WHITEPAPER

The Industrial SIF Prevention Framework

Why Incident Data Alone Can Miss High-Consequence Exposure

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AI-Powered Safety & Risk Intelligence

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Executive Summary

Over the past two decades, industrial safety performance has improved significantly. TRIR and LTI rates have declined across many sectors, supported by stronger processes, training, and compliance systems.

Yet serious injuries and fatalities (SIFs) continue to occur — even in organizations with strong safety records. According to the National Safety Council, SIF events account for a disproportionate share of workplace fatalities despite decades of declining total recordable rates.

The underlying challenge is how risk becomes visible — and how attention is naturally drawn toward what happens most often:

> **Traditional safety programs have been highly effective in reducing frequent, lower-severity incidents. But because attention is often shaped by frequency, severe but less frequent exposure patterns can remain comparatively under-visible.**
>
> SIF events are driven by high-energy exposures — conditions where the physics of the environment determine whether the outcome is a near miss or a life-altering event.

85%
of SIF events
involve high-energy hazards [1]

5,283
workplace fatalities
in the U.S. in 2023 [2]

~70%
of pSIF precursors
go unreported [1]

Sources: National Safety Council (NSC) Injury Facts 2024; Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries 2023; Campbell Institute pSIF Research 2022.

As a result, there is often a critical gap: the data used for safety reporting does not adequately reflect the exposures that drive serious injury and fatality risk. Because frequency naturally shapes where attention flows, the exposures that matter most — rare, high-energy, high-consequence — can remain comparatively invisible.

This paper introduces an exposure-based safety model and outlines a practical framework for identifying, measuring, and controlling high-energy risk across industrial operations.

1. The Limitation of Incident-Based Safety

Most industrial safety systems are built around incident tracking. Metrics such as Total Recordable Incident Rate (TRIR) and Lost Time Injury (LTI) rates have played an important role in improving workplace safety.

However, these metrics share a fundamental limitation: **they are lagging indicators.** As Manuele[3] and other SIF researchers have documented, the statistical correlation between recordable injury frequency and SIF occurrence is weak — sometimes approaching zero.

They describe outcomes that have already occurred — but they do not necessarily provide visibility into whether the most dangerous exposures are under control.

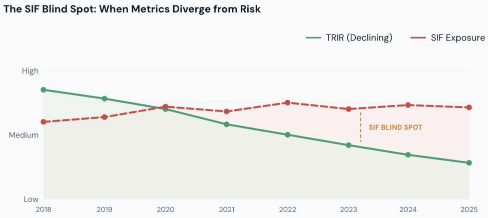
In many operations, it is possible to achieve historically low TRIR levels while maintaining significant exposure to high-consequence hazards.

2. The SIF Blind Spot

Serious injury and fatality (SIF) events typically emerge from high-energy hazards. Research from the Campbell Institute[1] and DecisionPoint[5] has consistently identified these primary SIF exposure categories:

- Pedestrian–equipment interactions in mixed-traffic environments
- Energy isolation failures during maintenance
- Machinery and moving equipment hazards (struck-by, caught-between, crush)
- Loss of containment or uncontrolled energy release

These hazards behave differently from low-severity risks. They are often less frequent, less visible in traditional reporting systems, and disproportionately severe in outcome.



The SIF Blind Spot: When Metrics Diverge from Risk

Figure 1: Conceptual illustration. TRIR trends downward while high-energy SIF exposure remains elevated — a pattern widely documented in SIF prevention literature.

KEY INSIGHT

> **High-consequence risk can exist independently of recordable injury trends.**
>
> A facility may report excellent safety performance while still experiencing repeated high-energy near misses in specific zones, shifts, or operational conditions. This disconnect represents the SIF blind spot.

Why Catastrophic Events Often Remain Underrepresented in Safety Data

The underrepresentation of high-consequence risk in safety data is not a failure of reporting — it is a structural characteristic of how frequency shapes attention.

Several factors contribute to this pattern:

- **Frequent events naturally dominate reporting.** When an organization processes hundreds of first-aid incidents and minor recordables per year, these events consume the majority of investigation and reporting bandwidth.
- **Severe events are rare and low-sample.** SIF-potential events may occur only a few times per year at a given facility — too infrequently to form statistically visible trends in conventional safety dashboards.
- **Many SIF precursors are not preceded by minor incidents.** Unlike the assumptions of traditional safety pyramids, high-energy exposures often do not generate a trail of lower-severity warnings before a catastrophic outcome occurs.[1][3]
- **Low frequency does not equal low exposure.** A forklift–pedestrian near miss that occurs three times per week may never result in a recordable injury — but the underlying exposure remains constant and consequential.

> **Frequency tends to drive attention, while severity determines consequence.**
>
> The most catastrophic events often do not occur frequently enough to dominate conventional reporting. This is precisely why exposure-based visibility is essential.

