VISUALIZING HIDDEN HAZARDS AND BLIND SPOTS

Using AI/ML for SIMOPS

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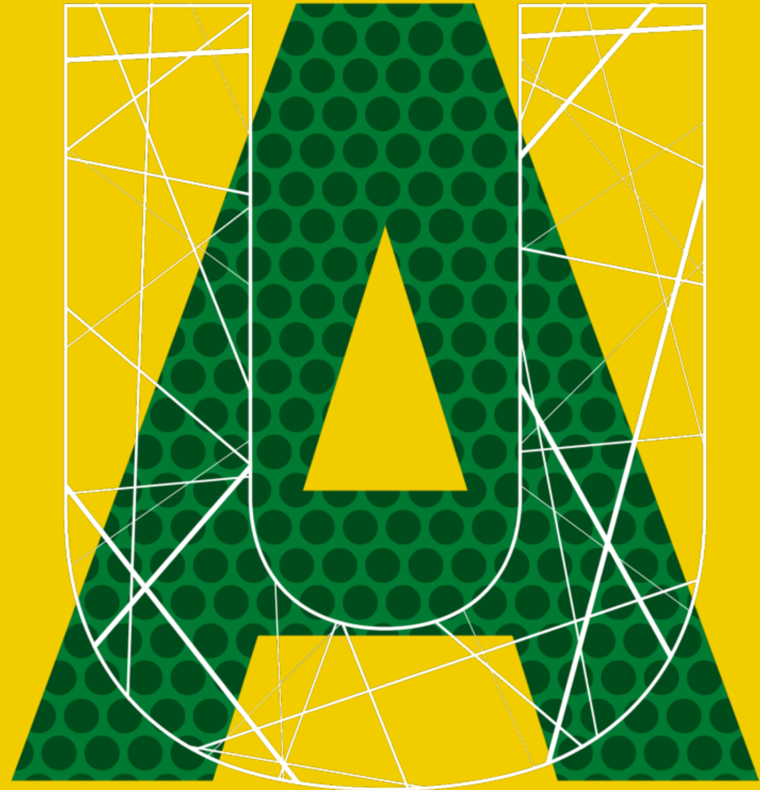
Using AI/ML to compare what happened, what was checked, and what was assured - so SIMOPS blind spots become visible.



SIMOPS risk lives in the interfaces

The risk is not only the individual task. It is the interaction between tasks, people, equipment, controls, and changing conditions.

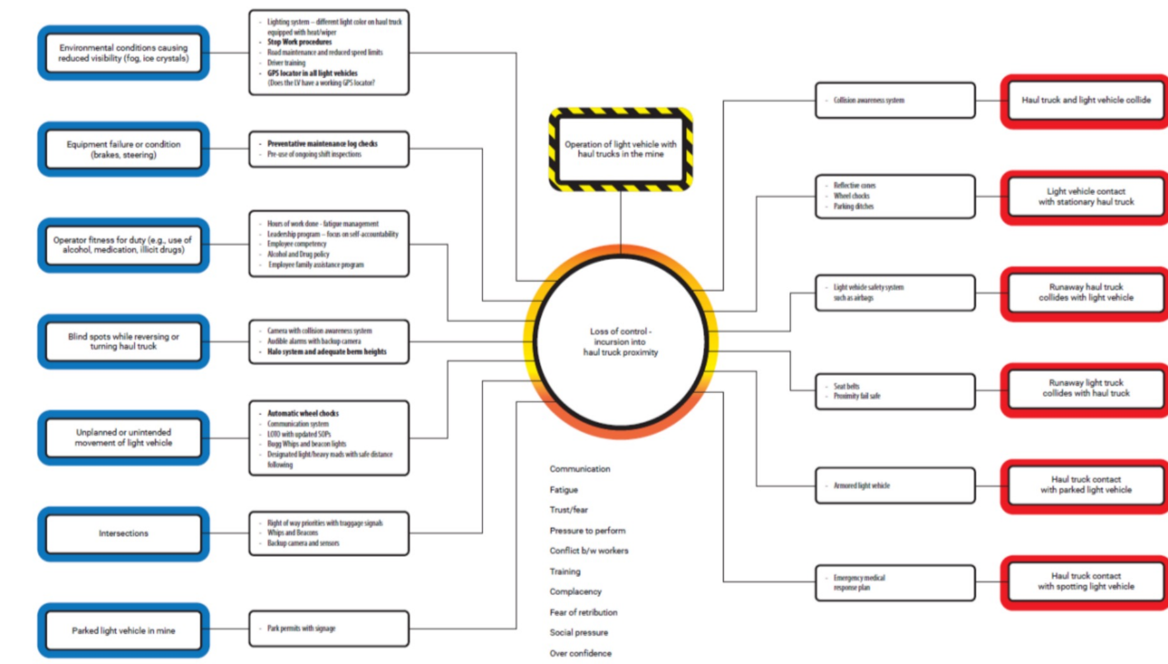


Fig. 1. Bowtie for Heavy/Light Vehicle interaction with causes (blue boxes)

