RISKOPILOT

Time to act

What technology can and cannot add to critical controls

An evidence review for executive committees and boards in high-hazard industries. Eight fatal event families, six official investigations, one investment test and the leadership conditions that make protection possible.

RISKOPILOT RESEARCH
CRITICAL CONTROLS SERIES
BRUNO HOUNKPATI

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RISKOPILOT.COM

ABOUT THIS REPORT

What this is, and what it is not

This is an evidence review with a proposed decision method. It reads the published research and six official investigations, then turns them into a test a capital committee can apply and six conditions leaders must create.

It contains no new field data. Riskopilot bought and tested no equipment for it. Where we propose something, the page says so.

The report extends the Riskopilot critical control health method (CCHI). CCHI verifies controls before people are exposed. This report covers the next question: when a control is challenged or fails during the work, does anything give people time to act?

How to read the labels

FACT A finding taken from a named source, with its date and scope.

INFERENCE Our reading of what the facts imply.

ILLUSTRATION An invented example or number, used to explain a method.

RECOMMENDATION What we advise executive committees and boards to do.

Numbers in small gold type point to the source register on pages 42 to 44.

Who it is for

Executive committees and boards who approve safety technology budgets, and the operations, engineering and HSE leaders who must make those budgets protect people.

Contents

Executive summary 03
Exhibit 1. One truck, seven days, 580 alarms 06
How this extends CCHI 07
Part 1. What the evidence can support 08
Part 2. The investment test 12
Part 3. Eight fatal event families 19
Part 4. Six investigations 24
Part 5. Eight technology functions 28
Part 6. What leaders must create 31
A 90–day plan 40
What would change these recommendations 41
Source register 42
Verification note, author and licence 45

Scope and transfer

Most of the published evidence comes from construction and mining in the United States and the United Kingdom. Readers in mining, cement, energy and heavy industry in Africa and Europe should treat every finding as a hypothesis to test on their own site, under their own law. Page 41 sets out the limits.

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EXECUTIVE SUMMARY

Fund the control that removes the exposure. Then test what is left.

Safety technology is sold on what it detects. People are protected by what happens next: someone acts, in time, and the work reaches a safe state. The published evidence says a great deal about the first and very little about the second.

The decision

RECOMMENDATION Before approving a monitoring or AI system for a fatal risk, require the sponsor to pass five gates (page 13). The first gate ends most proposals: if a layout change, a redesign or a different work method removes the exposure, fund that.

Where exposure remains, approve a bounded pilot only when the team can name the residual exposure, the decision the information would change, and the person able to act on the hardest shift.

Reject any proposal whose success measure is the number of devices installed.

Why

FACT In a NIOSH field study, a radar system on a mine haul truck raised an alarm on 94% of 618 reversing movements over seven days. It missed nothing. Only 235 of the 580 alarms, 41%, required immediate action or extra caution.[1]

INFERENCE A system can be technically right almost every time and still add little to the driver's decision.

Five findings

1. The outcome evidence is thin. FACT A 2023 mapping review screened 392 records on digital safety interventions in construction and kept 24. Most gave low to no evidence of better conditions or fewer injuries.[2]

2. Detection is one of four things to prove. INFERENCE Detection, timely action, reduced exposure and fewer injuries each need their own evidence. A result at one level cannot stand in for another.

3. Alarms have a deadline and a recipient. FACT UK regulator guidance: alarm settings must leave the operator time to respond, and each alarm needs a defined response.[11]

4. Investigations rarely find a missing signal. INFERENCE In five of the six cases reviewed here, an alarm sounded, damage was visible or a test was carried out before people were harmed. What failed was authority, competence or verification.[5, 6, 8, 23, 24]

5. Workers decide whether it works. FACT In one US survey, 59% of field labour respondents would not voluntarily use a location-tracking wearable.[4]

The question for the executive committee

Take the last control that failed on one of our sites. Did we lack a timely signal, someone qualified to act, or the authority and money to restore protection? Fund the answer.

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EXECUTIVE SUMMARY

What leaders must create

Technology can buy time. Whether anyone is placed, competent and authorised to use that time is decided by leaders, usually long before the day.

Three leadership lessons

1. The signal is rarely what is missing. INFERENCE In five of six official investigations, an alarm sounded, damage was visible or a test was carried out before people were harmed.[5, 6, 8, 23, 24]

2. Authority shared by everyone is held by no one. FACT At the Florida bridge, cracking was documented and five parties failed to stop work or close the road.[6]

3. Decisions far from the workface set the conditions at it. FACT At Texas City, budget cuts of 25% preceded the loss of a board operator. Operators had worked at least 29 consecutive 12–hour shifts.[23]

What the research adds

FACT In a randomised study, feedback to supervisors on their daily safety talk improved crew behaviour and audit scores.[26] In another, leadership visits lowered staff ratings of improvement unless senior managers took responsibility for fixing what they heard.[27]

No study has shown a leadership practice reduces fatalities. Page 32 sets out the limits.

Six conditions, six executive tests

CONDITION	ASK
1. Authority held by one named person	Who can stop this work at 02:00 on a Sunday? One name, one deputy.
2. Competent cover on the hardest shift	Which duty does this cut leave uncovered?
3. No penalty for stopping	Who absorbed the cost of the last stop?
4. Bad news travels	What did the executive committee last hear about a failed critical control?
5. Money to restore	Who can spend today to fix it?
6. Independent verification	How many re-checks found a false pass?

Evidence for each condition is on pages 34 and 35.

The leader's own part

Ask which duty goes uncovered before every cut. Fix what you hear. Stop reading injury rates as proof of control. Check what you reward. Put names and deputies on every stop decision, rehearse it, and answer the first stop well.

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EXECUTIVE SUMMARY

What to do in the next 90 days

Four decisions, each with an owner and a test of success. Page 40 gives the full plan.

DECISION	OWNER	WHEN	WHAT GOOD LOOKS LIKE
Reconstruct one failed control	Site director, with HSE	Days 1 to 15	One recent case, traced from first warning to verified restoration. The executive committee sees when exposure ended, who authorised the repair and what the next shift verified.
Put every live technology proposal through the five gates	Capital committee chair	Days 15 to 45	Each paper names the exposure, the best conventional alternative on the same boundary, the person who acts and the full-life cost. Proposals that fail gate 1 are converted into redesign budgets.
Test the six leadership conditions	CEO and executive committee	Days 1 to 90	The reconstructed case put through all six tests. An authority map with names and deputies for each fatal risk. One out-of-hours stop rehearsed and timed.
Run one bounded pilot, or none	Operations director, with the technical authority	Days 45 to 90	Acceptance criteria signed before testing. Results reported with denominators, misses, late warnings, nuisance alarms per hour and time in unknown state. A written decision: adopt for the tested use, redesign, or withdraw.

What this report will not tell you

Which product to buy. It names functions, not brands. Nor will it give an injury-reduction percentage. The research does not support one.

Where it fits in the Riskopilot method

CCHI asks, before work starts, whether every critical control on a fatal-energy pathway is verified.[20]

This report applies the same discipline to technology. A sensor that warns sits low in the hierarchy. It earns investment only after the higher options have been priced and found impractical.

What would change our advice

A controlled field study showing that a specified warning function reduces exposure at comparable work volume, on equipment and conditions like yours, would justify moving faster than this report recommends. We found none for the functions reviewed. Page 41 lists the other triggers.

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EXHIBIT 1 · MOBILE EQUIPMENT

One truck, seven days, 580 alarms

The best field study we found on proximity warning shows why a procurement test needs two denominators: how often the system speaks, and how often the driver needs to hear it.

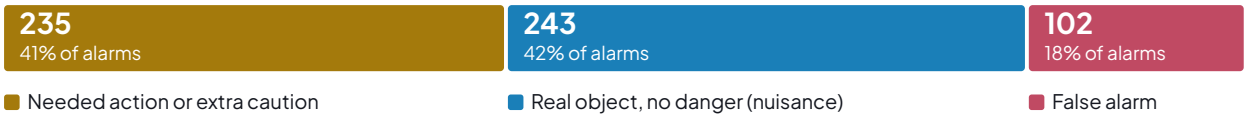
EXHIBIT 1

The radar missed nothing. Most of what it said required no action.

618 reversing movements in seven days



What the 580 alarms meant for the driver



Needed action or extra caution · Real object, no danger (nuisance) · False alarm

Missed alarms recorded: 0

The radar found what was there. Six alarms in ten still asked nothing of the driver.

Three-way split is Riskopilot arithmetic from Table 1 and section 4.1 of the paper: 235 + 243 + 102 = 580.

FACT Source: T. Ruff, "Evaluation of a radar-based proximity warning system for off-highway dump trucks", Accident Analysis & Prevention 38 (2006), 92 to 98, Table 1 and section 4.1. NIOSH Spokane Research Laboratory. One large haul truck at a surface copper mine in Arizona, seven days of normal operation, after two years of development with the manufacturer. Alarms were classified by reviewing video. The study did not measure injuries. [1]

What it means

INFERENCE A supplier can truthfully report zero missed detections for this installation. A driver on the same truck hears an alarm on almost every reversal and learns that most can be ignored. Both statements describe the same seven days.

FACT The author's own conclusion was that sensor systems should be paired with cameras, so the operator can check the source and urgency of an alarm. [1]

What to ask a supplier

RECOMMENDATION Ask for both denominators on equipment like yours.

- Of all movements, how many triggered an alert?
- Of all alerts, how many required the operator to do something?
- How were periods with no alert sampled for missed encounters?
- Can we export every time-stamped alert?

A system that cannot answer the second question has not been tested for the thing you are buying.

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METHOD

How this extends CCHI

CCHI answers one question before exposure: is every critical control verified? This report follows the same pathway into the work, to the moment a control is challenged.

EXHIBIT 2

Three moments on one fatal-energy pathway

BEFORE EXPOSURE

The gate

Every critical control verified as present, functional and in use, or the task stops. Covered by the CCHI methodology and rollout playbook.

