

Safety alchemy: false assurance by converting operational risks into milestone documents

Ben Hutchinson, Sidney Dekker & Andrew Rae

To cite this article: Ben Hutchinson, Sidney Dekker & Andrew Rae (21 Oct 2026): Safety alchemy: false assurance by converting operational risks into milestone documents, Safety and Reliability, DOI: [10.1080/09617353.2026.2745288](https://doi.org/10.1080/09617353.2026.2745288)

To link to this article: <https://doi.org/10.1080/09617353.2026.2745288>



© 2026 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group



Published online: 21 Oct 2026.



Submit your article to this journal [↗](#)



View related articles [↗](#)



View Crossmark data [↗](#)



RESEARCH ARTICLE



OPEN ACCESS



Safety alchemy: false assurance by converting operational risks into milestone documents

Ben Hutchinson , Sidney Dekker and Andrew Rae

Safety Science Innovation Lab, Griffith University, Nathan, Queensland, Australia

ABSTRACT

For many organisations, managing safety also encompasses managing a system of safety documents. These documents are ‘enabling devices’: they function as institutional passports that allow work to commence or advance. Previous work indicates that such documents can contribute to safety beliefs and practices becoming decoupled from operational risks. In this project we analysed reports from seven major accidents to identify how this decoupling occurs. The analysis revealed a recurring process we term ‘safety alchemy’: the conversion of unresolved uncertainty and operational risk into perceived certainty and organisational assurance through the creation, completion, revision, or acceptance of safety artefacts, without a corresponding improvement in the underlying control of risk. The process was fuelled by documentation displacing attention from underlying problems and becoming authoritative accounts of safety. These findings identify specific ways in which safety management system processes can create false risk assurance. These mechanisms offer practical opportunities for improved review and audit of safety management systems.

ARTICLE HISTORY Received 2 March 2026; Revised 18 September 2026; Accepted 23 September 2026

KEYWORDS Major accident; risk assessment; engineering failure

1. Introduction

Written artefacts, such as plans, standard operating procedures, risk registers, and risk assessments, fulfil important roles within organisations. They facilitate the control and coordination of performance, provide a source of codified knowledge (Weichbrodt, 2015), and help establish routines (D’Adderio, 2011). Because they are useful, organisations often make them mandatory through gateways, milestones, or reviews that prohibit work from commencing until specified artefacts are in place (e.g., operating procedures or risk assessments).

CONTACT Ben Hutchinson ben.hutchinson@griffith.edu.au Safety Science Innovation Lab, Griffith University, 170 Kessels Rd, Nathan, Queensland 4111, Australia.

© 2026 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. The terms on which this article has been published allow the posting of the Accepted Manuscript in a repository by the author(s) or with their consent.

Once an artefact is mandatory, it may serve not only its intended operational function but also an enabling function: it becomes a passport through which work is authorised to commence. We call artefacts serving this function ‘enabling devices’ (Hutchinson et al., 2022). Although created to influence routines or address operational problems, artefacts can produce behaviours that split from their intended purpose (Bea, 1996; Hollnagel, 2015; Pentland & Feldman, 2008; Sanne, 2008). An artefact represents a routine but is not the routine itself (D’Adderio, 2011), no matter how precisely the two are intended to align. At the extreme, this means that it is more important for a document to say the ‘right’ things than to say realistic things.

Moreover, a document that serves as an enabling device may explicitly contradict operational reality and permit work to advance despite unresolved safety issues. This is not merely a distinction between work-as-imagined and work-as-done, nor ineffective ‘tick and flick’ safety processes. Some divergence between abstractions of work and local operational conditions is inevitable. In these cases, though, the artefact’s enabling function fully subverts its intended operational function. Rather than enforcing the positive function of the document, the gateway has caused the document to make misleading claims in order to get through the gateway.

Under these circumstances, enabling devices create decoupling: confidence in safety exceeds the actual effectiveness of risk control. Management of the artefact is conflated with management of the operational issue (Hutchinson et al., 2022). Stakeholders develop unwarranted confidence that an issue is being adequately addressed, because the document says the issue is being addressed. This confidence is inconsistent with the written process’s capacity to manage the issue in question.

Prior work has demonstrated the existence and importance of the problem described so far: that enabling devices can facilitate decoupling by creating unwarranted confidence in safety efforts (Hutchinson et al., 2024a, 2024b). However, the explanations for why this happens have yet to be confirmed.

This paper analyses the mechanisms by which documents establish unwarranted confidence; that is, how enabling devices induce a heightened sense of safety among personnel despite a lack of adequate evidence. Understanding these mechanisms will support the design of review processes specifically to identify such problems.

The research question is: How do safety artefacts acting as enabling devices create and sustain decoupling between documentary assurance and the operational control of risk?

2. Background

2.1. The positive role of artefacts

Functional planning uses human experience to guide present or future action (Clarke, 1999, p. 7). Artefacts support this process by codifying what

an organisation expects to happen and how stakeholders should respond. In doing so, they legitimate work as sufficiently understood to proceed. This reflects a key purpose of developing artefacts: to cement current knowledge around an issue or goal and to detail outcomes and activities that are expected to occur. By offering a single version of ‘truth’, artefacts act as a blueprint for the future (Clarke, 1999, p. 41).

Safety risk artefacts play an important role in this broader planning process. Safety artefacts deal with threats to the core planned activities: they describe and analyse the threats, as well as the planned or potential responses to those threats. They demonstrate to external stakeholders that the threats have been or will be adequately dealt with (Rae & Provan, 2019). The transition from early planning to work commencement is difficult to advance when uncertainty around threats is high. People need some degree of certainty; without certainty, the world would appear too chaotic and unordered to reliably deliver on goals (Clarke, 1999). Through the use of safety artefacts, some uncertainties are translated into (apparently) better-known and understandable units (Clarke, 1999).