3. High-Energy Exposure as the Core Driver of SIF Risk

At the core of SIF prevention is a principle grounded in energy-based risk theory: **the severity of an outcome is largely determined by the energy involved in the exposure.** This concept, rooted in William Haddon's energy transfer model and reinforced by the NSC's pSIF framework[6], has become foundational to modern SIF prevention.

In industrial environments, this includes:

- Vehicle mass and speed (e.g., forklifts, heavy equipment)
- Mechanical forces from moving machinery
- Stored or uncontrolled energy (electrical, hydraulic, thermal)

When a high-energy exposure occurs, the difference between a near miss and a fatality is often circumstantial, not structural. As Conklin[4] has observed, the presence or absence of serious harm in high-energy events is frequently a matter of luck rather than control.

Therefore, reducing SIF risk requires:

1. Identifying where high-energy exposures occur

2. Understanding how frequently they occur
3. Controlling the conditions under which they happen

4. The Trio Mobil SIF Exposure Framework

To operationalize the shift from incident-based to exposure-based safety, we propose a three-layer model:

Layer	Purpose	Key Elements
1. Detection	Capture relevant events and interactions	Pedestrian–vehicle proximity events; unsafe acts and near misses; deviations from safe operating procedures
2. Exposure	Transform events into meaningful patterns	Recurring interaction zones; exposure density and frequency; time-based and shift-based clustering; behavioral trends
3. Control	Risk mitigation and validation	Engineering and administrative controls; effectiveness of existing controls; reliability of protection mechanisms

5. Incident-Based vs. Exposure-Based Safety

Dimension	Incident-Based	Exposure-Based
Focus	Past incidents	Potential future events
Data type	Recorded injuries	Interactions, near misses, conditions
Visibility	High	Often low
Frequency	High	Lower, but recurring
Severity focus	Low–medium	High consequence
Decision driver	What happened	What could happen

> The shift is not about replacing incident metrics — but **complementing them with exposure visibility.**

6. Operationalizing SIF Prevention

Moving from theory to practice requires addressing several key questions:

1. How do you detect meaningful signals?

Organizations must move beyond incident logs and begin capturing near misses, unsafe interactions, and high-risk proximity events.

2. How do you distinguish signal from noise?

Not all events carry equal risk. Prioritization should focus on high-energy interactions, repeated exposure patterns, and structural risk conditions.

3. How do you identify recurring exposure patterns?

SIF risk is often location-specific, time-dependent, and behavior-driven.

4. How do you verify safeguards?

Controls must be evaluated not only by design, but by real-world effectiveness, consistency of operation, and coverage of actual exposure conditions.

7. Practical Example: Forklift–Pedestrian Interactions

In large manufacturing and logistics environments, one of the most common SIF exposure categories is forklift–pedestrian interaction. OSHA data[7] indicates that forklift-related incidents account for approximately 85 fatalities and 34,900 serious injuries annually in the United States alone. Typical patterns include:

- Repeated near misses in high-traffic intersections
- Pedestrian encroachment into vehicle pathways
- Limited visibility during loading or turning
- Congestion during shift changes

KEY INSIGHT

The incident rate is low. The exposure is not.

This illustrates why exposure visibility is essential for SIF prevention.

OBSERVED PATTERNS

Multi-Site Manufacturing Operations — Forklift Exposure Patterns

Across multiple large manufacturing deployments, including multi-site operations, continuous pedestrian–forklift proximity monitoring has consistently revealed exposure patterns not visible in traditional incident reporting.

In several cases, internal safety metrics showed zero forklift-related recordable injuries over extended periods (e.g., 12–18 months).

Within the first 30 days of monitoring, systems typically identified:

- **40–60 high-energy proximity events per week** per site cluster
- **2–4 recurring blind-spot zones** accounting for the majority of critical interactions
- **Shift-change congestion patterns** creating significantly elevated exposure density

None of these exposures had appeared in incident reports or near-miss logs. The incident record was strong. The exposure profile was not.

Based on exposure insights, organizations implemented targeted controls — physical barriers, traffic flow redesign, and automated speed reduction — resulting in **60–80% reduction in critical proximity events within 60–90 days.**

METHODOLOGY NOTE

> **Proximity event definition:** Any pedestrian–forklift interaction where closing distance fell below 2.0 meters while the vehicle was in motion (speed > 0.5 km/h).
>
> **High-energy threshold:** Events classified as critical when vehicle speed exceeded 5 km/h at the point of closest approach, or when the pedestrian was in the vehicle's blind zone at the time of detection.
>
> **Volume normalization:** Event counts were normalized against daily forklift operating hours and pedestrian traffic density per zone to control for activity variation.
>
> **Interventions:** Reduction ranges reflect combined measures including physical barriers at identified blind-spot zones, one-way traffic redesign in high-density aisles, automated speed reduction via proximity alert integration, and targeted operator coaching informed by interaction heatmaps. Results vary by site configuration.