DURING THE WORK

The challenge

Conditions change. A control is breached or degrades. Does a signal reach someone who can act in time? **This report.**

AFTER A FAILURE

The restoration

Who verifies the repair, who releases the work, who funds the fix. Introduced on page 38 and developed in the next report in this series.

Riskopilot framing. The gate is described in the CCHI methodology proposal, last reviewed 16 September 2026. [20]

What carries over from CCHI

Evidence that is only a document counts for nothing. FACT At the CCHI gate a control is verified or it is not, and a paper record alone does not verify it. [20] INFERENCE The same holds for a dashboard. A green tile is a record. The protected state is a physical fact someone must establish.

The hierarchy of controls comes first. FACT CCHI ranks barriers from elimination down to protective equipment, because higher controls depend less on a person acting correctly at the moment of risk. [20] INFERENCE A warning depends entirely on that. It belongs near the bottom of the ladder. A system that stops the machine itself is a different control and sits higher.

What this report adds

A test for technology. Five gates that decide whether a monitoring function deserves a pilot, and what would count as passing (page 13).

A way to measure time. A warning is useful only if sensing, recognition and stopping fit inside the time available (page 14).

Honest statistics for small pilots. What a clean run of 30 trials does and does not show (page 15).

A monitoring function that passes the test can supplement verification inside the L.O.C.K. loop. It does not earn protection points on its own account unless the site's technical authority credits it as a critical control and puts it through the gate. [20]

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PART 1

What the evidence can support

Two systematic reviews, one field study and a recent review of computer vision. Together they justify testing selected functions. They do not justify fleet purchases.

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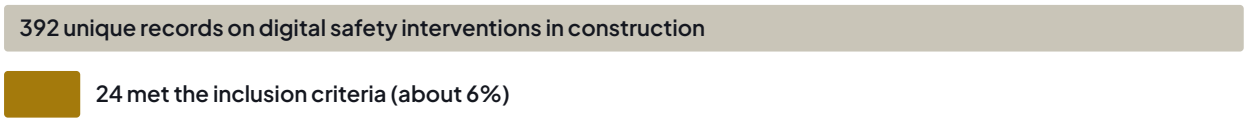
PART 1 · THE EVIDENCE BASE

Plenty of technology, little proof of protection

The strongest syntheses we found agree with each other. Research on safety technology is mostly about building it. Evidence that it protects people at work is scarce.

EXHIBIT 3

What a systematic search of digital safety interventions in construction retained



Most of the 24 were about developing the technology.
They gave low to no evidence of better working conditions or fewer injuries.

FACT Source: C. Trask and H. Linderoth, "Digital technologies in construction: a systematic mapping review of evidence for improved occupational health and safety", Journal of Building Engineering 80 (2023), 108082. The counts describe that review's selection, not this report's. [2]

The wider picture is no stronger

FACT The Cochrane review of interventions to prevent injuries in construction workers included 17 studies: 14 interrupted time series and three controlled before-and-after studies. Its search ran to April 2017. The reviewers rated the evidence as very low quality. [3]

FACT For most included studies the reviewers could not be confident that the intervention, and not something else happening at the same time, explained the change. [3]

INFERENCE This is the central problem for any site pilot. Layout, training and technology usually change together. Page 16 shows how to separate them.

Computer vision: strong benchmarks, weak field validation

FACT A review of automated construction monitoring published in 2026 identifies gaps in real-world validation, in how well datasets generalise and in standard metrics. [9] We read its abstract, highlights and introduction, not the full text.

INFERENCE A model that scores well on a benchmark has been tested on images like its training data. Your site at dusk, in dust, with a new subcontractor's vehicles, is a different test.

What we conclude. RECOMMENDATION Keep the existing protective arrangements in place. Test selected functions against them. Give no operational safety credit to a new system until the site has shown reliable action, workforce acceptance and maintained performance.

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PART 1 · STANDARD OF PROOF

Four levels of proof, four different denominators

A person steps into a crossing. A camera classifies an image. An alarm reaches the cab. The driver interprets it. The machine stops. A benchmark score measures one link in that chain.

EXHIBIT 4

Each step up needs its own evidence. Most claims stop at level 1.



INFERENCE Riskopilot framework, built on the evidence gaps reported in sources 1, 2, 3 and 9. Bottom line shows where evidence at each level usually comes from.

How to use the ladder

RECOMMENDATION Ask every sponsor and supplier which level their evidence reaches, and with what denominator.

- **Level 1** counts eligible encounters, each compared with an independent reference.
- **Level 2** counts encounters where the right action finished before the last safe moment.
- **Level 3** counts exposures per unit of comparable work: per movement, per entry, per lift.
- **Level 4** needs a population and a period large enough for rare events. A single site will not have it.

The practical target is level 3

INFERENCE For a site, the best achievable proof is usually an observable intermediate outcome. A crossing was eliminated. A faulty isolation was found before entry. An alarm prompted withdrawal in time.

RECOMMENDATION Report these with their denominators, the conditions observed and the plausible alternative explanations. Record work phase, weather, fleet mix and delivery volume alongside the counts, because exposure moves with all of them.

Treat rare serious injuries as context. A short pilot on one site cannot estimate lives saved, and a report that claims to should be sent back.

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PART 1 · METHOD AND LIMITS

How this review was done

A targeted review, not a systematic one. We say so because the difference matters to how much weight an executive committee should put on it.

What we did

We searched English-language sources for evidence on proximity warning, wearables, computer vision, digital permits and field evaluation of safety technology in construction and hazardous operations. We added event-specific searches of regulator, investigation-agency and standards sources.

Each source was selected for its relevance to a specific claim. Reviews anchor statements about the wider evidence. A primary field study informs one use case. Investigations establish a documented sequence of events.

Every figure in this report was traced to its original source on 19 November 2026. Where a second independent source exists, we checked it. The verification note on page 45 lists what rests on one source.

What we did not do

- No pooled effect estimate. The studies are too different to combine.
- No second reviewer for source selection.
- No purchase or physical test of any equipment.
- No site data. Every worked number is marked as an illustration.

Where the review is likely to be wrong

LIMIT	LIKELY EFFECT
English-language, publicly indexed sources	Under-represents regulators and research in French, Spanish, Portuguese and other languages.
US and UK investigations	Legal duties, contracting models and enforcement differ elsewhere.
Published studies only	Unsuccessful commercial deployments are rarely written up, so the true record may be weaker than the literature.
Construction and surface mining	Findings need fresh testing for underground work, process plants and marine operations.
Some papers read at abstract level	Marked in the source register. Detail in the full text could qualify our summary.

How to challenge this report

If you hold a source that contradicts a conclusion here, record its comparator, denominator, environment and outcome, and send it to contact@riskopilot.com. A newer product release changes what is available. It does not by itself change the evidence that it works.

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PART 2

The investment test

Five gates, a time budget and the statistics of small pilots. Everything a capital committee needs to tell a protective function from an expensive record.

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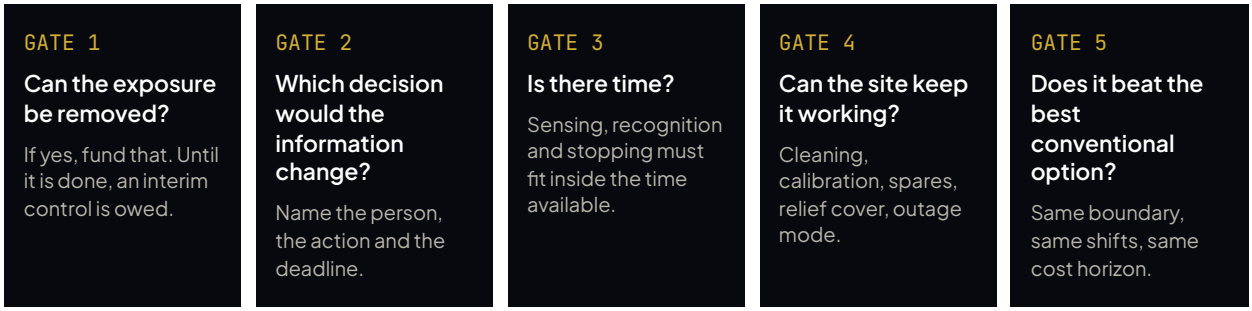
PART 2 · THE TECHNOLOGY CONTRIBUTION TEST

Five gates before any money moves

RECOMMENDATION A proposed method. Put each proposal through the gates in order. A "no" at any gate ends the technology case. Gate 1 carries a clock, so the test cannot become a reason to do nothing.

EXHIBIT 5

The technology contribution test



Riskopilot proposal. Gate 1 applies the hierarchy of controls. Gate 3 follows regulator guidance that alarm settings must leave time to respond. [11, 20]

GATE	EVIDENCE THE SPONSOR MUST BRING	FAILS WHEN
1. Remove	The least-cost credible redesign, priced on the same boundary, with a removal date set by the executive committee. Until that date an interim engineered control is owed.	No physical alternative has been priced, or the redesign has no date and no interim control.
2. Decide	One recipient, one expected action, one escalation route for each alert. The same on nights, at weekends and for contractors.	The output is a digest for managers. It may support learning. It is not a warning.
3. Time	A measured or bounded time budget from sensing to safe state, with its uncertainty (page 14).	The margin is negative, or smaller than the uncertainty.
4. Sustain	Named owner for cleaning, calibration and revalidation. Spares and service within reach. A defined mode for loss of power or network.	Nobody on site can restore it, or the crew cannot tell a stale value from a live one.
5. Compare	The same exposure handled by the best conventional arrangement, over the same shifts, with correct decisions before the deadline counted for both.	The technology matches the conventional option at higher cost, or adds burden without changing decisions.

When to stop investing. If the hazard is hidden from the sensor, if the time left is negative, if the reference cannot tell a true event from a false one, or if the crew lacks authority to act, do not scale the monitoring claim. Redirect the money to separation, redesign or verified equipment selection.