2.2. *Artefacts as enabling devices*

An enabling device is an artefact that is required for work to proceed. The artefact may be required explicitly through a contractual requirement or process gate, or implicitly by the need to resolve anxiety or uncertainty around an issue (Hutchinson et al., 2022). The term ‘enabling device’ is neutral. To argue that an artefact has an enabling function is not a positive or negative evaluation, but merely describes a secondary and legitimate purpose of the artefact in addition to its primary functional purpose. As argued in Hutchinson et al. (2022), artefacts are often studied and understood in terms of their primary functional purposes, as in, informing or coordinating work activities or risk management. But they also serve indirect enabling purposes.

Enabling devices usually start with the intention to influence operational reality. Take, for example, a confined-space permit. The original intention is that no one should enter a potentially unsafe confined space without appropriate preparation, such as testing for dangerous gas. This preparation is documented in a permit, and the authorisation of that permit becomes a procedural gateway. No one may enter a confined space without a signed permit. Now, the ‘appropriate preparation’ for entering a confined space is no longer the gas testing itself, but the completion and authorisation of the permit. The use of permits in this way is generally considered to be a safety improvement, because it facilitates oversight activities such as audits and spot-checks. A permit is visible to oversight; an undocumented gas test is not. However, the content of the permit may fail to accurately represent whether the testing has occurred, producing confidence that exceeds what the permit has functionally achieved. This is

decoupling between the permit's intended and practical effects. The permit may even become understood as more important than the testing, receiving more attention in secondary activities such as training, inductions, audits, and inspections. There may be contractual requirements to use the permit even in the absence of requirements for the gas testing.

2.3. How do artefacts shift beliefs?

Enabling purposes are legitimate, but mistaking these purposes for the direct functional goals of the artefact can be dangerous. Artefact writers, or the overall system custodians (like senior managers), may have misplaced beliefs about the role and effectiveness of documented systems in influencing operational practices and risks.

Effort often shifts towards demonstrating perceived assurance or tweaking paperwork at the expense of operational management. For example, risk management prior to the 1998 Esso Longford gas plant accident focused more on managing documented systems than the 'practical functioning of the plants' (Longford Royal Commission, 1999, p. 200). In such cases, documents become surrogates for the issues they represent.

This shift from issues to artefacts fuels a false sense of safety: because an artefact exists and appears authoritative, the system is assumed effective. Clarke's (1999) 'fantasy document' describes an extreme form of this shift: the Port of Valdez's ocean oil spill plan allayed public and regulatory concerns despite relying on claims with no precedent (Clarke, 1999). Ross et al. (2016) extended the concept to 'fantasy objects', showing how ineffective shelter-in-place kits legitimised the operation of a US Army chemical-weapons facility by implying that its risks were understood and controlled.

Hutchinson et al. (2022) showed that other safety artefacts, such as safety management system processes and risk assessments, serve a similar legitimising function, where creating a physical artefact disproportionately increases stakeholder assurance relative to how that issue is practically managed.

2.4. Ontological alchemy as applied to safety artefacts

This unwarranted confidence reflects a broader organisational tendency to mistake symbolic representations for reality. Dekker and Nyce (2015) call this 'ontological alchemy': subjective experiences are transformed into measurable figures that acquire the status of objective reality. For example, numerical workload scores can displace examination of the underlying experiences from which they were derived.

In a similar fashion, unresolved uncertainties, risks, assumptions, plans, and expectations are translated into risk assessments, procedures, permits, registers, and other safety artefacts. These artefacts may then acquire authority disproportionate to the strength of their relationship with operational

conditions. Thus, uncertainty about operational conditions is transmuted into objective truth that the document exists and says the ‘right’ things.

As Clarke (1999) explains, documents have a peculiar power to create a single source of ‘truth’, silencing other plausible interpretations of reality. Even where the document is not objectively incorrect, its epistemological status as a source of truth may still exceed its power to accurately and appropriately represent real and ongoing uncertainty.

2.5. Enabling devices tempt the management of documents over issues

Whereas a common intention of artefacts is to directly inform or guide the management of an operational issue or risk, enabling devices can drive decoupling because the artefact becomes the centre of attention rather than the intended issue.

This mismatch can be seen through the difference between specifications and requirements. A requirement can be considered a ‘problem to be solved, described in terms of the real world’ (Jackson, 2010, p. 3). Specifications, on the other hand, describe the intended behaviour of a component (Jackson, 2010) or for our purposes, an artefact or safety measure. Specifications can be explicit (a document is stipulated by a regulation, safety management system, or auditor) or implicit (a manager needs something to reassure them, and a safety document meets that need).

An organisation may need to ensure adequate mine ventilation—the requirement—but respond by creating a ventilation plan (a specification). Satisfying the specification does not guarantee meeting the requirement. Hayes (2015, p. 203) highlights this problem in the San Bruno pipeline explosion: compliance with database risk rankings and inspection algorithms failed to ensure asset integrity because the underlying data and methods were ‘flawed in both concept and practice’.

3. Method

3.1. Inclusion criteria

This study is based on a purposive sample of major accidents. Accidents were selected based on pre-existing discussion, either in the official report or in third-party commentary, about the role of safety artefacts in the accident (see Table 1).

The following inclusion criteria were used when selecting accident reports:

- A publicly available accident report with sufficient information about safety artefacts.
- Analysis of organisational factors beyond a simple technical failure.

Table 1. List of accident sources included in the study.