How to read this figure

The center is the loss-of-control condition: heavy/light vehicles, people, and work areas coming into unsafe interaction. The left side is where conditions accumulate; the right side is why it matters.

SIMOPS issue

No single control owns the interface. Route planning, traffic control, communication, visibility, equipment condition, supervision, and work planning must function together.

Key point

Each activity may appear controlled on its own, while the interface remains weakly controlled as a system.

Source: Lefsrud et al., Building Resilience final report, 2025, doi: 10.7939/82144

What AI/ML compares

The method compares incident language with inspection or assurance language to find weak alignment - then flags where domain review should look.

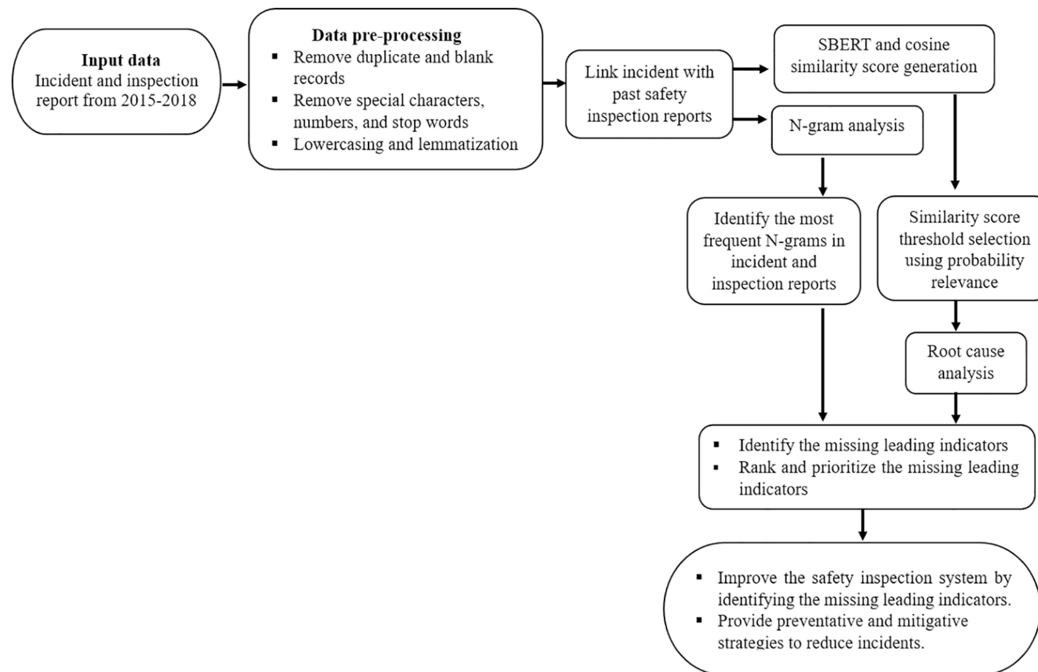


Fig. 1. Research method adopted in this study.

What is being compared

Incident descriptions are compared with prior inspection or assurance descriptions for semantic alignment.

Pipeline

Clean text → link records by time/class → create embeddings → calculate similarity → review low-alignment pairs.

Interpretation check

Low alignment is not treated as proof. RCA, bowties, Sankeys, N-grams, and co-occurrence networks support interpretation.

Source: Charuvil Elizabeth et al., Journal of Safety Research, 2025, doi: 10.1016/j.jsr.2025.02.007

Category visibility is not pathway visibility.