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PART 2 · GATE 3

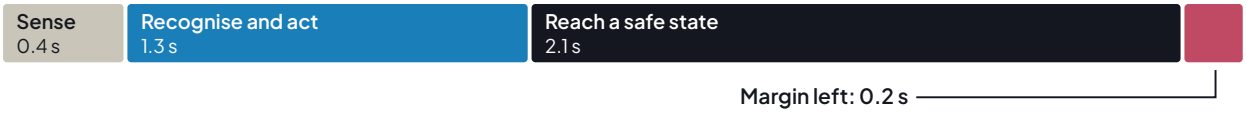
A warning has a deadline

Start at the last moment the machine can still reach a safe state. Work backwards through stopping, actuation, the operator's recognition, alarm delivery and sensing. What is left is the margin.

EXHIBIT 6

An illustrative time budget for a reversing vehicle

Time available before harm: 4.0 seconds (invented for illustration)



Margin left: 0.2 s

If the combined timing uncertainty is larger than 0.2 s, this evidence cannot support acceptance.
"Sense" covers sensing and alarm delivery. A brochure's processing latency is only part of it.

ILLUSTRATION Every value is invented to show the method. None is a design threshold. The site's technical authority sets real values and the margin it requires.

How to measure it

RECOMMENDATION Use the swept path of the manoeuvre for a turning or articulated machine. Straight-line distance can hide exposure.

Synchronise clocks before the test and check them again afterwards. Where you can, measure total elapsed time directly instead of adding components. Record whether component measurements overlap.

What the regulator says

FACT UK Health and Safety Executive guidance on alarm management says alarm settings should leave the operator enough time to complete the response before conditions worsen. It cites a refinery incident in which staff faced a barrage of alarms for five hours beforehand.[11]

What to record for the committee

Configuration tested. Approach and target. Time available. Measured total and its uncertainty. Margin the site requires. The competent engineering decision, with a name and a date.

A system that stops the machine is a different control

INFERENCE Remove the operator's 1.3 seconds and the margin changes completely. That is what an intervening system does, which makes it an engineering control and not a warning. FACT South African mining regulations require certain machines to brake automatically if the operator does not act, in force since 21 December 2022.[30] A 2015 US rule requires the same of continuous mining machines.[31] NIOSH researchers judged such systems could have prevented 82% of 39 past fatalities, and documented electronic interference with them.[32] INFERENCE We found no independent evaluation of outcomes since.

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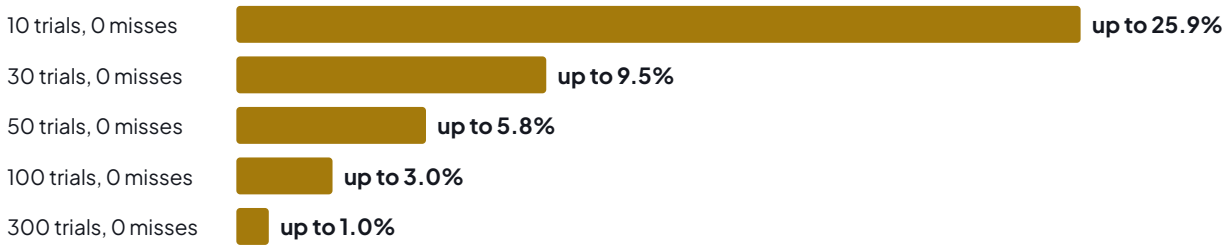
PART 2 · READING PILOT RESULTS

What a clean pilot does and does not show

Thirty staged trials with no misses feels like proof. Statistically it still allows a miss rate of nearly one in ten.

EXHIBIT 7

After a run with zero misses, how high could the true miss rate still be?



One-sided exact 95% upper limit on the true miss probability: 1 – 0.05^(1/n). Assumes independent, representative trials.

FACT Standard exact binomial result, recalculated for this report. INFERENCE Repeating the same target in the same position on the same day gives far less assurance than the formula assumes.

Count encounters, not frames

RECOMMENDATION Define an eligible encounter before testing. A person visible in 60 consecutive video frames is one encounter. Counting frames inflates the sample and hides uncertainty.

A warning that arrives too late is a failure of timely detection, even when the target was identified correctly. Report late warnings separately from complete misses.

ILLUSTRATION Worked example: 48 timely warnings in 50 staged encounters is 96% timely detection, with two late and none undetected. Four nuisance warnings in eight observed equipment hours is 0.5 per hour. Neither number measures injuries prevented.

Look where the alarm did not sound

RECOMMENDATION An observer who reviews only alarm clips cannot find missed events. Pair random observation of quiet periods with staged tests in a closed area. Have disagreements settled by someone with no stake in the pilot passing.

The asymmetry that matters

RECOMMENDATION One observed critical miss can justify suspending a pilot. The reverse does not hold. No observed miss says nothing about conditions outside the tested envelope, especially night work and rare configurations. Say where the data are sparse.

This report proposes no universal sample size or acceptable failure probability. The technical authority sets both for the site.

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PART 2 · ATTRIBUTION

What a pilot can honestly claim

If the layout, the training and the technology all change in the same month, any improvement belongs to the package. A committee that credits the camera has made an inference the data cannot support.

EXHIBIT 8

Fewer conflicts can mean a less safe operation



Invented numbers. The count halved while the rate doubled.

ILLUSTRATION Illustrative comparison. A pilot phase with fewer deliveries will show fewer conflicts whatever the technology does.

Design the comparison first

RECOMMENDATION Separate the dates of physical redesign, training and digital introduction. Use comparable zones or time windows where the schedule allows. Stagger an advisory addition across similar areas and document any spillover between them.

Never withhold an established control to create a comparison group. Keep every prior barrier in place throughout.

Before the pilot starts, write down which findings would support redesign, a targeted extension or withdrawal.

Report rates with their context

RECOMMENDATION Alongside each rate, report the shift mix, how complete observation was and how a conflict was defined. An apparent deterioration may be a better count.

Never reward a falling alert count on its own

RECOMMENDATION Fewer alerts can mean less exposure. It can also mean a narrower detection zone, a fouled lens, less reporting or a device someone switched off. Check which before anyone is congratulated. Keep unknown denominators visible on the report.

Independent observation matters most where people are judged on the result. Select some observation periods before anyone has seen a dashboard. Check whether a run of identical green records comes from copy-forward entries.

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PART 2 · THE HUMAN SIDE

An alarm people can act on, with data they can live with

Two conditions decide whether a technically sound system survives contact with a workforce: operators can use what it tells them, and they accept how it watches them.

Design the alert around one person

FACT The UK regulator's guidance is that each alarm should serve a clear purpose for the operator and carry a defined response. It refers designers to EEMUA Publication 191. [11]

RECOMMENDATION For every alert, write down one recipient, one expected action, the time available and the route if nobody acknowledges it.

Review alarms with the operators who hear them. Ask which signals coincide with reversing beepers, radios or hearing protection. Test whether the person can tell a device fault from a real intrusion. Include contractors on unfamiliar equipment.

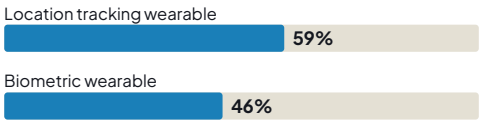
Acknowledge, correct and clear are three events. Capture each time if the system allows. An acknowledged alarm with exposure still present stays open.

If the team cannot maintain a warning function, withdraw it from credited use. Decisions then rest on the remaining verified physical controls.

Agree the data rules before collecting anything

EXHIBIT 9

Many workers would decline a wearable if given the choice



Would not agree to use the device voluntarily. US field labour, one sample.

FACT Source: H. Fugate and H. Alzraiee, Results in Engineering 17 (2023), 100841. Single source. The sample size was not visible to us. The figures justify testing acceptance locally. They do not predict adoption on your site. [4]

FACT EU-OSHA's 2024 principles call for involving workers from the start, collecting only data relevant to safety and health, and stating the system's purpose clearly. [12]

RECOMMENDATION Test the governance with a real request: a manager asks for a list ranking employees by camera alerts. Who can refuse, record the request and explain the approved purpose?

Worker sign-off records participation. It does not settle the legal basis, consultation duties or cross-border transfer. Get advice for each jurisdiction.

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PART 2 · GATE 5

Compare on the same boundary, over the whole life

The fair comparison is between three options for the same exposure: the best physical redesign, the residual-risk pilot, and both together.

What belongs in the cost

RECOMMENDATION Fix the evaluation period, currency and asset count. Get supplier quotes for your region, your support level and your configuration. Public price lists and product pages do not establish a delivered site price.

COST LINE	OFTEN MISSED
Installation	Lost availability while equipment is fitted
Training	Every shift, every contractor, every new starter
Upkeep	Cleaning, calibration, consumables, test gas
Connectivity	Subscriptions, gateways, local alarm fallback
Response labour	Investigating nuisance alarms, escalations
Change	Revalidation after software, layout or fleet changes
Exit	Decommissioning and data retention

Measures that help a committee decide

RECOMMENDATION Two measures make options comparable without pretending to value a life:

- **Cost per removed exposure point**, for redesign options.
- **Cost per verified protected operating hour**, for monitoring options.

Show uncertainty as alternative quotes and deployment scenarios. Separate the one-time pilot expense from the recurring fleet cost.

Assign no monetary benefit to avoided fatalities without a defensible model and independent review.

The order of decisions

RECOMMENDATION An option that fails a mandatory control condition is ineligible, however cheap. Among the options that pass, compare operational value, workforce burden, evidence quality, support and total cost of ownership.

> **Sites with limited connectivity.** Choose the baseline physical control first. Cost the offline workflow and local competence before specifying cloud monitoring. Local alarms, physical boundaries and named decision-makers must hold for a full shift with no link to head office.

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PART 3

Eight fatal event families

For each: the state that protects people, how to verify it at the workface, what technology can add and what it cannot settle.