Accident	Description	Primary references
Texas City refinery explosion and fire	In 2005, an overfilled raffinate splitter released flammable liquid during start-up at BP's Texas City refinery. The resulting explosions and fire killed 15 people located in or near temporary office trailers	Mogford (2005) U.S. Chemical Safety and Hazard Investigation Board (2007)
Esso Longford gas plant accident	In 1998, a heat exchanger at Esso's Longford gas plant fractured after heated oil entered a vessel made brittle by extremely low temperatures. The resulting hydrocarbon release, explosions, and fire killed two employees	Longford Royal Commission (1999)
Buncefield facility fire and explosion incident	In 2005, petrol overflowed from a storage tank at Buncefield after a level gauge stuck and an overflow safety switch failed. The resulting vapour cloud ignited, causing an explosion and fire	COMAH Competent Authority (2011)
Pike River Coal Mine tragedy	In 2010, an explosion at the Pike River underground coal mine killed 29 workers. It resulted from ignition of a substantial volume of naturally occurring methane gas	Pike River Coal Underground Fan Risk Assessment Report (2007) Pike River Coal Ventilation Management Plan (2008) Royal Commission on the Pike River Coal Mine Tragedy (2012) Multiple court transcript records
Macondo well blowout / Deepwater Horizon oil spill	In 2010, the Deepwater Horizon drilling rig experienced a high-pressure methane gas expulsion from the well. The gas ignited and an explosion followed, killing 11 people and resulting in a large-scale oil spill	Deepwater Horizon Study Group (2011) National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (2011) United States Department of the Interior (2011) MacDonald (2010) Associated Press (2010) Cullen (1990)
Piper Alpha oil platform disaster	In 1988 on the Piper Alpha platform, an unsecured blind flange was believed to have resulted in a leak of gas condensate. The gas ignited, explosions followed, and 167 workers were killed	
Australian Government Home Insulation Program deaths	In 2009–2010 the Australian Government ran an initiative called the Homeowner Insulation Program, which incentivised homeowners to install insulation in their homes. The program was cancelled prematurely after the deaths of four installers in separate events between October 2009 and February 2010. Three deaths resulted from electrocution and the fourth from hyperthermia	Hanger (2014)

Reports were only included if the artefact acted as a 'gateway' or 'enabling device', meaning that the artefact's existence, or believed existence, allowed work to proceed despite a known or discoverable safety gap. Simple clerical errors in documentation or application of processes, or general discrepancies between work-as-imagined and work-as-done

were excluded unless they directly enabled hazardous work to commence or continue.

Where available, we also analysed court transcripts and ancillary reports. The sample primarily comprised petrochemical and oil and gas accidents because detailed reports were available; we additionally included one underground coal-mining accident and the Australian Home Insulation Program due to the extensive information available.

3.2. Analysis

Analysis followed a two-layered approach. First, we identified mismatches where an artefact made a claim about a physical state or process that was contradicted by other evidence in the report (e.g., describing an uninstalled system as operational). Second, we interpreted why each mismatch arose using textual evidence and investigators' accounts. This process unavoidably involves *post hoc* rationalisation and hindsight bias. We recognised this trade-off in our previous paper (Hutchinson et al., 2024b) and argue that value can still be derived from data that is 'persuasive rather than conclusive' (Hopkins, 2014). Nevertheless, the first layer of analysis partially mitigates these *post hoc* effects because it relies primarily on comparing the documented claims against verified physical realities. For the interpretive layer, we remain transparent about relying on the 'idealised model' of safety, either explicitly held by investigators or inferred from the data, to understand the mechanisms of decoupling.

We used progressive focusing (a specific form of thematic analysis) to evaluate the accident reports. Thematic analysis is a method for 'identifying, analysing and reporting patterns (themes) within data' (Braun & Clarke, 2006, p. 79). Chunks of text, sentences, or key phrases were assigned codes, which were labels used to describe the data and identify themes. Themes interpret patterns of codes deemed important to the research question (Maguire & Delahunt, 2017).

Progressive focusing iteratively compares data with established theory, using discipline-specific 'norms and pre-understandings' (Alfoldi & Hassett, 2013, p. 281) while remaining responsive to emergent findings (Sinkovics & Alfoldi, 2012).

We employed three coding steps: initial, focused, and theoretical coding (Charmaz, 2006). Literature on symbolic planning, safety risk, and provisional numbers informed the research questions and sensitising concepts (Clarke, 1999; Hayes & Hopkins, 2015; Hutchinson et al., 2018, 2022; Lampland, 2010). NVivo 11 was used to code all findings.

3.2.1. Initial coding

The first step involved reading the sources, including transcripts, research papers, plans, and risk assessments. Initial coding drew on work-as-imagined/work-as-done, fantasy planning, and symbolic planning (Clarke, 1999; Hayes

& Hopkins, 2015; Hutchinson et al., 2018), and Weick's (1995) proposition that people often seek plausibility over accuracy. Example codes included 'Plan or risk assessment says something will be done, but was never done', 'Symbolic plan or planning', and 'Assumptions about reality that were not true'.

3.2.2. *Focused coding*

We then decomposed the initial codes into more specific categories, including 'Organisations not focusing on the things deemed pertinent in artefacts', 'Reference to an artefact or requirement that did not apparently exist' and 'Controls that did not operate as operators or designers expected'.

3.2.3. *Theoretical coding*

Theoretical coding then examined the relationships between these categories and organisational performance, informed by the NVivo network analysis. We then reapplied the final codes to the reports to test whether the examples were sufficient and whether interpretations remained plausible (plausibly here refers to instances where data interpretation was speculative; Corbin & Strauss, 2008, p. 159). Existing research on symbolic planning and safety risk informed conceptually consistent themes, including artefacts without clear functional purposes.

4. Results

Across the numerous safety artefacts and practices examined (detailed in Appendix Table A1), a recurring process emerged that explains how enabling devices fuel decoupling. Building on Dekker and Nyce's (2015) notion of ontological alchemy, we call this process 'safety alchemy':

The process by which unresolved uncertainty, operational risk, or incomplete knowledge is transformed into perceived certainty and organisational assurance through the creation, completion, revision, or acceptance of safety artefacts, without a corresponding improvement in the underlying control of risk.

Safety alchemy is the process that creates or sustains decoupling, which is the disparity between confidence and operational reality. As shown in Figure 1, it operated through two linked pathways: enabling devices displaced focus from uncertain operational conditions towards concrete documentary criteria, and became authoritative accounts of what was considered safe, controlled, or expected to occur.

4.1. *Safety alchemy displaces attention from uncertainty to documentary certainty*

The data reveal that trust in documented systems is constructed by translating uncertainty into concrete criteria. This translation process is essential for enabling work and is explored through the following sub-themes.

