Why has the value of risk management been so difficult to measure?

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After the foregoing discussion on the value of risk management, the obvious next question is why has the value of risk management been so difficult to measure? Perhaps because operational risk management is not better integrated? If so, how can we do improve integration?

Oooof. These are harder questions.

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Finding solutions has motivated my 10 years as an engineering professor, PhD in Business Strategy, two decades of industry and regulatory experience, and two engineering degrees… I summarize my thoughts and welcome others' insights into this gnarly conundrum.

First.

WE NEED A COMMON LANGUAGE AND DATA TO UNDERSTAND RISK.

While definitions may seem dry and dull, construct clarity is key for leaders to knowledgeably discuss and make decisions about their organizational risks. After all, how do we understand what we are talking about if we do not share a common language and data?[1]

Risk is most often defined as the *possibility of loss or injury,*[2] while others include upside: "uncertainty about outcomes that can be either negative or positive."[3] When we think of risk, we often consider personal behaviours. "She's a risk taker, she rides motorcycles!"[4] Thus, formal risk assessment tends to include two foundational elements – probability/possibility and consequence. The first element can be expressed as a qualitative likelihood (she often gets speeding tickets), a quantitative probability (10% chance of surgery complications), or a frequency (100-year flood). To quantify the qualitative, we need a numerator and a denominator — such as 'often' equals one speeding ticket/month. If you don't have data on the population of activities you're interested in (all motorcycle trips, all surgeries), company operations (all train miles, all crane lifts) or time periods (all precipitation events in all years, all man-hours), then you don't have a denominator, and you cannot legitimately quantify a likelihood.

What does this mean for us as organizational leaders? Ask about the population data – the denominator – from which likelihoods are being drawn. Are these data generalizable to the activity you're considering? For example, if you're relying on data on 'probability of failure on demand' (PFD) for plant operators or pressure relief valves, ask where the data comes from. Is it your company's data[5] or another's, say from another country, decade, or even century? Is it reasonable to use this data? Or are there fundamental operational, geographical, or temporal differences that make these data irrelevant? For example, if a 1-in-100-year flood has happened three years in a row, then maybe the intensity-duration-frequency (IDF) precipitation curves need to be revisited for your area. Environmental agencies and insurance companies are reviewing these return rates now and, in some cases, refusing to insure properties in flood-prone areas.[6]

There is a range of possibilities about what will happen on any *particular trip*, activity, or year. We understand (perhaps unconsciously) that our estimates of likelihood are distributions and not a single value. As an example, researchers asked people to assign a numerical probability to various statements of likelihood (Fig 1). Even *always* doesn't mean '100% of the time', but some range between 85%-100%.[7,8] Some consequences seem so unlikely, that they are called Black Swans.[9] However, in many cases, these incidents are a result of a sequence of *rarely* or *never* events with long/fat tail distributions; unforeseen but not impossible.

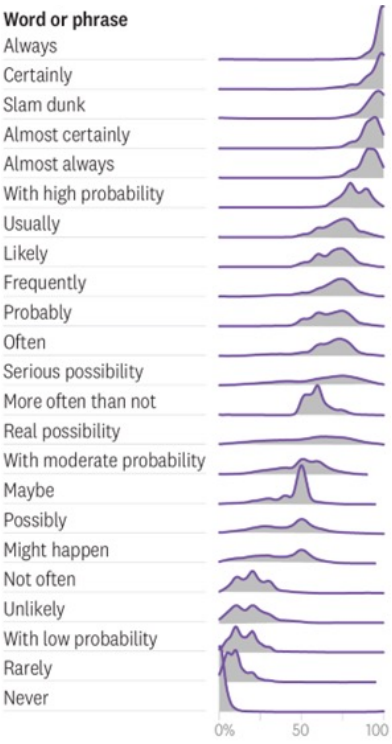


Fig 1: Distribution of likelihood estimates.

The second element of risk assessment is **consequence** - usually focussed on negative outcomes like death, economic loss, production or reputational impacts, or property or environmental damage. To understand possible consequences, review your company's hazard inventory or risk register. Are these organized in a way that makes sense – say clustered by operational activity, likelihood, consequence level, or (better yet) by common causes or controls? Or are there an overwhelming number of rows (thousands even?!),[10] not organized in any particular order? Disordered data is an indicator of disordered management. And if risk data is missing, it's not getting managed at all (!!!).