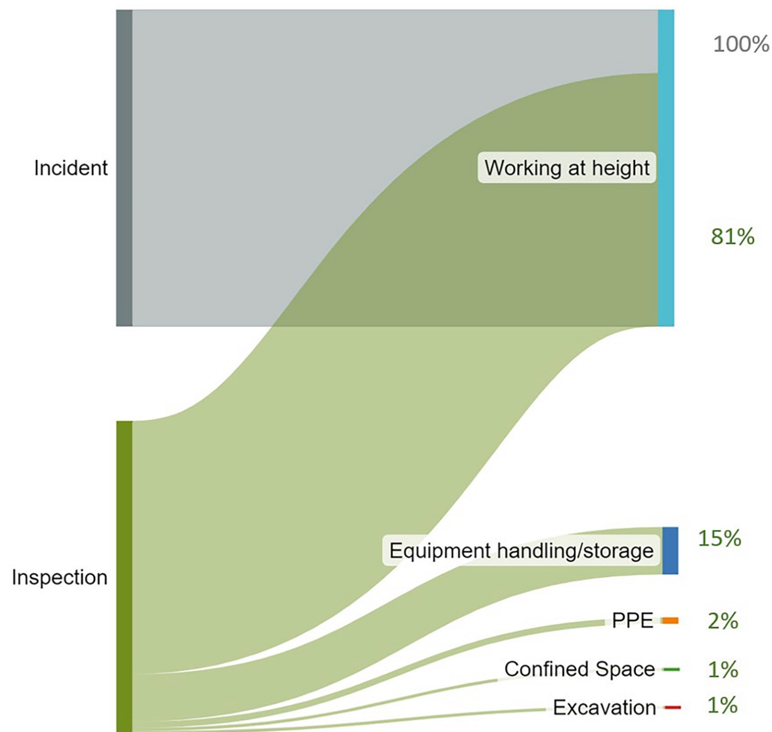


Fig. 5. Sankey diagram showing the most and least captured indicators in incidents and inspections for the Class A cluster.

What the figure shows

Working at height is visible in both streams: 100% of the selected Class A incidents and 81% of inspections.

The blind spot

The category is recognized, but the loss-of-control pathway may be under-specified: dropped objects, temporary access, fall protection gaps, exclusion zones, adjacent work, or cleanup nearby.

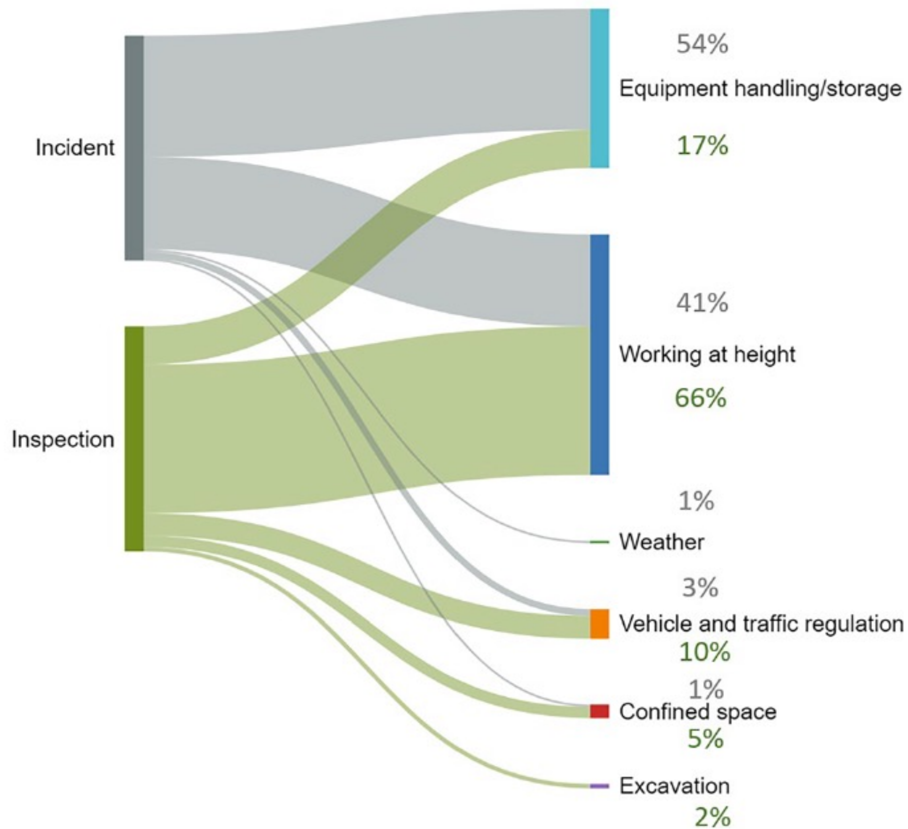
SIMOPS question

Are we checking the hazard label, or the specific interface scenario by which it becomes serious?