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PART 3 · EVENT FAMILIES

RECOMMENDATION The entries on these pages are Riskopilot recommendations for site design and assurance, informed by the regulator guidance cited. Local law and the site's approved procedures govern. Assign a named person and a qualified relief to each owner role before the task.

EVENT 01 · OWNER: ROOFING SUPERVISOR

Falls through openings and fragile surfaces

PROTECTED STATE	**Collective protection at every exposed edge and opening on the authorised route.**
REMOVE FIRST	Ground-level assembly or remote inspection that removes the roof visit.
VERIFY AT THE WORKFACE	Walk the route before handover and after any delivery or change to the deck. Match covers to the approved design.
TECHNOLOGY CAN ADD	Plan overlays and image review can flag a visible gap.
IT CANNOT SETTLE	A camera cannot establish a cover's load capacity or fixing. A photograph taken before materials arrived says nothing about now.
MEASURE	Edges checked after a configuration change, out of edges affected. [13]

EVENT 02 · OWNER: TRAFFIC MANAGER

Mobile plant striking pedestrians

PROTECTED STATE	**Maintained separation and controlled crossings for the whole movement, including visiting drivers.**
REMOVE FIRST	One-way routes, timed delivery windows and layouts that minimise reversing.
VERIFY AT THE WORKFACE	Walk the route from the cab and from the pedestrian approach, with equipment stationary and secured. Recheck on every changed layout.
TECHNOLOGY CAN ADD	Radar, cameras and tags can add a cue at residual conflict points.
IT CANNOT SETTLE	Tags do not cover visitors without tags. Cameras do not see through a parked vehicle. Evidence from a mine haul truck does not authorise a hired excavator.
MEASURE	Observed conflicting movements, out of comparable vehicle movements, by gate and shift. [1, 14]

Choosing the critical few. Start with the event and work backwards. Identify the control whose absence materially raises the likelihood or consequence. Define the observable state it must hold and who can establish it. A gate, a pre-shift check, a camera and a dashboard that share one power supply are not four barriers. Count common-cause loss explicitly, as CCHI does. [20]

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PART 3 · EVENT FAMILIES

EVENT 03 · OWNER: APPOINTED LIFTING LEAD

Suspended loads and dropped objects

PROTECTED STATE	**An approved lift plan and a controlled load path, with effective exclusion and agreed communications.**
REMOVE FIRST	Assembly at ground level, or a load path moved away from occupied areas.
VERIFY AT THE WORKFACE	Check actual load, configuration, ground and exclusion boundary against the plan. Confirm communication with the person directing the lift.
TECHNOLOGY CAN ADD	A schedule-linked model can expose overlapping activities before mobilisation. A geofence can flag intrusion.
IT CANNOT SETTLE	Neither establishes ground bearing capacity or rigging suitability. A permit can cover the lift and miss workers arriving from another contractor.
MEASURE	Lifts with a field-confirmed clear load path, out of lifts observed. [16]

EVENT 04 · OWNER: TEMPORARY WORKS COORDINATOR

Excavation and temporary works collapse

PROTECTED STATE	**An approved design, a checked configuration and release by the designated competent person.**
REMOVE FIRST	Design for actual loading, staging, adjacent structures and ground conditions.
VERIFY AT THE WORKFACE	Match the installation and sequence to the approved revision. Escalate movement, water, damage or unplanned loading. Reinspect after relevant change.
TECHNOLOGY CAN ADD	Survey points and movement sensors can track a precursor.
IT CANNOT SETTLE	Monitoring helps only if movement comes first, with enough lead time and someone able to interpret it. A stable reading from a badly placed sensor is weak evidence.
MEASURE	Changed conditions followed by competent reassessment before entry, out of changes observed. [15, 17]

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PART 3 · EVENT FAMILIES

EVENT 05 · OWNER: ELECTRICAL AUTHORITY

Electrical contact or energisation

PROTECTED STATE	**The correct circuit and every relevant source identified, isolated and verified under an approved procedure.**
REMOVE FIRST	De-energised work as the plan, with temporary supplies and other trades' changes mapped.
VERIFY AT THE WORKFACE	The authorised electrical team reconciles the physical asset with the current diagram and verifies its state at the point of work.
TECHNOLOGY CAN ADD	Digital drawings, labels and revision control support identification.
IT CANNOT SETTLE	A scan confirms a database lookup. It cannot prove the electrical state of a conductor. A replacement panel can inherit the old label.
MEASURE	Sampled jobs with correct field identification and witnessed verification, out of applicable jobs sampled. [18]

EVENT 06 · OWNER: MAINTENANCE SUPERINTENDENT

Crushing and entanglement during maintenance

PROTECTED STATE	**Physical restraint or isolation of every hazardous energy source, verified for the task and held through shift change.**
REMOVE FIRST	Access designed so the task is done without entering the danger zone.
VERIFY AT THE WORKFACE	Trace sources at the equipment. Verify the safe state. Confirm custody and coordinate contractors before the work boundary changes.
TECHNOLOGY CAN ADD	A digital procedure manager can reduce ambiguity about assets and isolation points.
IT CANNOT SETTLE	A record that a document was opened gives no physical assurance. Test version conflicts, shared accounts and offline permits before relying on it.
MEASURE	Independent observations that found a discrepancy before exposure, out of opportunities. [19]

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PART 3 · EVENT FAMILIES

EVENT 07 · OWNER: ENTRY SUPERVISOR

Confined-space atmospheric exposure

PROTECTED STATE	**Approved entry conditions: verified isolation, suitable atmospheric testing, communication, an attendant and workable rescue.**
REMOVE FIRST	External inspection or cleaning that avoids entry.
VERIFY AT THE WORKFACE	Identify the actual contaminants and check the sensor suits them. Verify devices, locations and communication. Demonstrate the rescue arrangement before entry.
TECHNOLOGY CAN ADD	Connected detectors can share an alarm with the attendant. Remote inspection can remove some entries.
IT CANNOT SETTLE	A remote dashboard can show normal readings from a device that is not where the entrant will be. Connectivity can inform managers while the entrant still has no warning.
MEASURE	Entries with every prerequisite verified at the point of entry, out of entries sampled. [7, 21]

EVENT 08 · OWNER: AREA OPERATIONS MANAGER

Fire, explosion and acute hazardous release

PROTECTED STATE	**Verified isolation, atmosphere assessment and simultaneous-operations controls matched to the possible release and ignition sources.**
REMOVE FIRST	A cold method in place of hot work.
VERIFY AT THE WORKFACE	Reconcile the work boundary with process drawings and field conditions. Agree what changes cancel the permit.
TECHNOLOGY CAN ADD	A permit platform can reveal simultaneous jobs on connected assets.
IT CANNOT SETTLE	A digital record cannot determine the atmosphere inside connected equipment or prove an isolation still holds. Detection helps only for substances and places it can see.
MEASURE	Relevant changes that triggered permit reassessment, out of relevant changes observed. [8]

When the control fails. In every family the first move is the same: stop the affected work, make the area safe, and have a competent person reassess before anyone returns. Technology changes how fast the failure is seen. It does not change who must decide.

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PART 4

Six investigations

What official inquiries established, the earliest decision worth re-examining, and what a hypothetical device could not have settled.

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PART 4 · INVESTIGATIONS

CALIFORNIA, 18 MAY 2000 · CALIFORNIA FACE REPORT 00CA006

A flagger struck by a reversing truck

FACT
ESTABLISHED

A construction flag person on a freeway project was fatally backed over by a tractor-trailer side dump truck. The truck's back-up alarm was working. It moved only a few feet in reverse. The flagger had his back to the truck and was watching traffic. [5]

INFERENCE
WHAT FAILED

The lane closure separated the work zone from live traffic. Nothing separated a person on foot from a reversing vehicle inside the closure. An audible warning was present and did not protect him.

RECOMMENDATION
DECISION TO EXAMINE

At planning: trace every reversing route and every pedestrian post inside the closure. During the job: stop when a route or a person's position cannot be accounted for.

INFERENCE
TECHNOLOGY COULD NOT SETTLE

A camera or radar might have given the driver another cue. The record cannot establish detection, reaction or stopping distance for a device that was not there.

MIAMI, 15 MARCH 2018 · NTSB REPORT HAR-19/02, ADOPTED 22 OCTOBER 2019

Florida International University pedestrian bridge

FACT
ESTABLISHED

Six people died and ten were injured when a partly built bridge fell onto an open road. The NTSB found the probable cause was load and capacity calculation errors in the design. An inadequate peer review contributed. Cracking was observed and discussed before the collapse. The NTSB found that the failure of five parties to stop work and close the road added to the severity. [6]

INFERENCE
WHAT FAILED

Several parties already held evidence of cracking. The missing element was a decision: who judges that the structure is no longer safe to stand under, and who can order the road closed.

RECOMMENDATION
DECISION TO EXAMINE

At design: secure competent independent review. During construction: name one authority for public exclusion, and a deputy who holds that authority outside office hours.

INFERENCE
TECHNOLOGY COULD NOT SETTLE

Automated crack tracking could have documented progression. Nothing in the investigation suggests more images would have produced a closure that people with the evidence in hand did not order.

A site exercise from the bridge case. RECOMMENDATION Rehearse an after-hours disagreement between contractor and designer about visible distress. Record the time the area is actually secured, and who can authorise reopening.

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PART 4 · INVESTIGATIONS

TEXAS, 15 NOVEMBER 2014 · US CHEMICAL SAFETY BOARD, FINAL REPORT 25 JUNE 2019

DuPont La Porte toxic release

FACT
ESTABLISHED

About 24,000 pounds of methyl mercaptan escaped inside a manufacturing building and four workers died. Two of them had entered the building in response to a colleague's distress call. The CSB cited flawed engineering design and a lack of adequate safeguards. [7]

INFERENCE
WHAT FAILED

A worker facing an abnormal process condition and colleagues responding to distress face different hazards. The rescue decision has to be workable before the emergency, not invented during it.