If your company doesn't have a hazard inventory or risk register, effectively your company is a blind person wandering around a mine field, liable for the actions of its wandering! Ask your risk experts to create a hazard inventory immediately. Ignorance is no defense.[11]

Oftentimes, we might understand our operational hazards but not have data on the frequency of each negative outcome. This is especially true for new or emergent hazards that we don't understand fully. We don't need to quantify the probabilities to manage the risks, if the **credible worst-case scenario** is acceptable. If this scenario is entirely unacceptable, then the hazard needs to be controlled to make this outcome impossible. For example, if your company has lithium metal batteries being stored in a warehouse, that could start on fire, kill workers, and wipe out your inventory, then invest in fire detection and an appropriately sized, specified, and maintained deluge system to make such a fire impossible.[12] If an engineer says that 'the factor of safety is less than unity', this is techno-speak for 'the operational load is greater than the structure is designed for and it can fail at any time!' Ask: What is our credible worst-case scenario? Is this survivable? If not, how can we make this impossible?[13]

Second.

WE NEED TO REGULARLY ASSESS OUR COMPANIES' RISKS.

Risk assessment is the process of determining 'What could go wrong?' – the hazards, 'How likely is it?' – an estimation or calculation of the probabilities/frequencies, and 'How bad could it be?' – for the range of consequences. This could be a prospective assessment, if I am designing a new process or facility – like siting a hydrogen-refueling station in a residential community.[14] With this, we can avoid risks entirely by designing hazards out of the system.[15-18] What you don't have can't leak[19] — whether it's eliminating toxic chemicals, suspended loads, or web/cloud-connected data that can be breached. Or it could be a retrospective assessment, if I am analyzing an incident (my company's or another's) — like a train derailment and release of special dangerous goods.[20] With this, we can learn from our mistakes and others' to improve our systems.

Risk assessment supports decision-making under conditions of uncertainty. Our methods evolve, along with our awareness and understanding. Risk assessment starts with qualitative methods for new hazards we might not understand or don't have data for probabilities and consequences (i.e., lab leaks from microbiology facilities). Then, as we begin to understand the high consequence, 'Stuff That Kills You" (STKY) hazards and direct controls,[21.22] we invest in more detailed semi-quantitative and quantitative methods to calculate probabilities and consequences, cost-benefit analysis to prioritize risk reductions, and guided decision-making.

Risks are not static or absolute and are not perceived uniformly by all stakeholders.[23] Perceptions of risk –and of risk mitigation – can be amplified or diminished by such factors as proximity, time, vulnerability, knowledge, scale of impact, tone of messaging and the publics' or stakeholders' understandings, perspectives and preferences. Thus, risks must be assessed regularly. More dynamic conditions – a changing context (new regulations, (sub)contracting, insurance, population encroachment) or changing operations (new maintenance activities, process modifications, automation, employees) – require more frequent re-assessment cycles.

Third.

WE NEED STRUCTURES, POLICIES, AND REWARD SYSTEMS TO INTEGRATE AND EMBED RISK MANAGEMENT ACROSS

This includes a corporate risk group and champions (demonstrating management commitment), and integrated key risk indicators (KRI) across strategic and business planning, operations (production, maintenance, contracting), human resources (competency assurance, incentives/penalties), and loss control (fines, lawsuits, product quality, business interruption).[24] Integrating your approach creates a *systems perspective* for avoiding losses and maximizing gains, measuring these, and learning and improving.

Peter Senge— the godfather of organizational learning — argues that companies' only sustainable advantage is to learn faster than their competition through systems thinking. "Systems thinking is a framework for seeing interrelationships rather than things, for seeing patterns rather than static snapshots. It is a set of general principles spanning fields as diverse as physical and social sciences, engineering and management."[25]

This equips us to see risk as dynamic interconnections in your organization's ***system****:*[26]

- as an arrangement of parts or elements,
- in an interacting combination,
- organized to achieve one or more of stated purposes, and
- that together exhibit behaviour or meaning that the individual elements do not.