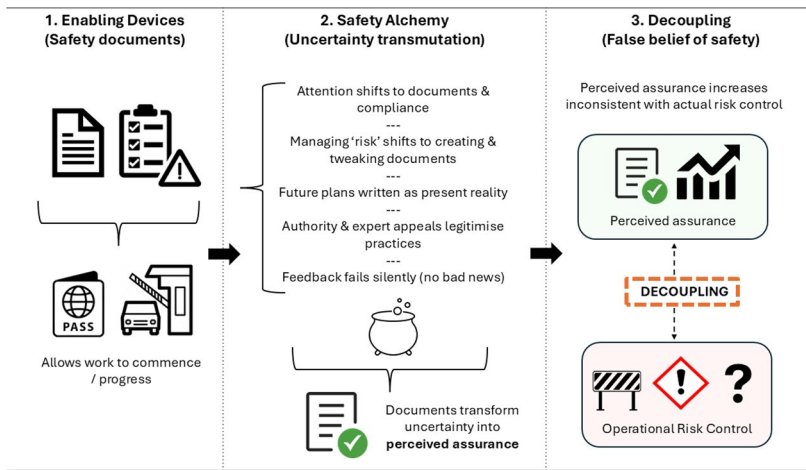


Figure 1. Conceptual representation of safety alchemy.

4.1.1. From meeting difficult-to-measure requirements to meeting easy-to-check specifications

Safety alchemy permits specifications to be treated as evidence that the underlying requirement has been met.

Pike River's ventilation management plan highlights this disparity. Its stated requirement—its whole purpose—was to 'effectively control the ventilation and gas monitoring activities ... to effect overall gas management' (*Pike River Coal Ventilation Management Plan*, 2008, p. 4). Yet its specifications only partially supported that requirement, allowing the plan to symbolically assume the role of the gas management system itself.

Buncefield's Loss Control Manual required a list of critical parts (COMAH Competent Authority, 2011). Although described as 'critically reviewed as a result of risk assessment' (COMAH Competent Authority, 2011, p. 27), the list was inaccurate, unsuitable for maintaining safety-critical equipment, and said to have been 'put together without any fundamental rationale' (COMAH Competent Authority, 2011, p. 27). The required deliverable (the critical parts list) had displaced its intended function.

The Australian Home Insulation Program similarly, and falsely, assumed that states and territories would regulate health and safety without further intervention from the federal government (Hanger, 2014, p. 151), and that a consultant-assisted process would comprehensively evaluate program delivery risks (Hanger, 2014, pp. 121–122, 144). These assumptions may explain why the risk of serious installer injury was removed from the risk register before being submitted to DEWHA (the Department of the Environment, Water, Heritage and the Arts, the federal government agency tasked to execute the insulation program), even though it was initially flagged during a risk identification workshop (Hanger, 2014, pp. 115–116). Influenced by these assumptions, the risk assessment gave the program team the answer they needed for the initiative to progress despite the misalignment between initial specifications and safety requirements.

4.1.2. From managing risk to correctly following risk-management processes

The Macondo and Pike River cases highlight how alchemical risk-management processes converted unacceptable uncertainty into administratively acceptable risk. For Macondo, a rapid push resulted in the offshore exploration industry moving into ultra-deep waters. The push came with significant challenges to overcome, including an increase in uncertainty around hazards arising from the ultra-deepwater marine environment, hydrocarbon reservoirs, and the hardware to manage production (Deepwater Horizon Study Group, 2011, p. 11).

Such uncertainties had to be matched by assurance that these challenges could be managed, such as through BP's Regional Oil Spill Response Plan (ROSRP). The ROSRP provided stakeholders with assurances, including the federal government whom approved the plan, that it was based on proven equipment and technology and that its worst-case oil spill responses were realistic (Associated Press, 2010). At Pike River, a facilitated risk assessment workshop prompted stakeholders to downgrade several underground-fan risks from 'unacceptable' to 'acceptable' after controls were proposed, despite unresolved uncertainties (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 85).

In both cases, the process produced agreement that risk had been 'managed' without corresponding reductions in the likelihood or magnitude of harm, that is, they were largely symbolic administrative exercises. BP's plan proved inadequate for the anticipated oil spill scale (Associated Press, 2010; MacDonald, 2010). Pike River's fan placement risk assessment documented several controls that were never implemented, nor were effective mechanisms implemented to ensure follow-through. This argument mirrors the 'tombstone effect' in incident investigation, where investigations function as a 'procedural ritual, leaving behind a memorial that does little more than allow a claim that something has been done' rather than genuinely preventing a future incident (Peerally et al., 2017, p. 419).

4.1.3. From managing risk to creating a suitably detailed enabling artefact

Increasing an artefact's detail may improve compliance with its specifications without bringing it closer to its operational requirement. Under safety alchemy, the artefact can legitimate work before achieving its intended safety function. Making specifications ever more elaborate increases the chance that people focus on meeting the individual specifications divorced from whether the requirements are met.

Tweaking Pike River's ventilation plan (e.g., the specifications), could not compensate for the absent air-monitoring devices. Nor could revising BP's oil spill response improve its deficiencies, like irrelevant content (e.g., references to walruses and other animals non-existent in the Gulf),

inadequate emergency response equipment, and overstated recovery capacity which produced an ‘impressive but unrealistic response capacity’ (National Commission on the BP Deepwater Horizon Oil Spill & Offshore Drilling, 2011, p. 133).

A review at Piper Alpha identified that the permit system was not being consistently applied between Piper and its sister platform. The permit system was subsequently rewritten to ensure that it met its intended purpose. Rewriting the procedure was believed to have ‘tightened up the [permit] system’, despite actually *having changed very little* between revisions (Cullen, 1990, p. 230).

Of interest is what the Vice-President of Operations at Piper (and a key witness in the inquiry) believed to have been the purpose of the permit system. He asserted that the process must ‘fulfil its purpose for *controlling work* and *find acceptance* from as many people as possible’ (Cullen, 1990, p. 230; emphasis added). Changing the form provided the critical ‘safety work’ (Rae & Provan, 2019) needed to convince stakeholders that the situation was improved, despite being decoupled from the reality that:

- the permit system did not actually control work (at least not in the way imagined); and
- there may have been little acceptance or deep knowledge of the process or what it was intended to achieve.

Operationally, the permit system at Piper Alpha failed to control and prevent night-shift staff from working on the condensate injection pump while the pressure safety valve was, unbeknownst to the staff, removed from the system (Cullen, 1990, p. 194). The permit system appears to have undergone safety alchemy, such that additional—perhaps trivial—revisions to the process helped meet individual specifications in the absence of meeting the requirements.