RECOMMENDATION
DECISION TO EXAMINE

Trace the possible release path and the tasks people do nearby. Verify how an alarm reaches entrants, adjacent workers and responders, and who accounts for each person.

INFERENCE
TECHNOLOGY COULD NOT SETTLE

Connected detectors could spread a warning, if the substance is detectable at the right place. That does not establish who could have escaped, or that a rescuer would have held back.

LOUISIANA, 8 FEBRUARY 2017 · US CHEMICAL SAFETY BOARD REPORT 2017-03-I-LA, 24 APRIL 2018

DeRidder hot work explosion

FACT
ESTABLISHED

Three contractors died and seven were injured when a tank exploded during hot work at a pulp and paper mill's annual shutdown. Workers had tested for a flammable atmosphere outside the tank before starting. The flammable atmosphere was inside it. [8]

INFERENCE
WHAT FAILED

The test was done and passed. It measured the wrong place. The location of the work was treated as the boundary of the hazard, when connected equipment held the fuel.

RECOMMENDATION
DECISION TO EXAMINE

At planning: the process owner and the contractor identify connected spaces, process changes and the evidence needed to authorise the work.

INFERENCE
TECHNOLOGY COULD NOT SETTLE

Linking permits to process assets could have flagged the tank. A digital record cannot determine the atmosphere inside it.

What these four cases have in common

INFERENCE A reversing alarm that worked. Cracks that were documented. A gas test taken in the wrong place. A distress call that drew colleagues into danger. Each case turns on a boundary drawn wrongly or a decision nobody was placed to make.

RECOMMENDATION Use investigations to design exercises, not to justify purchases. They cannot prove a device would have prevented the event.

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PART 4 · INVESTIGATIONS

TEXAS, 23 MARCH 2005 · US CHEMICAL SAFETY BOARD REPORT 2005-04-I-TX, 20 MARCH 2007

BP Texas City refinery explosion

FACT
ESTABLISHED

Fifteen people died and 180 were injured when hydrocarbon vapour exploded during the start-up of a process unit. The CSB found that fixed spending had been cut by 25% from 1999 and that a further 25% was sought in 2004. Board operators for the unit had gone from two to one. A 2003 review recommended a second operator for start-ups and was not acted on. Operators had worked 12-hour shifts for at least 29 days in a row. Audits from 2002 onward reported serious problems to executives and at least one board member. [23]

INFERENCE
WHAT FAILED

The people on shift that day worked inside conditions set years earlier and far from the unit. Each of those conditions was a leadership decision.

RECOMMENDATION
DECISION TO EXAMINE

Before a budget or headcount change is approved: which critical duty goes uncovered, on which shift, and who has signed for that?

INFERENCE
TECHNOLOGY COULD NOT SETTLE

Instruments were already there and failing. One high-level alarm worked and a second did not. The CSB found work orders could be closed without the repair being done. A new sensor would have joined the same queue.

GULF OF MEXICO, 20 APRIL 2010 · NATIONAL COMMISSION REPORT TO THE PRESIDENT, JANUARY 2011

Macondo well blowout

FACT
ESTABLISHED

Eleven men died when the well blew out. The Commission found that the negative-pressure test, the check on whether the well was sealed, was run and interpreted improperly, and that this was a major contributing factor. Neither the operator nor the rig owner had an internal procedure for the test or formal training in it. Nothing required the crew to seek a second opinion from shore on confusing data. The Commission named a failure of management by the three main companies as the root cause. [24]

INFERENCE
WHAT FAILED

A critical verification existed, was performed and returned a warning. The people reading it had no procedure, no training and no obligation to escalate.

RECOMMENDATION
DECISION TO EXAMINE

For each critical verification: who is competent to interpret it, which result forces a stop, and who must be called when the reading is unclear?

INFERENCE
TECHNOLOGY COULD NOT SETTLE

The pressure data were already in front of the crew. More data would not have supplied the rule for reading them.

Why these two are here. FACT Both inquiries placed the cause in management decisions: organisational and safety deficiencies at all levels of the company in one, a failure of management in the other. [23, 24] INFERENCE They show what the first four cases only hint at. The conditions at the workface are made elsewhere. Part 6 takes up that argument.

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PART 5

Eight technology functions

Assessed as functions, not brands. For each: where it fits, how to test it, how it fails and what to ask a supplier.

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PART 5 · TECHNOLOGY FUNCTIONS

What to test, and what to ask

RECOMMENDATION Riskopilot proposals. Never create a real person-vehicle conflict or a hazardous atmosphere to validate a system. Use surrogates, closed areas, training copies and approved fixtures.

FUNCTION	WHERE IT FITS	ACCEPTANCE TEST	HOW IT FAILS	ASK THE SUPPLIER FOR
Visual pedestrian detection around vehicles	Residual conflict points after segregation.	Surrogate target at the edge of the configured zone, in glare, at dusk and partly hidden. Compare with a marked ground reference. Log missed and late warnings separately.	Lens fouling, camera movement, processing delay, alerts competing with other cab sounds.	Exact software version, confidence settings, offline behaviour, mounting validation, right to export time-stamped alerts.
Proximity radar and equipment telemetry	Blind areas on large plant, paired with a camera view.	Compare detections with independent observation, including irrelevant fixed objects. Report by manoeuvre.	Clutter, installation geometry, warning overload. A valid detection of an irrelevant object still distracts.	Raw event export, filtering logic, maintenance diagnostics, a documented commissioning test.
Vehicle intervention (automatic slow or stop)	An engineering control, not a warning. Only with manufacturer and competent engineering acceptance for the specific machine.	Review failure states and stopping envelope with no people in the test area.	Unexpected braking, mismatch with machine configuration, effect on following traffic.	Machine compatibility, documented operating envelope, change control, evidence for each safety function claimed.
Connected portable gas detection	Entries and areas where the actual gas is detectable by the fitted sensor.	Confirm local alarm and remote notification separately. Demonstrate behaviour when the link drops, without exposing anyone.	Wrong sensor for the gas, unreachable sampling point, flat battery, remote data delay.	Sensor configuration, certification for the intended area, consumables, calibration and maintenance records.

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PART 5 · TECHNOLOGY FUNCTIONS

FUNCTION	WHERE IT FITS	ACCEPTANCE TEST	HOW IT FAILS	ASK THE SUPPLIER FOR
Digital isolation and procedure management	Sites with many assets and changing contractors.	Seed a wrong revision in a training copy. Check an authorised person can find, quarantine and replace it, including printed copies.	Obsolete diagrams, unowned revisions, ambiguous equipment identity, offline discrepancies.	Approval workflow, revision history, permissions, offline behaviour, contractor access with temporary credentials.
Schedule-linked site models	Planning meetings, to find when a lift, a route or a delivery conflicts with another task.	Move a delivery and a lift into the same window in a test copy. See whether the planner spots it and assigns a field check.	Missing temporary elements, outdated programme, contractor changes not entered.	A demonstration on your file formats and calendar. Who updates temporary conditions between revisions.
Remote internal inspection (drones, crawlers)	Removing human entry, where image quality meets the maintenance decision.	Trial against known targets in a safe training space. Establish image sufficiency, lost-link behaviour and retrieval.	Poor light, dust, hidden geometry, a lost vehicle that someone must retrieve. Atmosphere compatibility is a hard screening question.	Which defects the payload can resolve, which environmental approvals cover the exact configuration.
AI review of permits and inspections	Triage of completed records, pointing a reviewer to the passage behind each flag.	An adjudicated sample with real omissions, correct records and ambiguous wording. Reviewers blind to the tool for the comparison.	Unsupported text, a convincing explanation about the wrong asset, silent changes in model behaviour, data leakage.	Version identification, data handling terms, export of source references, an off switch. Repeat acceptance after material change.

The eighth row is different

INFERENCE An AI reviewer does not sense the physical world. It reads records. Its failure mode is a fluent, confident summary that refers to the wrong asset, revision or condition.

FACT The US National Institute of Standards and Technology's AI Risk Management Framework organises this work under four functions: govern, map, measure and manage.[22]

RECOMMENDATION Restrict the role to triage. Keep verification and release with designated people.

Three rules for every row

RECOMMENDATION **Evaluate the machine and the operator together.** A clear picture on a monitor does not show that detection covers the working envelope, or that the driver will look.

Retest after change. Service, a software update or a new layout can each invalidate acceptance.

Separate advice from authority. A display or an AI dashboard carries no automatic authority to alter a protective circuit, change a permit or release machinery.

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PART 6

What leaders must create

Technology can buy time. Only leaders can make sure someone is placed, competent and authorised to use it. What research and six investigations show about the conditions that make protection possible.

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PART 6 · THE RESEARCH

What leadership research can and cannot show

Leaders are told that visible commitment prevents accidents. The research supports something narrower and more useful: what leaders say every day, and whether they fix what they hear.

EXHIBIT 10

Three studies, three strengths of evidence

STUDY	DESIGN AND SETTING	WHAT IT FOUND	LIMIT
Zohar and Polachek, 2014 [26]	Randomised field study. One heavy manufacturing plant, 364 workers.	Supervisors received two feedback sessions over 12 weeks on how they combined safety and production in daily talk with their crews. Safety climate, safety behaviour and independently measured audit scores improved against the control groups.	One plant. Outcomes are behaviour and audit scores, not serious injuries.
Tucker and Singer, 2015 [27]	Randomised field study. Hospitals, 56 work areas against 138 controls, 18 months.	A senior-manager walk-round programme lowered staff perception that performance was improving. Results were better where senior managers took responsibility for resolving the problems raised.	Hospitals, not heavy industry. The outcome is staff perception.
Clarke, 2013 [25]	Meta-analysis of published studies.	Leaders who actively monitor and correct are associated with rule compliance. Leaders who inspire and involve are associated with workers taking part in safety.	Associations from surveys. Cause and direction are not established.