Most industries' operations and built infrastructure are **socio-technical systems** - which include technical systems that are designed, built, and operated by technical criteria and governed by organizational policies, rules, and processes and the people who use and interact with the technical system. High-consequence incidents are usually the result of failures in several social and technical elements. Thus, we need a multi-level systems view of how our operations function and fail.

By identifying nonlinear dynamics like feedback loops, tipping points, and leverage points, systems approaches can explain emergent outcomes that are unintended, unexpected, or delayed in time or space.[27,28]

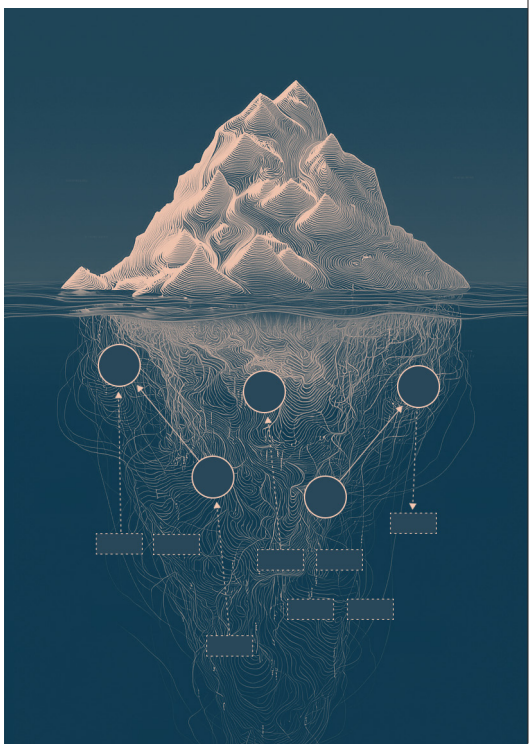
In complex systems, incidents can result from dysfunctional interactions between perfectly functioning — reliable and non-failed— elements.[29] This can be software that operates according to its specifications but not anticipating new operational conditions, like increased data entry speed.[30] It could be disaggregated design and operational teams that are unaware of how their independent decisions might interact with others' decisions and lead to an accident.[31] Each local decision might be 'correct' within its context but lead to dysfunctional interactions. Thus, safety is a property of the system and not of any one element. We can have reliable components in an unsafe system. Creating a systems view helps you to see these interactions.

Lastly.

BY ANALYZING INCIDENT DATA, WE CAN IDENTIFY THE LEADING KEY RISK INDICATORS (KRIs), ACROSS BUSINESS FUNCTIONS AND UNITS.

Do you know what (high-energy) hazards are most likely to cause a serious incident or fatality in your company? Do you have direct controls in place, functional, and nonbypassable to prevent these? If you have an operations/risk management system, you might say, "We're managing occupational/process safety already. Thanks. We're good!" Yet, without analyzing the connections between elements in your management system(s), you're still siloing safety/risk, blinkering your understanding, and under-leveraging opportunities for improvements.

While companies store incident data in thousands of reports, few conduct detailed analysis to learn and prevent future incidents. Furthermore, related datasets (maintenance, production, competency assurance, employee surveys) are rarely integrated to understand them as leading indicators or key risk indicators (KRIs). We used machine learning and keyword analysis to analyze an energy company's incident reports to determine which weaknesses in the process safety management elements[32] were most likely to directly and indirectly be involved in incidents. The biggest weaknesses were in: Asset Integrity and Reliability (47%), Management Review and Continuous Improvement (15%), Hazard Identification (11%) and Contractor Management (8%).[33] See Fig 2. From this, we provided practical recommendations to reduce/eliminate these latent causes and define the return on investment.[34] Since this company has a lot of fixed infrastructure, it made sense that 47% of incidents were caused by asset integrity/reliability. We also use natural language processing and machine learning to analyze the relative influence of human and organizational factors on incidents. And we found that lack of communication (32%), fatigue (17%), and trust/fear (15%) were the top three causes of incidents.[16] Mis/distrust and fear are especially pernicious, as these lead to information hiding, especially problematic for high task-interdependent industries. For other hazardous industries, like construction or manufacturing, the causes will be similar, but the relative influence will differ.