4.1.4. *From managing the issue to establishing a system*

Safety systems may similarly become substitutes for managing the issues they represent. At Esso Longford, the Longford Royal Commission remarked that the Operations Integrity Management System (OIMS) was a difficult management system for operators to understand and comprehend. In other cases, critical components of the management system had not been properly implemented or were considered defective (Longford Royal Commission, 1999, p. 200). The commission believed the administrative maintenance of OIMS *became an end in itself* and distracted efforts away from actually operating the plant (Longford Royal Commission, 1999, p. 200). To a degree, efforts put into administering OIMS and using the documented artefacts were ‘divorced from operations in the field’ (Longford Royal Commission, 1999, p. 200) and Esso’s confidence in its system was misplaced.

4.1.5. *From measuring safety performance to verifying auditable traces*

Safety management systems can provide ambiguous or misleading feedback. This pseudo-feedback takes the form of auditable outputs which provide stakeholders with the impression that the process is functioning as expected when it may not be.

Both Pike River and Piper Alpha emphasised the importance of their training and induction systems. Pike River maintained a comprehensive induction training process for new employees, but it could not always adequately maintain this standard (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 67). For example, some specialised machinery and plant operators had little or no training in gas monitoring, and insufficient training in emergency response (Royal Commission on the Pike River Coal Mine Tragedy, 2012, pp. 58, 64–65).

Pike River scheduled daily hour-long training sessions on-site (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 64). Nevertheless, due to production staffing pressures (where attendance often dwindled to fewer than two personnel), training was eventually cancelled (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 64).

Training was considered important but significant gaps existed. A Statutory Mine Manager¹ at Pike River was sometimes unaware of what specific training had been undertaken by hydro-mining operators (Transcript of Hearing, 2012a, 2012b, 2012c, pp. 5087–5088). Further, the Statutory Mine Manager referred to the daily training program as evidence that critical training was covered, but he was unaware of just *what* was covered during the sessions (Transcript of Hearing, 2012a, 2012b, 2012c, pp. 5087–5088).

The disparity is further evidenced by the critical mine safety rules induction process for new employees. A comprehensive ‘General Safety Induction’ handbook was issued to all new Pike River employees (Transcript of Hearing, 2011a, 2011b, 2011c, p. 3764). To avoid overloading new employees with rules, a summary of the General Safety Induction booklet was delivered in an induction presentation. A requirement of Pike River’s safety manual was that contractors were to be supervised by Pike staff and to undergo Pike’s own induction (Royal Commission on the Pike River Coal Mine Tragedy, 2012, pp. 66–67), including complying with the Mine Manager’s rules (which provided guidance for workers going underground).

In many cases, contractors did not undergo thorough Pike inductions (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 67). Elsewhere, they received shorter inductions which did not cover the Mine Manager’s rules in depth (Transcript of Hearing, 2011a, 2011b, 2011c, p. 3766). While the Mine Manager’s rules were available in hard-copy during inductions, they may not have actively been distributed to workers or given much focus (Transcript of Hearing, 2011a, p. 3766,

2011c, p. 4170, 4213). This occurred despite the belief among some Pike staff that employees and contractors ‘have all been trained ... have all been through the inductions ... [and] are all aware of the mine manager’s rules’ (Transcript of Hearing, 2012a, 2012b, 2012c, p. 4426). Little or no effort was made to test the extent of workers’ knowledge of critical safety documents (Transcript of Hearing, 2011a, 2011b, 2011c, pp. 4213–4214).

Pike’s belief in the criticality of the Mine Manager’s rules or thorough inductions was not matched by a reliable means to deliver on these beliefs, nor, it appears, a means to identify that these systems were not functioning as expected.

In all, training and induction records provided auditable traces without equivalent assurance of competence. Table 2 lists the mechanisms by which safety alchemy displaces attention from uncertainty to documentary certainty.

Table 2. Summary of factors involved in how enabling devices reduce perceived or actual uncertainty.

Proposition	Examples
From meeting difficult-to-measure requirements to meeting easy-to-check specifications	Specifications, such as the various stipulations in a plan, are managed instead of the plan’s overarching requirements. E.g., the critical parts list at Buncefield was developed to meet the discrete need (specification) for a list rather than the intended function of the list (requirement)
From managing risk to correctly following risk-management processes	Enabling devices transform uncertainty and unacceptable risks into acceptable risks by giving the appearance that the issues are well understood and controlled. E.g., significant uncertainties of ultra-deepwater oil drilling matched by an oil spill response plan providing assurance that uncertainties could be managed
From managing risk to creating a suitably detailed enabling artefact	The point that an artefact has met its enabling function before properly delivering on its safety requirements, enabling work to commence before the artefact has delivered its intended purpose. E.g., theoretical argument about tweaking/improving ventilation plan even though critical air monitoring devices were not available
From managing the issue to establishing a system	Efforts are directed to managing systems under a misaligned belief that the issue of interest is also being appropriately managed. E.g., at Esso Longford gas plant the administrative burden of managing the safety system distracted attention away from managing the plant
From measuring safety performance to verifying auditable traces	Safety management systems provide ambiguous or misleading feedback in the form of auditable outputs, giving stakeholders the impression that the process is functioning as expected when it may not be

4.2. *Safety alchemy fuels safety artefacts to be regarded as authoritative accounts of safety*

Artefacts influence work by serving as authoritative information sources; they reflect the actual, or perceived, state of knowledge surrounding an issue and how to manage it. This phenomenon is discussed via four sub-themes, summarised in Table 3.

4.2.1. *Describing future plans or intentions in the present tense*

Artefacts can conflate future intentions with present conditions by describing planned future arrangements as though they already exist.

Pike River’s ventilation plan described a required tube-bundle gas detection system as if it was a continuously operating feature, although it had not been installed (Transcript of Hearing, 2011a, 2011b, 2011c, pp. 4023–4024). The plan lacked other key features and parts of it were ignored in practice (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 134). The plan therefore authorised work on the documentary assumption that gas detection was *already* established.

Table 3. Mechanisms by which enabling devices become authoritative sources of information.

