable / acceptable - improve with barrier - engineer out			Risk is tolerable / acceptable - may be managed by use of procedures, works instr, training, maintenance procedures etc		

	Financial (MEuro)	Operations	Quality	Reputation / Community	Process Safety	Environment	Safety & Health
A	<1	Most production can be CCI Calder	Minimal annoyance		1x Minor Maintenance LOPC		Minimum 1 Customer
B	10-50	Major damage to more than one plant Production > 1 month	Loss of more than 1 strategic customers	International media attention	10 Minor maintenance LOPC MARS incident	Serious international environmental impact	1 fatality
C	50-80	Major damage to plant Production > 6 months	Loss of strategic customer	National media attention	1,000 – 10,000kg ammonia	Serious national environmental impact	Permanent Disability
D	10-20	Major damage to plant Production > 6 months	Serious complaint from distinct customer	Local media & public attention Significant SHE incident	250-1000kg ammonia Direct reading	Very serious long term environmental impact at regional level	LWDC > 3 weeks
E	1-10	Moderate damage to equipment / plant Production > 1 week	Major customer complaint, returns	Limited media & public attention Reportable SHE incident	50-250kg ammonia release PSR - Tier 1/Tier 2	Serious but reversible short term impact on regional / Strategic level	LWDC >7days or due to chemical exposure
F	0.5-1	Minor / Superficial damage to equipment / plant No production loss < 1day	Minor customer complaint	Community concern via complaints	1-10kg ammonia release High risk LOPC	Moderate reversible short term impact on local / Strategic level	LWDC <7days due to Personal Safety or Medical treatment or restrictions
G	<0.5	Minor / Superficial damage to equipment No production loss	Minimal non-conformance requiring rework No customer impact	<10 person internal complaints	Any LOPC Non-reportable LOPC	Moderate reversible short term impact on Community	First Aid / No injury

Consequence / Impact

1	2	3	4	5	6	7
Unforeseen	Highly unlikely	Very unlikely	Low	Possible	Likely	Almost certain
1 in 100,000 yrs	1 in 10,000 yrs	1 in 1,000 yrs	1 in 100 yrs	1 in 10 yrs	1 in 1 yrs	1 in 1 yrs
1x10-5	1x10-4	1x10-3	1x10-2	1x10-1	1x10-0	1x10-0

Likelihood



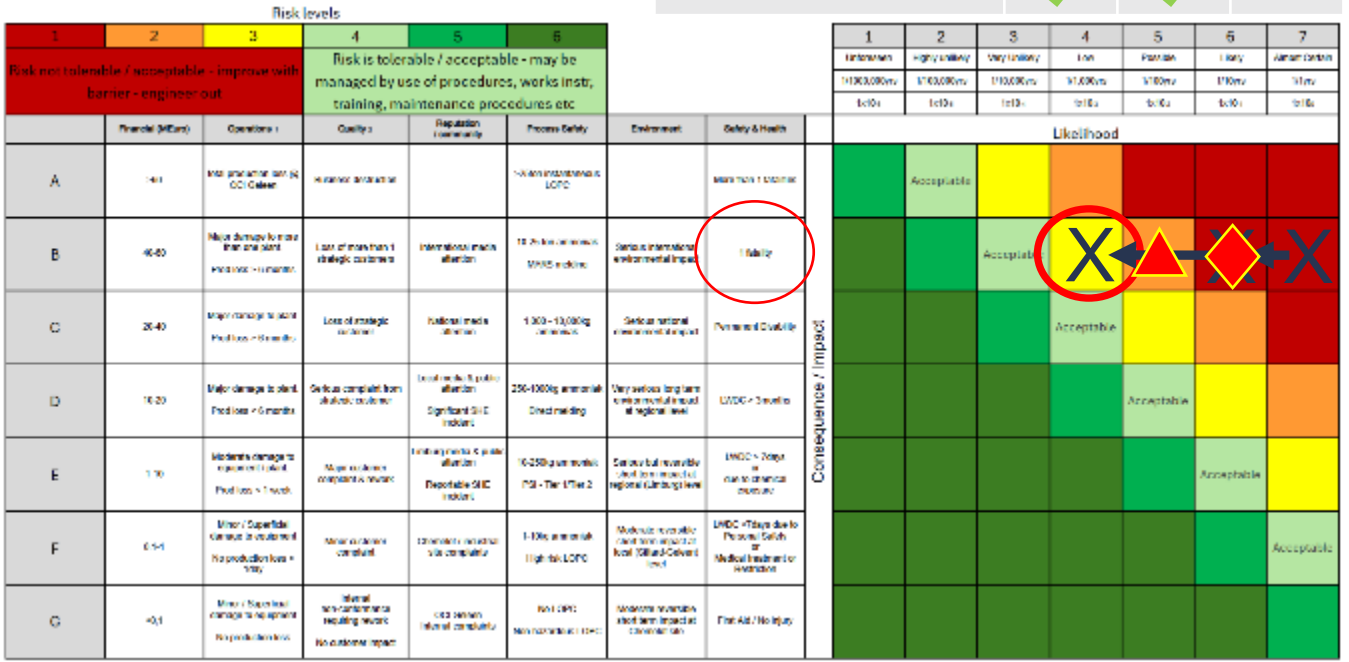
HAZOP node: BFW supply Nitric Acid plant

Scenario: Failure of 1 of the P203 pumps during normal full load production at SZF5

old plant

- PM plan adherence – 100%
- MTBF – 12months
- MTTR – 6months

Maintenance priority	P0	P1	P2
PSL2678 / 1x pump	◆	▲	
FSL2605	◆	✓	
LSL2602	✓	✓	
LSL2603	✓	✓	



Thank you!
Questions?