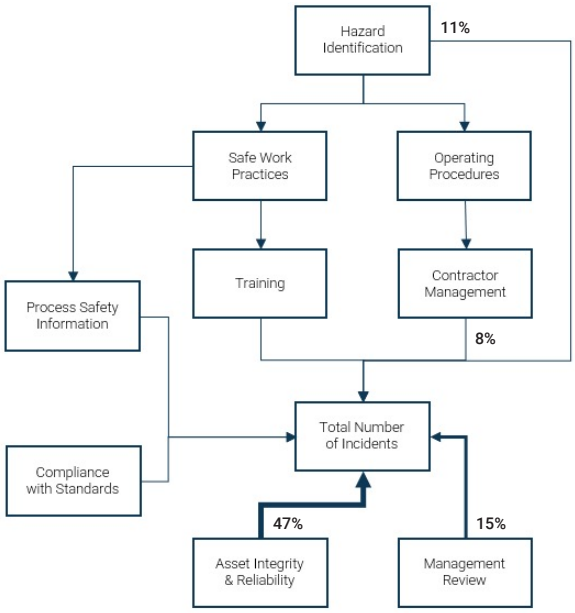


Fig 2: Bayesian Network Analysis of relationships between Process Safety Management elements and the total number of incidents.

In sum:
To glean the maximum value from risk management efforts and ensure sustainable competitive advantage, we need to:

1) create common language and data to understand risk,
2) regularly assess risk,
3) integrate and embed risk across our management systems, and
4) analyze incidents to identity precursory conditions across business functions and units.

STARTING WITH DATA ANALYSIS WILL ENSURE THAT YOU CAN MEASURE IMPROVEMENTS AND SUSTAIN ATTENTION.

YOUR COMPANY WILL HAVE MORE DATA THAN YOU THINK AND YOU NEED LESS DATA THAN YOU EXPECT.

Take action now to protect and enhance your organization's performance, contact:

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1 To enhance understanding of some of the most used terms used in the practice of dam engineering, we compiled a list of about 40 common words, phrases and organizational roles. We then scanned documents produced by 11 sources (regulators, agencies and associations) to identify definitions of key terms. Of these key terms, only four terms were defined by more than half of the sources. Over 30 technical terms that we thought were commonly used, were not clearly defined. Either these terms were not considered to be relevant by most sources or were assumed to be universally understood, both of which are problematic. See: Boswell, J., Rentz, A., Cavanagh, P., Staples, L., & Lefsrud, L.M. 2019. *Preliminary Work by the Dam Integrity Advisory Committee Towards Thinking Clearly and Communicating Effectively About Risk.* https://www.cdabulletin-digital.com/cdaq/0221_spring_2021/MobilePagedArticle.action?articleId=1670112

2 Merriam-Webster Dictionary, https://www.merriam-webster.com/dictionary/risk

3 Elliott, M.W. (2018). *Risk Assessment and Treatment* 2nd Edition ed. The Institutes.

4 Yes, I used to ride motorcycles.

5 If your company tests controls to verify functionality, then you can calculate your own PFDs. Nuclear does this well.

6 Or worse – some insurers are refusing to pay out loss claims. If you must sue your insurance company to try ad get a claim paid, it's worse than having no insurance at all!

7 Mauboussin, A., & Mauboussin, M. J. (2018). If you say something is "likely," how likely do people think it is. *Harvard Business Review*, 3. https://hbr.org/2018/07/if-you-say-something-is-likely-how-likely-do-people-think-it-is

8 Also known as 'fuzzy' numbers.

9 Taleb, N. N. (2010). The Black Swan: The Impact of the Highly Improbable: With a new section:" On Robustness and Fragility" (Vol. 2). Random house trade paperbacks.

10 Hazard and Operability (HAZOP) studies and Process Hazard Analysis (PHA) will generate thousands of scenarios for a large facility. An experienced facilitator can winnow these down to the high-risk scenarios.

11 Lawyers, especially, will argue this point.

[12] Verzoni, A., (2024) Fatal South Korea Factory Fire Highlights Need for Better Battery Regulation. https://www.nfpa.org/news-blogs-and-articles/blogs/2024/06/24/south-korea-battery-factory-fire-highlights-need-for-better-battery-regulation

[13] Cost Benefit Analysis equips decisionmakers to evaluate and chose alternative methods of control.