Proposition	Examples
Describing future plans or intentions in the present tense	Enabling devices facilitate the commencement of operational planning by conflating future objectives with present realities, such that arrangements for the future can be written into plans and believed to be likely to come to fruition when needed. E.g., Pike River ventilation management plan written as if an essential ventilation system was installed; work continued under this assumption despite the system not being installed
Asserting the acceptability of risks in the absence of realistic assessment	Enabling devices silence competing possibilities in favour of creating a single version of ‘truth’. E.g., insulation installer injury was removed as a credible risk from the Australian Home Insulation Program’s risk register
Expert appeals that allay concerns	References to standards and guides or consultation with expert advice may help increase assurance that the issues are addressed disproportionate to the actual effect. E.g., the Australian home insulation program used an external risk consultant to facilitate risk workshops, which introduced a false degree of safety
Failed-silent feedback mechanism	Safety management system processes do not provide feedback that they are not functioning as expected. E.g., gas sensors at Pike River ‘latching’ on to maximal values and not communicating actual gas levels in the mine or how critical computerised data was not evaluated at BP Texas City

A requirement at Buncefield was for the establishment's operator to develop a safety report as a condition under the UK COMAH regulations. Safety reports require the operator to demonstrate the steps that will be taken to prevent major accidents. While the safety report indicated that relevant industry codes had been assessed, the bunds for capturing spilled materials were not up to specification against the codes (COMAH Competent Authority, 2011, p. 21). The bunds in reality did not match what was described in the artefacts (and had been observed to occasionally leak from the joints). Further, some elements of the safety report were more aspirational 'rather than a true reflection of conditions on site' (COMAH Competent Authority, 2011, p. 29), or, as we argue, likely to be in the future.

A Pike River ventilation and gas monitoring assessment also recorded actions required before hydro extraction, but they remained incomplete at the time of the explosion (Royal Commission on the Pike River Coal Mine Tragedy, 2012, pp. 164–165). The Mine Manager asserted that 'None of these issues are show stoppers and some will take time to implement' (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 165). Given that those actions would take time to implement, the assessment may therefore have converted unresolved issues into a plausible roadmap of actions; facilitating work to commence under the assumption that the issues would be addressed in *due time* – or the future state.

4.2.2. *Asserting the acceptability of risks in the absence of realistic assessment*

By acting as authoritative sources of organisational knowledge, artefacts shape what stakeholders believe, or should believe, about risks. At Macondo, BP believed that a catastrophic well blowout did not have a significant likelihood of occurring and cemented this belief in the well-permitting documentation (Deepwater Horizon Study Group, 2011, p. 84). The absence of identified risks within these assessments fostered 'deeply flawed and deficient risk assessment management processes' among operational and management teams (Deepwater Horizon Study Group, 2011, p. 87); resulting in inadequate protective barriers believed to be functional for the task.

At Texas City, the isomerisation start-up procedures lacked adequate operator instructions on how to safely undertake the activity or the critical parameters to monitor (U.S. Chemical Safety & Hazard Investigation Board, 2007, pp. 77–78). Moreover, some of the risk assessment protocols did not direct risk evaluators to consider major hazards (Mogford, 2005, pp. 92, 94). In the Macondo risk register, 23 risks were identified but only three categories of risk were selected: cost, production and schedule. Here, a 'well control problem' was defined as a cost risk rather than a safety risk (United States Department of the Interior, 2011, p. 177).

During the Australian Home Insulation Program, an initial list of risks was developed. The list identified 'installer injury' as a credible risk that

was ‘almost certain’ to occur. Despite this assessment, the formally recognised risk of installer injury was removed from the risk assessment (Hanger, 2014) that was submitted to DEWHA. In doing so, the omission either reinforced the belief among the DEWHA risk management working group that installer injury was not a credible program risk, or reinforced the belief that managing installer injuries was the responsibility of state government agencies and not the federal government.

Artefacts can therefore sensitise personnel to specified hazards while desensitising the organisation to risks they omit or classify as acceptable.

4.2.3. *Expert appeals that allay concerns*

Organisations seek to give legitimacy to artefacts and activities by appealing to expert advice or to external standards and guidelines. This increased legitimacy is not always warranted. The Australian Home Insulation Program used an external risk consultancy to increase the credibility of its risk assessment. However, the consultant was not a subject matter expert, and did not consider it within its remit to personally identify risks (Hanger, 2014, pp. 110–112). By engaging the consultant, a perception was reinforced that a ‘comprehensive risk assessment’ (Hanger, 2014, p. 121) was completed – even without engaging all necessary stakeholders (e.g., absent electrical trades; Hanger, 2014, p. 91).

Another example is the OIMS at Esso Longford. OIMS was believed to be a ‘world class system and complied with world’s best practice’ (Longford Royal Commission, 1999, p. 200). While the system was based on world-class guidelines, it did not practically function as one (Longford Royal Commission, 1999, p. 200). According to the commission, the OIMS contained important elements that were largely defective and repetitive, and contained ‘impenetrable’ language (Longford Royal Commission, 1999, p. 200). This led to a system that was difficult for personnel to understand and use.

Pike River also invested in a system considered world-class (Royal Commission on the Pike River Coal Mine Tragedy, 2012, pp. 73, 176), although many documents remained as drafts or were not followed. Management nevertheless installed the main ventilation fan underground – a globally unique design (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 84) requiring a ‘high level risk assessment’ (*Pike River Coal Underground Fan Risk Assessment Report*, 2007, p. 3). Belief in a world-class system may have helped legitimate the underground fan placement.

In the case of the Australian Home Insulation Program, some program references such as the Installation Guidelines specified that certain insulation products must be installed in compliance with the Building Code of Australia. However, the references in the building code refer to installation standards for ensuring *energy efficiency* and not for the health and safety considerations of installing insulation (Hanger, 2014, p. 199). Further, a pocketbook was distributed to insulation installers to guide safe and

effective installation practices but referred to a standard that had no application to the insulation used within that program (Hanger, 2014, pp. 199–200).