Source: Charuvil Elizabeth et al., Journal of Safety Research, 2025, doi: 10.1016/j.jsr.2025.02.007

Blind spot type 2: attention is displaced from the incident pattern

54% incidents vs. 17% inspections: attention displacement.



What the evidence says

For Class B records, equipment handling/storage represented 54% of incidents but 17% of inspections. Working-at-height attention was higher in inspections than in incidents.

What is different from Slide 4

The issue is not that a known label hides a pathway. The dominant incident pattern is not where inspection attention is concentrated.

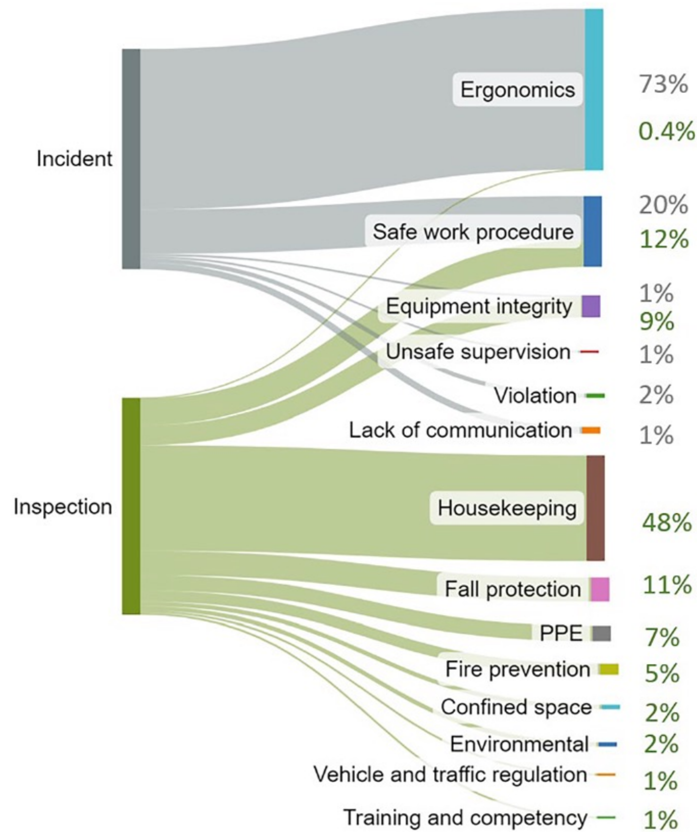
SIMOPS relevance

Equipment handling and storage sit between formal tasks: moving, staging, parking, lifting, storing, maintaining, and accessing equipment. Those logistics create line-of-fire, congestion, access, dropped-object, and interaction risks.

Source: Charuvil Elizabeth et al., Journal of Safety Research, 2025, doi: 10.1016/j.jsr.2025.02.007

Blind spot type 3: the system sees what is easiest to see

73% incidents vs. 0.4% inspections: salience bias.



What the evidence says

For Class C records, ergonomics represented 73% of incidents but 0.4% of inspections. Housekeeping dominated inspection attention at about 50%.

Interpretation

Housekeeping is visible and easy to correct. Ergonomic exposure is embedded in how work is performed: posture, force, repetition, reach, awkward access, and manual handling.

PSM translation

We can see the permit, barricade, valve tag, checklist, or completed CCA. Harder to see: whether the control still fits the work as performed, whether the interface has changed, or whether the assurance question targets the right failure mode.

Source: Charuvil Elizabeth et al., Journal of Safety Research, 2025, doi: 10.1016/j.jsr.2025.02.007

From blind spots to better-aimed assurance questions

The value is not more questions. It is questions aimed at the pathway the system was missing.

KNOWN HAZARD, HIDDEN PATHWAY

Question shift

Question shifts from the hazard label to the loss-of-control pathway.

Example assurance questions

- Is the work still inside the intended permit boundary?
- Who else is exposed by adjacent work?
- Is supervision present for the high-risk interaction?
- Did the pre-job inspection identify the pathway, not just the hazard category?

Focus: Pathway — permits, adjacent work, supervision

ATTENTION DISPLACEMENT

Question shift

Question shifts from inspection activity to interface control.

Example assurance questions

- Where will equipment move, wait, lift, store, or block access?
- How are line-of-fire, congestion, staging, and access being controlled?
- Who owns the transition between work fronts?