FACT Findings as reported by the authors. The two randomised studies are the strongest designs we found on leadership practice.

What this supports

INFERENCE Two things a leader does have experimental backing. Talking about safety and production together, in ordinary daily exchanges, changes what crews do. Asking people for problems and then not resolving them makes things worse than not asking.

INFERENCE Both findings point the same way as the six investigations. What protects people is a leader's response, not a leader's presence.

What it does not support

INFERENCE No study here measured fatal or serious injuries. On the ladder on page 10, leadership research reaches level 2 at best: people acted differently. Nobody has shown the step to fewer deaths.

RECOMMENDATION So treat leadership programmes as you would a monitoring system. Name the decision they should change. Test whether it changed. Do not accept attendance figures or visit counts as proof.

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PART 6 · THE PATTERN

Six investigations, one pattern

Read side by side, the six cases in Part 4 show the same thing. Information was available. The protective decision belonged to nobody who could make it.

EXHIBIT 11

What was available, and the decision nobody was placed to make

CASE	FACT WHAT WAS AVAILABLE	INFERENCE THE DECISION THAT WAS MISSING	INFERENCE CONDITION ABSENT
Flagger, 2000[5]	A working back-up alarm.	Keep people on foot out of the reversing path inside the closure.	1. Authority
Florida bridge, 2018[6]	Documented cracking, discussed by the parties on the day.	Stop work and close the road. Five parties could have. None did.	1. Authority 6. Verification
La Porte, 2014[7]	A distress call. Known process problems, with improvements postponed.	Fund the fix earlier. Hold responders back from the building.	3. No penalty 5. Resources
DeRidder, 2017[8]	A gas test, taken outside the tank.	Decide who was in charge of the tank and its contents. Staff were confused about that.	1. Authority 6. Verification
Texas City, 2005[23]	One working alarm. Audits since 2002 that reached executives.	Keep a second operator for start-ups. Act on the audits.	2. Cover 4. Bad news 5. Resources
Macondo, 2010[24]	A pressure test that showed the well was not sealed.	Call for a second opinion on a confusing reading.	2. Cover 4. Bad news

Facts from the official reports cited. The second and third columns are Riskopilot's reading. Six inquiries chosen by us are not a sample: they show how conditions fail, not how often.

Three lessons

1. The signal is rarely what is missing. INFERENCE In five of the six cases an alarm sounded, damage was visible or a test was carried out.

2. Authority shared by everyone is held by no one. INFERENCE Five parties at the Florida bridge could each look at the other four. It has to sit with one name, assigned in advance.

3. Decisions made far from the workface set the conditions at it. FACT At Texas City, budget cuts ordered at group level preceded the loss of the second board operator.[23] INFERENCE The operator on shift inherited that decision.

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PART 6 · THE OPERATING ENVIRONMENT

Six conditions that make protection possible

An intervention at the workface needs an environment that allows it. These are the six conditions the evidence points to. Leaders create each one, and no one else can.

EXHIBIT 12

The operating environment, condition by condition (1 to 3)

CONDITION	FACT WHAT THE EVIDENCE SHOWS	RECOMMENDATION EXECUTIVE TEST
1 **Authority held by one named person** For each fatal risk, one named person and one named deputy can stop the work and restrict the area, at any hour, across every contractor.	At the Florida bridge the NTSB found that five parties failed to stop work and close the road. Authority shared by five was held by none. [6] At DeRidder the CSB found confusion among mill staff about who was in charge of the tank. [8]	Pick one fatal risk. Who can stop it and restrict the area at 02:00 on a Sunday? Ask for a name and a deputy, then phone them.
2 **Competent cover on the hardest shift** Someone qualified to interpret the control and act is present and not committed elsewhere, including nights, start-ups and shutdowns.	At Texas City the unit's board operators had been cut from two to one, a recommended second operator for start-ups was never added, and operators had worked at least 29 consecutive 12-hour shifts. [23] At Macondo there was no procedure or formal training for the critical test. [24]	Before approving a staffing, roster or monitoring change, require the sponsor to state which duty goes uncovered and on which shift.
3 **No penalty for stopping or reporting** The person or contractor who stops a task or reports a failed control does not lose pay, bonus or the next contract for it.	At La Porte the CSB found the bonus structure may have discouraged workers from reporting injuries, incidents and near misses. [7] A 2004 survey at Texas City found employees believed production and budget compliance were rewarded above all else. [23]	Trace one recent stop through the invoices and the payslips. Who absorbed the cost? Read the bonus rules for what they reward.

How to use these pages. RECOMMENDATION Take the failed control you reconstruct in the first 15 days of the plan on page 40. Put it through all six tests. The condition that fails is where the next budget decision belongs.

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PART 6 · THE OPERATING ENVIRONMENT

EXHIBIT 12, CONTINUED

The operating environment, condition by condition (4 to 6)

CONDITION	FACT WHAT THE EVIDENCE SHOWS	RECOMMENDATION EXECUTIVE TEST
4 **Bad news travels, and gets an answer** Evidence that a critical control is failing reaches people with the power to act, and they respond in a way the reporter can see.	Texas City audits from 2002 reached executives and at least one board member. The CSB judged the response too little and too late, and found executives relied too heavily on injury statistics. [23] At Macondo nothing required a second opinion on confusing data. [24]	Ask what the executive committee last heard about a failed or impaired critical control, and what was done. If the answer is an injury rate, the channel is not working.
5 **Money and authority to restore** A failed critical control can be repaired or replaced without waiting for the next budget cycle, and repair records mean the repair was done.	At Texas City cost concerns discouraged replacing the blowdown drum with a flare system, and the maintenance system let work orders close without the repair. [23] At La Porte process improvements that could have prevented the release were postponed. [7]	Who can spend today to restore an impaired critical control, and up to what amount? Sample five closed work orders on critical controls and check the equipment.
6 **Verification independent of the job** The check that a control is in place is made by someone who does not carry the production target for that task, at the right place.	The Florida bridge peer review failed to detect the design errors. [6] At DeRidder the atmosphere was tested outside the tank and not inside it. [8] At Texas City supervisors signed off equipment checks that had not been done. [23]	Have a sample of verifications repeated by someone outside the production line. Count the false passes. CCHI tracks this as verification integrity. [20]

Why six, and not culture

INFERENCE "Safety culture" is where most leadership advice ends. It is hard to inspect and easy to claim. Each condition here can be tested on one case in an afternoon, and each has an owner with a budget.

How firm is the list

INFERENCE The six are our synthesis from six inquiries and three studies. Each is anchored in at least two official findings. The grouping is a proposal. A different set of cases could add a seventh.

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PART 6 · AUTHORITY

The leader's role: making authority real

The law lets a worker walk away from serious danger. It gives nobody the power to close the road. Leaders assign that power to one name, or nobody holds it.

What the law already provides

FACT The ILO Occupational Safety and Health Convention protects a worker who leaves a situation they reasonably believe presents imminent and serious danger. Until the employer has acted, they cannot be required to return. [28]

FACT The EU framework directive requires employers to let workers stop work and move to safety in serious, imminent and unavoidable danger, and to act themselves when the supervisor cannot be reached. [29]

What the law leaves to leaders

INFERENCE These are rights to remove oneself. The decisions that failed in Part 4 were over other people's work: close a road, hold a permit, call the shore. No statute names who makes those.

INFERENCE Stop-work authority asks the person with the least power to make the hardest call. Count each stop as a finding about an earlier decision.

RECOMMENDATION Three things make it real at 02:00.

- **One name, one deputy.** A role shared by several is held by none.
- **Rehearse it.** Remove the decision-maker in an exercise and time the stop.
- **Write it into contracts.** A stop in good faith is not charged to whoever made it.

EXHIBIT 13

An authority map for one fatal risk (template, complete with names)

DECISION	WHO HOLDS IT	OUT OF HOURS	EVIDENCE REQUIRED
Stop the task	Any worker or contractor	Not needed. The right is personal.	Their own account of what they saw
Restrict the area	Shift supervisor, by name	Named deputy on every shift	Physical boundary confirmed with the crew
Verify the control	Competent technical verifier, by name	Qualified relief, tested in an exercise	Field evidence for the right asset and scope
Release for restart	Designated operating authority	Named deputy with the same authority	Verification record, then a separate decision
Fund the restoration	Budget holder with an out-of-cycle limit	Duty manager with a stated amount	Proof on the next comparable job

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PART 6 · LEADERS THEMSELVES

What leaders do themselves

Six practices, each tied to a finding. None needs a programme. All of them need the leader's own time.

1. Ask the uncovered-duty question before every cut. FACT Texas City lost its second board operator after group-wide cost reductions, and a recommendation to restore one for start-ups was not acted on.[23] RECOMMENDATION Make "which critical duty goes uncovered?" a required line in every budget and headcount paper.

2. Fix what you hear, or do not ask. FACT In the one randomised trial of leadership visits we found, staff in visited areas came to rate improvement lower than staff in control areas. Results were better where senior managers took responsibility for resolution.[27] RECOMMENDATION Leave every site visit owning at least one problem, and report back to the person who raised it.

3. Put safety into the daily exchange. FACT When supervisors in a heavy manufacturing plant were given feedback on how they combined safety with production in everyday talk, crew behaviour and audit scores improved.[26] RECOMMENDATION Ask supervisors what they said to their crews about the job's fatal risk this morning, not what the poster says.

4. Stop reading injury rates as proof of control. FACT The CSB found Texas City executives relied too heavily on injury statistics while process safety declined.[23] RECOMMENDATION Ask for the state of critical controls. That is what CCHI measures.[20]

5. Check what you reward. FACT Two inquiries found pay or recognition working against reporting and safe operation.[7, 23] RECOMMENDATION Read the bonus scheme and the contractor terms as a worker would. Remove anything that pays for silence.

6. Verify one control yourself. RECOMMENDATION Each quarter, follow one critical control from the document to the workface with the person who relies on it. Hear their account before the supervisor's.