Note: Aggregated deployment data across multiple sites. Ranges represent observed outcomes across deployments.

8. The Real Challenge: Making Exposure Visible

Most safety leaders recognize the importance of SIF prevention. The challenge lies in operationalizing it. Key difficulties include:

- Limited visibility into day-to-day interactions
- Difficulty aggregating and analyzing exposure data
- Lack of tools to detect patterns across large operations
- Challenges in validating safeguard effectiveness

Addressing these challenges requires a combination of data collection, analytical frameworks, and operational integration.

9. Where Industrial Safety Is Heading

The next evolution of industrial safety is not defined by further reducing recordable incidents alone. It is defined by the ability to:

- Detect high-risk exposure earlier
- Understand how risk is distributed across operations
- Intervene before conditions escalate into serious events

> This represents a fundamental shift — from **reactive, incident-based models** to **proactive, exposure-based systems.**

10. Conclusion

Industrial safety has made significant progress — but the persistence of serious injuries and fatalities highlights a fundamental gap.

To address this gap, organizations must move beyond measuring what has already happened and begin managing what could happen.

SIF prevention requires:

- Visibility into high-energy exposure
- Identification of SIF precursors

- Verification of critical safeguards

In other words, the question changes:

FROM
"How many incidents occurred?"

→

TO
"Where could a life have been lost today?"

SIF Prevention Readiness Assessment

Use this checklist to evaluate your organization's current maturity across the three layers of SIF prevention. Each item reflects a capability that contributes to closing the SIF blind spot. This is a directional self-assessment designed to guide internal conversation — not a validated scoring instrument.

Detection Layer

☐ We capture near misses and unsafe interactions — not just recordable incidents.
☐ We have technology-enabled detection for pedestrian–vehicle proximity events.
☐ Our detection system uses multiple, independent sensing layers (e.g., vision + proximity) so that no single-point failure creates an undetected exposure.
☐ Our reporting system captures high-energy events separately from low-severity incidents.
☐ We collect data continuously (not just during audits or after incidents).
☐ Our detection technology addresses known blind spots — including behind racking, around corners, and at dock doors — where line-of-sight sensing alone cannot reach.
☐ Our system provides reliable detection at intersections and convergence points where multiple pedestrian and vehicle paths cross simultaneously.

Exposure Layer

☐ We can identify recurring interaction zones and high-density exposure areas.
☐ We analyze exposure patterns by shift, time of day, and operational condition.
☐ We distinguish between high-energy and low-energy events in our data.
☐ We track exposure trends over time — not just incident counts.
☐ Our safety reviews include exposure density data alongside traditional metrics.

Control Layer

☐ We verify that engineering controls are functioning as designed in real operations.
☐ We measure safeguard effectiveness using interaction data — not just compliance audits.
☐ We can validate whether corrective actions actually reduced the targeted exposure.
☐ We have a process for escalating when critical controls degrade or fail.
☐ Our leadership reviews include safeguard reliability alongside safety performance metrics.

Score	Maturity Level	Interpretation
14–17	Advanced	Strong SIF prevention foundation. Focus on optimization and validation.
9–13	Developing	Key capabilities in place. Gaps exist in exposure visibility or control verification.
5–8	Emerging	Incident-based system is solid. Exposure-based layer needs significant development.
0–4	Foundational	Traditional safety program. SIF blind spot is likely present and unaddressed.

About Trio Mobil

Trio Mobil develops AI-powered safety and risk intelligence solutions designed to provide visibility into high-energy exposure across industrial operations.

By combining real-time detection, exposure analytics, and safeguard validation, the platform enables organizations to move from incident-based safety toward proactive SIF prevention.

References & Further Reading

[1] National Safety Council (NSC). *Serious Injury and Fatality Prevention: Perspectives and Practices.* Campbell Institute, 2022.

[2] Bureau of Labor Statistics. *Census of Fatal Occupational Injuries.* U.S. Department of Labor, 2023.

[3] Manuele, F.A. *On the Practice of Safety.* 4th Edition. Wiley, 2013.

[4] Conklin, T. *Pre-Accident Investigations: Better Questions — An Applied Approach to Operational Learning.* Ashgate, 2012.

[5] DecisionPoint International. *SIF Precursor Analysis: Methodology and Application.* 2021.

[6] National Safety Council. *pSIF: Potential Serious Injury and Fatality Framework — Practitioner Guide.* 2020.

[7] OSHA. *Powered Industrial Trucks (Forklifts) — Hazard Recognition.* U.S. Department of Labor.

Organizations that succeed in this transition will not only reduce incidents — they will gain control over the exposures that matter most.

And that is where the future of industrial safety is being built.

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