4.2.4. *Failed-silent feedback mechanism*

A system ‘fails silent’ when a fault produces no observable indication of failure (Rela et al., 1996). Safety management processes can fail similarly when they generate no negative feedback that their assumptions or controls are invalid.

Gas sensors were installed in strategic places throughout the Pike mine as part of the mine’s methane explosion prevention program (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 29). Issues were identified in some of the gas sensors. Examples included sensors not working or having ‘latched’ onto their maximal methane reading and not being able to display any greater methane values (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 137; Transcript of Hearing, 2012b, pp. 4898, 4901, 4908, 4934). The latching was visible on computerised displays as flat lines. The Mine Manager said he was not aware of the sensors latching, even though he signed a ventilation survey which had a message in red capital letters indicating that the sensor had reported a spike of methane and had latched on to that reading (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 138).

The Mine Manager expected to be alerted to faulty or latched sensors when calibration staff performed routine calibrations (Transcript of Hearing, 2012a, 2012b, 2012c, p. 4902). This assumption had two problems:

- The reports identify no process guiding calibration staff on what types of faults or issues they needed to communicate to the Mine Manager.
- Even if calibration staff would have communicated latching or faults, a number of scheduled calibrations of the sensors apparently did not occur (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 138).

Consequently, these operational oversights invalidated the safety assumptions underpinning the gas monitoring system. Other failures were also not transmitted. No documented system ensured that the Mine Manager learned of methane readings above 5% (Transcript of Hearing, 2012a, 2012b, 2012c, p. 4930), nor that required Kestrel handheld monitors were periodically unavailable without his knowledge (Royal Commission on the Pike River Coal Mine Tragedy, 2012, p. 107). The lack of Kestrels highlights that formal systems, like ventilation management systems, address only the specific parameters formalised within an artefact, neglecting the broader operational spectrum. That is, if something is not strictly formalised, routinised, prioritised or resourced—or even just regularly discussed—then it may not get completed despite its importance.

A similar phenomenon was observed at Texas City, where computerised data for start-up critical events was not effectively monitored by management despite being readily available (U.S. Chemical Safety & Hazard Investigation Board, 2007, p. 76). These examples illustrate the misguided assumption that systems will automatically transmit 'bad news' or information that the system is not working as intended.

5. Conclusions

Across seven major accident investigations, we identified 'safety alchemy': a process through which unresolved uncertainty and operational risk are converted into authoritative documentary assurance without a corresponding improvement in risk control. Extending Dekker and Nyce (2015) concept of ontological alchemy, the process operated through two linked pathways: 1) enabling devices displaced focus from uncertain operational conditions towards concrete documentary criteria, and 2) artefacts became authoritative accounts of what was considered safe, controlled, or expected to occur.

The study provides a mechanism-based explanation linking enabling devices to false assurance. Reviews, audits, and verification activities should therefore test documented claims against operational evidence and actively seek disconfirming information. Safety artefacts remain necessary, but their existence, completion, or continual refinement should not be treated as evidence that the risks they describe are adequately controlled. Verification should also compare espoused safety priorities with actual resource allocations. Activities described as critical, such as training, may receive insufficient investment; their documented existence can then supply assurance without operational capability.

The problem of false assurance (Rae & Alexander, 2017) has been raised as a key mechanism in practical drift (Snook, 2002), where safety activities, rather than improving operational risk management, contribute to excessive confidence in measures that have already been taken. Existing empirical work on false assurance points out a consistent pattern of safety documents with what in hindsight appear to be glaring weaknesses, to the point of an apparently dangerous disregard for operational reality (Clarke, 1999; Rae et al., 2014).

However, while these interventions address the outputs of the safety system, further research is needed to understand their origins. Future research should use prospective, ethnographic methods to observe the document authorship process in real time, identifying the organisational pressures that compel practitioners to prioritise the *enabling* function of safety documents over their underlying safety requirements. Understanding these pressures is vital to ensuring that safety management remains grounded in the control of risk rather than becoming an administrative exercise.

As Hayes and Hopkins (2015, p. 173) assert: ‘Risk management is always problematic when the model itself—including the alchemical use of artefacts—‘becomes reality’.

Note

1. A critical role in that mining jurisdiction that required the supervision of health and safety at the underground mine.

Author contributions

CRedit: **Ben Hutchinson**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing; **Sidney Dekker**: Methodology, Supervision, Writing – review & editing; **Andrew Rae**: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – review & editing.

Notes on contributors

Ben Hutchinson (BAppSc(HMS)(Hons), MOHS, PhD) is a senior safety manager and part-time safety science researcher interested in major accidents, safety management system and auditing failures, critical control and barrier systems, and human factors and fatigue. Ben also maintains the Safe As Youtube and Spotify channels, and the SafetyInsights.org blog.

Sidney Dekker (MSc, MA, PhD) is Professor in the School of Humanities, Languages and Social Science at Griffith University in Brisbane, Australia. Sidney has lived and worked in seven countries across four continents. He founded the Safety Science Innovation Lab in 2012, which introduced ‘Safety Differently’ and ‘Restorative Just Culture.’ Both have inspired global movements for change and undergird Griffith University’s highly popular Graduate Cert in Safety Leadership. They encourage organisations to declutter their bureaucracy and enhance the capacities in people and processes that make things go well—and to offer compassion, restoration and learning when they don’t. An avid piano player and pilot, he has been flying the Boeing 737 for a European airline on the side. He is a trained mediator and chaplain, and volunteers in Brisbane as a critical crisis chaplain. Sidney’s research track record contains over \$7.5M in extramural funding. He is prolific and bestselling author of, most recently: *Random Noise*; *Stop Blaming*; *Foundations of Safety Science*; *The Safety Anarchist*; *The End of Heaven*; *Just Culture*; *Safety Differently*; *The Field Guide to Understanding ‘Human Error’*; *Second Victim*; *Drift into Failure*; *Patient Safety*; *Compliance Capitalism*, and *Do Safety Differently*.

Andrew Rae (BE(Hons), PhD) is an Associate Professor in School of Humanities at Griffith University, where he teaches courses on research methods and safety engineering, and leads the safety research program. Drew’s own research uses a mix of ethnography, field experiments and theory-building to investigate organisational safety practices. He is particularly interested in understanding the myths, rituals and bad habits that surround the work of managers and safety practitioners, and how this work influences front-line operations. Drew co-hosts the Safety of Work podcast and is on the editorial board of the journal Safety Science.