> **What this page does not claim.** No study shows these six practices reduce fatalities. Three rest on research into behaviour and perception, two on what inquiries found missing, one on our judgement. They are the best-supported use of a leader's hours that we can identify.

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PART 6 · AUTHORITY

Who can stop the work, and who can restart it

Once authority exists on paper, it has to work at the moment a control fails. Three records and two clocks keep it honest.

EXHIBIT 14

One warning, two clocks



Schematic. Lengths are not measurements. Restart is a third, separate decision by site operations.

RECOMMENDATION Riskopilot proposal. The next report in this series sets out the full method.

Stopping

RECOMMENDATION Give every worker and subcontractor a clear route to suspend an unsafe task and raise a concern. At induction, ask workers to explain the stop signal in their own language and show where to go if a supervisor disagrees.

The stop route must not depend on owning a smartphone.

A dispute over a signal stays open until a competent person has established the condition at the workface. Record the worker's account and tell them the outcome.

Restarting

RECOMMENDATION Three records, kept apart:

- **Repair complete** is a maintenance record.
- **Verified safe state** is field evidence from a competent person.
- **Restart** is a separate operating decision.

Record the names and times of technical verification and operational authorisation. Tell other crews before restarting shared plant.

Two clocks

INFERENCE Most sites track time to resume production. Few track the two clocks that matter for people: how long from the first warning until people were confirmed protected, and how long until the impaired control was verified as restored.

RECOMMENDATION Track both. Where a time is unknown, record it as unknown. A notification or an acknowledgement does not show that the crew was protected.

> **The CCHI stop-work protection charter** already commits leaders to protect anyone who stops a task at the gate.[20] Extend the same protection to stops during the work, and check whether the reporting worker or contractor later absorbed a cost.

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PART 6 · ASSURANCE RHYTHM

A routine for the shift, the week and the month

RECOMMENDATION A proposed rhythm. It pairs leading evidence that controls are in place with lagging evidence that they failed, as the UK regulator's guidance on process safety indicators recommends.[10]

WHEN	WHO	WHAT THEY DO	WHAT THEY LOOK FOR
Every shift	Supervisor and control owners	Identify the activities with fatal exposure. Ask each control owner for current evidence. Authorise within the local procedure.	Any failed control reported by any worker. A named person makes the area safe and records the action.
Every week	Project or site director	Sample verifications independently. Choose some observation periods before seeing any dashboard.	The story behind a green result. Runs of identical entries that suggest copy-forward.
Every month	Executives	Review exposure with failed or unknown controls, verified restoration time and recurrence after corrective action.	Whether the fix held on the next comparable job. Where it did not, reopen the budget or schedule decision.
Every quarter	Executive committee, then board	Take one apparently satisfactory job and one disputed restart. Hear the worker and the technical verifier separately.	Whether the constraint was competence, concurrent duties, authority, funding or layout. Fund that.

Design for the outage

RECOMMENDATION Map each signal from source to local warning, gateway, platform, person and audit record. Identify which functions survive loss of network and how the user knows a value is stale.

Distinguish three states on every display: measured safe, abnormal and unknown. If a required barrier cannot be verified, hold the affected work.

Sites with limited connectivity

RECOMMENDATION Allocate maintenance ownership before specifying hardware. Check spares, competent servicing, calibration gas and replacement lead times in the region.

Use pictograms and practical demonstration with teach-back. Confirm workers understand what an unknown status means for the job. Transfer pilot results to a second site only after a fresh walkdown, local legal review and worker consultation.

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ACTION PLAN

A 90-day plan for the executive committee

RECOMMENDATION Four stages and one leadership track, each with an owner, an output and a measure. Advance on evidence, not on the calendar.

STAGE	OWNER	ACTIONS	OUTPUT AND SUCCESS MEASURE
Days 1 to 15 Reconstruct	Site director, HSE lead	Pick the most recent failed or impaired critical control. Trace first warning, first effective protection, repair, verification and release. Interview the worker and the verifier separately.	A one-page trace with times, names and unknowns. **Measure:** the executive committee can state which of signal, competence or authority was missing.
Days 15 to 30 Map	Operations director, engineering	Map the work for the top fatal exposures. Identify where exposure can be eliminated. Capture workload, site geometry, contractor interfaces and an activity denominator.	A register of exposures with a priced physical alternative for each. **Measure:** every live technology proposal has a gate 1 answer.
Days 30 to 45 Screen	Capital committee chair	Run every proposal through the five gates. Convert gate 1 failures into redesign budgets. Select at most one pilot with one owner and one bounded setting.	A signed pilot charter: operating envelope, independent reference, expected protective action, acceptance criteria, withdrawal triggers. **Measure:** criteria signed before any test.
Days 45 to 90 Test and decide	Operations director, technical authority, worker representative	Run closed-area and shadow tests. Sample quiet periods. Keep all existing controls. Consult the workforce on data use.	A decision paper with denominators, misses, late warnings, nuisance rate, time in unknown state and full-life cost. **Measure:** a written decision to adopt for the tested use, redesign or withdraw.
Days 1 to 90 Leadership track	CEO, executive committee	Put the reconstructed case through the six conditions. Publish the authority map. Rehearse one out-of-hours stop. Review bonus and contract terms.	Six test results and a funded remedy. **Measure:** a named decision-maker and deputy for every fatal risk.

What the executive committee should receive on day 90

- The reconstructed trace, with the funded remedy.
- The six condition tests and the authority map.
- The exposures removed by redesign, counted.
- The pilot decision and the evidence behind it.

What it should refuse

- A count of devices installed.
- A falling alert count with no explanation.
- An injury-reduction claim from a single site.
- A pilot whose criteria were written after the results.

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LIMITS

What would change these recommendations

The advice in this report follows from the evidence available in November 2026. These are the findings that would move it.

IF THIS APPEARED	WE WOULD CHANGE
A controlled field study showing a specified warning function reduces exposure at comparable work volume, on similar equipment and conditions.	Move that function from “pilot only” to “adopt within the tested envelope”, and say so in an update.
Independent replication of a vendor’s detection and timing claims across several sites, with missed and late warnings reported.	Shorten the acceptance testing we recommend for that function on similar sites.
Evidence that a class of system degrades faster in dust, heat or low-connectivity conditions than suppliers state.	Tighten gate 4 and the revalidation interval for sites in those conditions.
A larger, multi-country study of worker acceptance with a reported sample and method.	Replace the single-source figures on page 17 and revise the consultation advice.
An investigation in which a monitoring system demonstrably prevented a fatal event, with the mechanism documented.	Add it to Part 4 as a positive case and draw out what made the response work.
Independent outcome data from sites where machine intervention is mandated.	Move vehicle intervention ahead of the pilot stage.
A controlled study in heavy industry linking a named leadership practice to verified control performance or serious-injury outcomes.	Rank the six practices in Part 6 by evidence, and say which to do first.

Transfer limits

INFERENCE Mining offers field experience with proximity sensing. Process industries contribute permit and indicator disciplines. Construction changes the geometry of exposure hour by hour. Transfer the control logic. Verify every assumption about the work environment.

A detector installed for a fixed layout can have a shorter validity period than its service interval. A delivery by a new subcontractor can create a route that did not exist an hour earlier.

Legal scope

FACT Rules differ by jurisdiction and by sector. As one example, the US general-industry standard on hazardous energy excludes construction from its scope.[19]

RECOMMENDATION Establish the governing law and the installation boundary before adapting any workflow in this report. Nothing here is legal advice or a substitute for the site’s approved procedures and its technical authority.

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SOURCES

Source register

Every source was opened and checked on 19 November 2026. The right-hand column states what we read and any limit on it. Preference order: official and primary sources, then peer-reviewed research. Manufacturer pages and press releases are not cited. They describe what a product is meant to do, not how it performs on a site.

NO.	SOURCE	TYPE, ACCESS AND LIMITS
1	Ruff, T. (2006). Evaluation of a radar-based proximity warning system for off-highway dump trucks. *Accident Analysis & Prevention* 38(1), 92 to 98. doi:10.1016/j.aap.2005.07.006. NIOSH Spokane Research Laboratory. https://stacks.cdc.gov/view/cdc/221128/cdc_221128_DS1.pdf	Primary field study. One truck, one mine, seven days. Full text read.
2	Trask, C. and Linderoth, H. (2023). Digital technologies in construction: a systematic mapping review of evidence for improved occupational health and safety. *Journal of Building Engineering* 80, 108082. doi:10.1016/j.jobe.2023.108082. https://www.sciencedirect.com/science/article/pii/S2352710223022623	Peer-reviewed mapping review. Abstract read. Counts confirmed in a second listing (ENETOSH).
3	van der Molen, H. et al. (2018). Interventions to prevent injuries in construction workers. *Cochrane Database of Systematic Reviews*, CD006251.pub4. https://doi.org/10.1002/14651858.CD006251.pub4	Systematic review, search to April 2017. Cochrane summary read. Data older than three years.
4	Fugate, H. and Alzraiee, H. (2023). Quantitative analysis of construction labor acceptance of wearable sensing devices to enhance workers' safety. *Results in Engineering* 17, 100841. doi:10.1016/j.rineng.2022.100841. https://www.sciencedirect.com/science/article/pii/S2590123022005114	Peer-reviewed survey, United States. Single source. Sample size not visible to us. Figures match the first author's 2022 thesis abstract.
5	California Fatality Assessment and Control Evaluation Program (2000). A construction flag person dies after being backed over by a truck. FACE report 00CA006. https://stacks.cdc.gov/view/cdc/168956/cdc_168956_DS1.pdf	Official investigation. Confirmed against the California Department of Public Health copy.
6	US National Transportation Safety Board (2019). Pedestrian bridge collapse over SW 8th Street, Miami, Florida, March 15, 2018. Highway Accident Report NTSB/HAR-19/02. https://www.ntsb.gov/investigations/AccidentReports/Reports/HAR1902.pdf	Official investigation. Probable cause read in the report and confirmed in trade press coverage of the board meeting.
7	US Chemical Safety and Hazard Investigation Board (2019). DuPont La Porte facility toxic chemical release. Final report released 25 June 2019. https://www.csb.gov/dupont-la-porte-facility-toxic-chemical-release-/	Official investigation. CSB summary and news release read. Detail on responders confirmed in two trade reports of the CSB findings.
8	US Chemical Safety and Hazard Investigation Board (2018). Packaging Corporation of America hot work explosion, DeRidder, Louisiana. Report 2017–03–I–LA. https://www.csb.gov/packaging-corporation-of-america-hot-work-explosion-/	Official investigation. CSB summary and news release read.
9	Li, L., Huang, Z., Wang, J., Du, B. and Dai, L. (2026). Automated construction monitoring based on computer vision: a comprehensive review. *Developments in the Built Environment* 25, 100832. doi:10.1016/j.dibe.2025.100832. https://www.sciencedirect.com/science/article/pii/S2666165925002327	Peer-reviewed review. Abstract, highlights and introduction read. Single source.
10	UK Health and Safety Executive (2006). Developing process safety indicators: a step-by-step guide for chemical and major hazard industries. HSG254. https://www.hse.gov.uk/pubns/priced/hsg254.pdf	Regulator guidance. Read.