Focus: Interface — movement, staging, access, ownership

SALIENCE BIAS

Question shift

Question shifts from visible conditions to exposure created by work as performed.

Example assurance questions

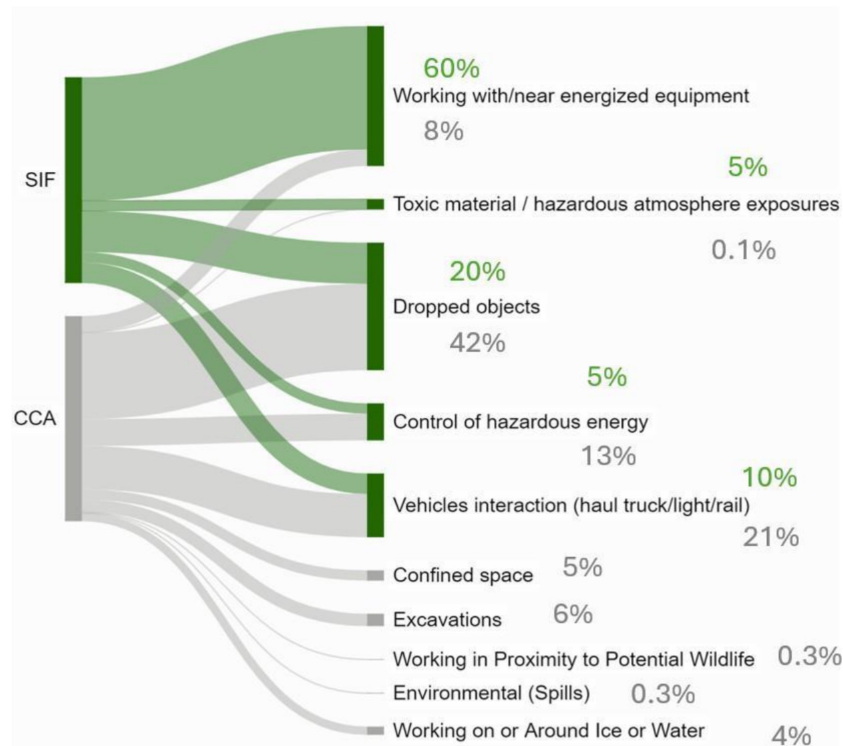
- What force, reach, posture, repetition, or manual handling is created by the task?
- Are mechanical aids, task redesign, job rotation, or rest breaks needed?
- Does the control still fit the way the work is actually being performed?

Focus: Exposure — force, reach, posture, repetition

Source: Charuvil Elizabeth et al., Journal of Safety Research, 2025, doi: 10.1016/j.jsr.2025.02.007

Critical control assurance can also have blind spots

Assurance volume is not assurance alignment: are we verifying the controls linked to the hazards showing up in SIF actual/potential records?



Why this matters now

The evidence examples showed how risk disappears from view. This figure moves the same logic into critical control assurance.

Key finding

Mining & Tailings example: working with/near energized equipment appeared in 60% of SIF records versus 8% of CCA; toxic/hazardous atmosphere exposure appeared in 5% versus 0.1%.

SIMOPS question

Do assurance questions reflect the actual interfaces between energy sources, work fronts, equipment, permits, contractors, and controls?

Source: Lefsrud et al., Building Resilience final report, 2025, doi: 10.7939/82144

From mismatch to control quality

A useful visualization should lead to better questions about controls, assurance, and failure modes.