[14] Joshi, A., Sattari, F., Lefsrud, L., Tufail, M., & Khan, M. A. (2024). Mitigating uncertainty: A risk informed approach for deploying hydrogen refueling stations. *International Journal of Hydrogen Energy*, 74, 136-150.

[15] Kletz, T. A. (1996). Inherently safer design: the growth of an idea. *Process Safety Progress*, 15(1), 5-8.

[16] Schulte, P. A., Rinehart, R., Okun, A., Geraci, C. L., & Heidel, D. S. (2008). National prevention through design (PtD) initiative. *Journal of safety research*, 39(2), 115-121.

[17] Toole, T. M., & Gambatese, J. (2008). The trajectories of prevention through design in construction. *Journal of safety research*, 39(2), 225-230.

[18] Masys, A. J. (2018). Security by design. *Innovative Perspectives on Complex Problems*.

[19] Kletz, T.A. (1978). What you don't have, can't leak. *Chemistry and Industry*, pp. 287-292. May 6, 1978.

[20] Esmaeeli, N., Sattari, F., Lefsrud, L., & Macciotta, R. (2022). Critical analysis of train derailments in Canada through process safety techniques and insights into enhanced safety management systems. *Transportation research record*, 2676(4), 603-625.

[21] Hallowell, M. R. (2025). *Energy-Based Safety: A Scientific Approach to Preventing Serious Injuries and Fatalities (SIFs).* CRC Press.

[22] Lefsrud, L. M., Sattari, F., Gellatly, I. R., Wasel, C., Charuvil Elizabeth, R. M., Abdolmaleki, A., & O'Neill, T. (2025). Final Report for Creative Sentence: Building Resilience into Safety Management Systems: Precursors and Controls to Reduce Serious Injuries and Fatalities (SIFs). https://ualberta.scholaris.ca/bitstreams/59a0eca0-fcfc-4629-b6a0-c6ed0288ed51/download

[23] How your company responds is a function of your safety culture. Diagnosing safety culture maturity is the next discussion paper topic.

[24] Fraser, J.R.S, & Simkins, BJ. (2021) The challenges of and Solutions for Implementing Enterprise Risk Management. *In Enterprise Risk Management: Today's Leading Research and Best Practices for Tomorrow's Executives*. Wiley.

[25] Senge, P. M. (2006). The fifth discipline: the art and practice of the learning organization (Rev. and updated.). Doubleday/Currency.

[26] See INCOSE – International Council on Systems Engineering, www.incose.org

[27] Kimsey, M., Besharov, M, Casasnovas, G., & Mollerer, M.A. (2025). Thinking in systems: From ceremonial to meaningful use of systems perspectives in organization and management research. *Academy of Management Annals*, Vol. 19, No. 2, 736–762. https://doi.org/10.5465/annals.2022.0081

[28] Leveson, N. G. (2016). *Engineering a safer world: Systems thinking applied to safety* (p. 560). The MIT Press.

[29] Leveson, N., Dulac, N., Marais, K., & Carroll, J. (2009). Moving beyond normal accidents and high reliability organizations: A systems approach to safety in complex systems. *Organization studies*, 30(2-3), 227-249.

[30] Rawlinson, J. A. (1987). Report on the Therac-25. OCTRF/OCI Physicists Meeting, Kingston, Ontario, May 1987

[31] Rasmussen, J. (1997) Risk Management in a Dynamic Society: A Modeling Problem. *Safety Science* 27 (2/3): 183–210.

[32] The Center for Chemical Process Safety (CCPS) started in 1985 following Bhopal and introduced their process safety management (PSM) system in 1992. Their system and depicts 20 elements clustered as four pillars holding the roof of the PSM temple. https://www.aiche.org/topics/process-safety/elements-process-safety

[33] Sattari, F., Macciotta, R., Kurian, D., & Lefsrud, L. (2021). Application of Bayesian network and artificial intelligence to reduce accident/incident rates in oil & gas companies. *Safety Science*, 133, 104981.

[34] Sattari, F., Lefsrud, L., Kurian, D., & Macciotta, R. (2022). A theoretical framework for data-driven artificial intelligence decision making for enhancing the asset integrity management system in the oil & gas sector. *Journal of Loss Prevention in the Process Industries*, 74, 104648.