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SOURCES

NO.	SOURCE	TYPE, ACCESS AND LIMITS
11	UK Health and Safety Executive. Alarm management. Human factors topic guidance. https://www.hse.gov.uk/humanfactors/topics/alarm-management.htm	Regulator guidance. Read on 19 November 2026.
12	European Agency for Safety and Health at Work (2024). Principles for implementation and use: smart digital systems to improve workers' safety and health. https://healthy-workplaces.osha.europa.eu/sites/hwc/files/hwc/publication/Principles-implementation-use-smart-digital-systems_EN.pdf	EU agency guidance. Read.
13	UK Health and Safety Executive. Fragile surfaces. Construction safety topic guidance. https://www.hse.gov.uk/construction/safetytopics/fragile.htm	Regulator guidance. Read.
14	UK Health and Safety Executive. Traffic management on site. Construction safety topic guidance. https://www.hse.gov.uk/construction/safetytopics/vehiclestrafficmanagement.htm	Regulator guidance. Read.
15	UK Health and Safety Executive. Temporary works. Construction safety topic guidance. https://www.hse.gov.uk/construction/safetytopics/temporary-works.htm	Regulator guidance. Read.
16	UK Health and Safety Executive. Lifting operations. Construction safety topic guidance. https://www.hse.gov.uk/Construction/safetytopics/lifting-operations.htm	Regulator guidance. Read.
17	US Occupational Safety and Health Administration. 29 CFR 1926.651, Specific excavation requirements. https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.651	US regulation. Read.
18	US Occupational Safety and Health Administration. 29 CFR 1926.417, Lockout and tagging of circuits. https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.417	US regulation. Read.
19	US Occupational Safety and Health Administration. 29 CFR 1910.147, The control of hazardous energy (lockout/tagout). Scope exclusion at paragraph (a)(1)(ii)(A). https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.147	US regulation. Read.
20	Hounkpati, B. (2026). Critical control health (CCHI): methodology proposal, last reviewed 16 September 2026, and The CCHI rollout playbook. Riskopilot. https://riskopilot.com/riskolabs	Riskopilot's own method. Read on 19 November 2026. "Critical control" is used as in the mining industry's good practice guide, which we did not re-open.
21	US Occupational Safety and Health Administration. 29 CFR 1926.1204, Permit-required confined space program. https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926.1204	US regulation. Read.

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SOURCES

NO.	SOURCE	TYPE, ACCESS AND LIMITS
22	US National Institute of Standards and Technology (2023). Artificial Intelligence Risk Management Framework (AI RMF 1.0). NIST AI 100–1. https://nvlpubs.nist.gov/nistpubs/ai/NIST.AI.100-1.pdf	US standards body. Read.
23	US Chemical Safety and Hazard Investigation Board (2007). Refinery explosion and fire, BP Texas City, March 23, 2005. Investigation report 2005–04–I-TX, with the Board's summary of findings, 20 March 2007. https://www.csb.gov/u-s-chemical-safety-board-concludes-organizational-and-safety-deficiencies-at-all-levels-of-the-bp-corporation-caused-march-2005-texas-city-disaster-that-killed-15-injured-180/	Official investigation. Board's summary read. Casualties and cost-cutting finding confirmed in the CSB chairman's 2007 congressional testimony. Other organisational details rest on the summary.
24	National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (2011). Deep water: the Gulf oil disaster and the future of offshore drilling. Report to the President, January 2011. https://purl.fdlp.gov/GPO/gpo2978	Official inquiry. Findings on the pressure test and root cause read in Oil & Gas Journal's report of the Commission's findings (12 January 2011), not in the report itself. Death toll confirmed in the report's dedication.
25	Clarke, S. (2013). Safety leadership: a meta-analytic review of transformational and transactional leadership styles as antecedents of safety behaviours. *Journal of Occupational and Organizational Psychology* 86(1), 22 to 49. doi:10.1111/j.2044–8325.2012.02064.x. https://doi.org/10.1111/j.2044-8325.2012.02064.x	Peer-reviewed meta-analysis. Abstract read, confirmed in a US government patient-safety digest.
26	Zohar, D. and Polachek, T. (2014). Discourse-based intervention for modifying supervisory communication as leverage for safety climate and performance improvement: a randomized field study. *Journal of Applied Psychology* 99(1), 113 to 124. doi:10.1037/a0034096. https://doi.org/10.1037/a0034096	Peer-reviewed randomised field study. Abstract read. Plant size from the first author's 2014 conference presentation.
27	Tucker, A. and Singer, S. (2015). The effectiveness of management-by-walking-around: a randomized field study. *Production and Operations Management* 24(2), 253 to 271. doi:10.1111/poms.12226. https://core.ac.uk/download/28948587.pdf	Peer-reviewed randomised field study, hospitals. Open-access manuscript read in full.
28	International Labour Organization (1981). Occupational Safety and Health Convention, No. 155. Articles 13 and 19(f). https://www.ilo.org/dyn/normlex/en/f?p=NORMLEXPUB:12100:0::NO::P12100_ILO_CODE:C155	International treaty. Legal effect depends on ratification and national law. Text read in several reproduced copies. The official page did not load on the day.
29	Council Directive 89/391/EEC of 12 June 1989 on measures to encourage improvements in the safety and health of workers at work. Articles 6(4) and 8(3) to 8(5). https://eur-lex.europa.eu/eli/dir/1989/391/2008-12-11	EU law, applied through national legislation. Articles read in the retained UK copy and confirmed in a second reproduction.
30	Republic of South Africa (2015). Mine Health and Safety Act, 1996: regulations relating to machinery and equipment, regulation 8.10. Government Notice R.125, Government Gazette 38493, 27 February 2015. https://www.gov.za/sites/default/files/gcis_document/201503/38493reg10369gon125.pdf	National regulation. Applies where there is a significant risk of collision. Text read. Commencement of the automatic-braking sub-regulations on 21 December 2022 confirmed in two legal and trade reports.
31	US Mine Safety and Health Administration (2015). Proximity detection systems for continuous mining machines in underground coal mines. Final rule, 80 FR 2188. https://www.msha.gov/news-media/special-initiatives/2015/09/27/final-rule-proximity-detection-systems-continuous-mining	US regulation. Agency summary read. It reports no outcome data since the rule took effect.
32	NIOSH researchers. Proximity detection zones: designs to prevent fatalities around continuous mining machines, and a further NIOSH paper on electronic interference with proximity detection systems. https://pmc.ncbi.nlm.nih.gov/articles/PMC4982554/	Government research. Retrospective review of 39 fatalities. The authors note the data do not support statistically significant conclusions. Abstracts read.

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VERIFICATION, AUTHOR AND LICENCE

Verification note

Confirmed in two independent sources

- Mapping review counts: 392 records, 24 included (source 2).
- Cochrane review: 17 studies, very low quality evidence (source 3).
- Florida bridge: casualties and probable cause (source 6).
- La Porte: date, substance, four deaths, responders (source 7).
- DeRidder: date, three deaths, seven injuries, test location (source 8).
- California flagger case: circumstances and working alarm (source 5).
- Wearables: 59% and 46% (source 4, and the first author's thesis, which is the same study).
- Texas City casualties and cost-cutting (23), Macondo deaths (24), the three leadership studies (25 to 27), EU directive articles (29), South African regulation and its commencement (30).

Resting on a single source

- All radar field-study figures (source 1). The paper itself was read in full.
- The computer-vision review's findings (source 9), read at abstract level.
- Regulator guidance statements (sources 10 to 19, 21, 22), each read at the official page.
- Texas City staffing, audit and maintenance details (23). Macondo test findings (24, via a trade report). ILO text (28, reproduced copies). US proximity rule and NIOSH findings (31, 32).

Could not be verified, and handled accordingly

- The sample size of the wearables survey. The figures are labelled as one sample.
- The victim's age in the California case, which the source gives two ways. Omitted.
- The haul truck's rated capacity. Omitted.

Calculations

All percentages, the three-way alarm split, the zero-miss bounds and the worked examples were recomputed when this document was built.

About the author

Bruno Hounkpati is a CEO and former VP HSE. He is the author of the Riskopilot critical control health method (CCHI) and its rollout playbook.

About Riskopilot

Riskopilot helps organisations in high-hazard industries investigate incidents and verify the controls that prevent fatal ones. Riskolabs is where its methods are published and tested in the open.

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Important

This report is general information for decision-makers. It is not engineering, legal or regulatory advice. Acceptance criteria for actual work are set by the site's technical authority under local law and approved procedures. Worked numbers marked as illustrations are invented.

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“A warning protects no one. A person with the time and the authority to act on it does.”

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