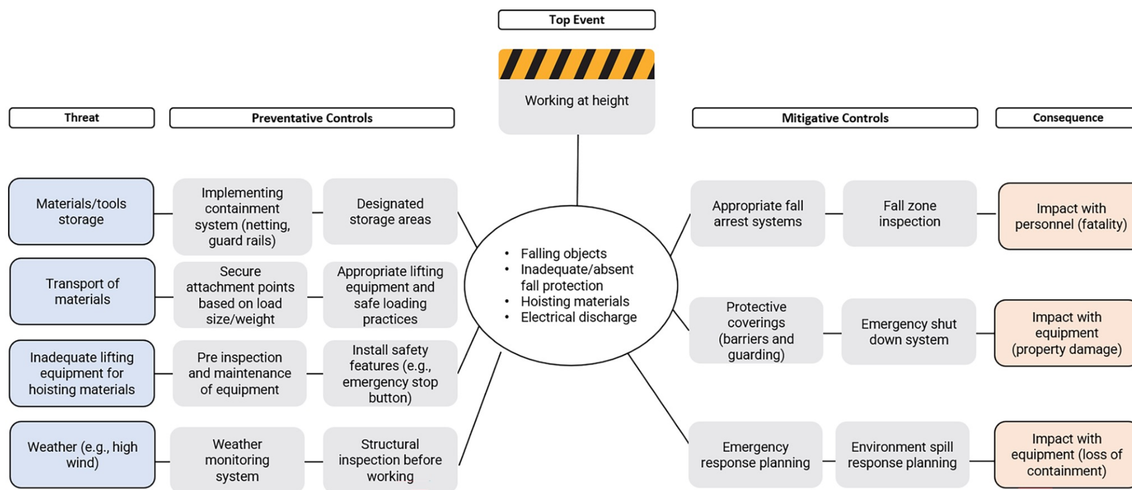


Fig. 7. Bowtie diagram for working at height.

What the bowtie adds

The Sankey tells us where attention may be misaligned. The bowtie helps decide what control conversation must change.

Better assurance questions

Which controls prevent the loss-of-control scenario? Which mitigate consequences? Which are critical? Which depend on another crew or work front?

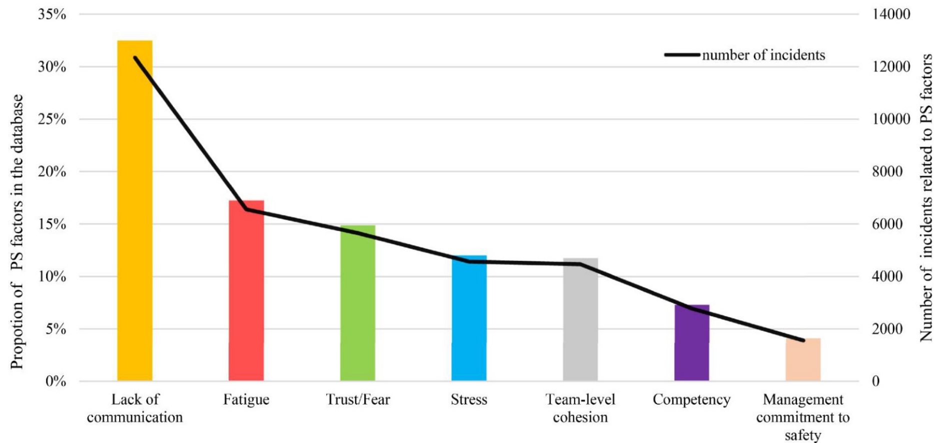
SIMOPS use

Ask whether each interface-sensitive control is present, functional, understood, and non-bypassable before and during work.

Source: Charuvil Elizabeth et al., Journal of Safety Research, 2025, doi: 10.1016/j.jsr.2025.02.007

SIMOPS also depends on communication, fatigue, trust, and coordination

SIMOPS interfaces are maintained socially before they fail technically.



gure 6. Major cause of incidents based on PS factors.

Why it matters

Interfaces are not managed by procedures alone. They are managed by people maintaining a shared picture of changing work.

Blind spots

Communication, fatigue, trust, and fear can degrade hazard recognition and control assurance before the technical barrier fails.

Practical implication

Analyze records for both physical hazards and human/organizational precursors to understand how interface controls degrade.

Source: Charuvil Elizabeth et al., International Journal of Construction Management, 2024, doi: 10.1080/15623599.2024.2417629

What this means for SIMOPS

The practical opportunity is to compare records for three kinds of blind spots: pathway, attention, and salience.

KNOWN HAZARD, HIDDEN PATHWAY

The category is visible; the loss-of-control pathway is not.

ATTENTION DISPLACEMENT

The system is looking hard, but not where risk is materializing.

SALIENCE BIAS

Inspection visibility follows what is easiest to see, not the exposure pattern.

COMPARE

Incidents · inspections · CCA · permits · work plans · lessons learned

VISUALIZE

Sankey · bowtie · co-occurrence · control pathway

STRENGTHEN

Better assurance questions · better SIMOPS reviews · stronger critical controls · better learning loops

AI/ML scales the comparison. Visualization makes the mismatch discussable.
Process safety expertise turns that visibility into stronger controls, better assurance questions, and better learning loops.

Developed through academic research; applied in practice through Insight Risk Systems.

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