ORCID

Ben Hutchinson  <http://orcid.org/0000-0002-6752-1930>

References

- Alfoldi, E. A., & Hassett, M. E. (2013). Dealing with unpredictability and change in longitudinal studies of organisations: A priori versus progressive focusing approach. In M. E. Hassett, & E. Paavilainen-Mäntymäki (Eds.), *Handbook of longitudinal research methods in organisation and business studies*. Edward Elgar Publishing.
- Associated Press. (2010, May 14). BP's Gulf of Mexico oil spill plan "vastly inadequate," AP investigation finds. *CBS News*. <https://www.cbsnews.com/news/bps-spill-contingency-plans-vastly-inadequate/>
- Bea, R. G. (1996). *Quantitative & qualitative risk analyses-the safety of offshore platforms* [Paper presentation]. Offshore Technology Conference. <https://doi.org/10.4043/8037-MS>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp0630a>
- Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Sage Publications.
- Clarke, L. (1999). *Mission improbable: Using fantasy documents to tame disaster*. University of Chicago Press.
- COMAH Competent Authority. (2011). *Buncefield: Why did it happen? The underlying causes of the explosion and fire at the Buncefield oil storage depot, Hemel Hempstead, Hertfordshire on 11 December 2005*. <http://www.hse.gov.uk/comah/buncefield/buncefield-report.pdf>
- Corbin, J., & Strauss, A. (2008). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3rd ed.). Sage Publications, Inc.
- Cullen, W. (1990). *The public inquiry into the Piper Alpha disaster*. H.M. Stationery Office.
- D'Adderio, L. (2011). Artifacts at the centre of routines: Performing the material turn in routines theory. *Journal of Institutional Economics*, 7(2), 197–230.
- Deepwater Horizon Study Group. (2011). *Final report on the investigation of the Macondo well blowout*.
- Dekker, S. W. A., & Nyce, J. M. (2015). From figments to figures: Ontological alchemy in human factors research. *Cognition, Technology & Work*, 17(2), 185–187. <https://doi.org/10.1007/s10111-015-0321-7>
- Hanger, I. (2014). *Report of the Royal Commission into Home Insulation Program*. Royal Commission into the Home Insulation Program.
- Hayes, J. (2015). Lessons for effective integrity management from the San Bruno pipeline rupture. *Process Safety Progress*, 34(2), 202–206. <https://doi.org/10.1002/prs.11746>
- Hayes, J., & Hopkins, A. (2015). *Nightmare pipeline failures: Fantasy Planning, Black Swans and Integrity Management*. CCH Australia Limited.
- Hollnagel, E. (2015). Why is work-as-imagined different from work-as-done?. In *Resilient Health Care: The resilience of everyday clinical work* (pp. 249–264). Ashgate.
- Hopkins, A. (2014). Issues in safety science. *Safety Science*, 67, 6–14. <https://doi.org/10.1016/j.ssci.2013.01.007>

- Hutchinson, B., Dekker, S., & Rae, A. (2022). Writing plans instead of eliminating risks: How can written safety artefacts reduce safety? *Safety Science*, 151, 105738. <https://doi.org/10.1016/j.ssci.2022.105738>
- Hutchinson, B., Dekker, S., & Rae, A. (2024a). Audit masquerade: How audits provide comfort rather than treatment for serious safety problems. *Safety Science*, 169, 106348. <https://doi.org/10.1016/j.ssci.2023.106348>
- Hutchinson, B., Dekker, S., & Rae, A. (2024b). How audits fail according to accident investigations: A counterfactual logic analysis. *Process Safety Progress*, 43(3), 441–454. <https://doi.org/10.1002/prs.12579>
- Hutchinson, B., Dekker, S., & Rae, A. J. (2018, May). *Fantasy planning: The gap between systems of safety and safety of systems* [Paper presentation]. Australian System Safety Conference 2018.
- Jackson, D. (2010). *Worked example of a problem from Leveson's "Safer World"*. <https://people.csail.mit.edu/dnj/talks/veldhoven10/comments-on-leveson-interlock-example.pdf>
- Lampland, M. (2010). False numbers as formalizing practices. *Social Studies of Science*, 40(3), 377–404. <https://doi.org/10.1177/0306312709359963>
- Longford Royal Commission. (1999). *The Esso Longford gas plant accident: Report of the Longford Royal Commission*. Govt. Printer for the State of Victoria.
- MacDonald, I. (2010). Deepwater disaster: How the oil spill estimates got it wrong. *Significance*, 7(4), 149–154. <https://doi.org/10.1111/j.1740-9713.2010.00449.x>
- Maguire, M., & Delahunt, B. (2017). Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *AISHE-J: The All Ireland Journal of Teaching & Learning in Higher Education*, 9(3), 3351. <https://doi.org/10.62707/aishej.v9i3.335>
- Mogford, J. (2005). *Fatal Accident Investigation Report, Isomerization Unit Explosion Final Report, Texas City, Texas, USA*
- 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. <https://cybercemetery.unt.edu/archive/oilspill/20121210200431/http://www.oilspillcommission.gov/final-report>
- Peerally, M. F., Carr, S., Waring, J., & Dixon-Woods, M. (2017). The problem with root cause analysis. *BMJ Quality & Safety*, 26(5), 417–422. <https://doi.org/10.1136/bmjqs-2016-005511>
- Pentland, B. T., & Feldman, M. S. (2008). Designing routines: On the folly of designing artifacts, while hoping for patterns of action. *Information and Organization*, 18(4), 235–250. <https://doi.org/10.1016/j.infoandorg.2008.08.001>
- Pike River Coal Underground Fan Risk Assessment Report. (2007).
- Pike River Coal Ventilation Management Plan. (2008). Pike River Coal.
- Rae, A. J., & Alexander, R. D. (2017). Probative blindness and false assurance about safety. *Safety Science*, 92, 190–204.
- Rae, A., & Provan, D. (2019). Safety work versus the safety of work. *Safety Science*, 111, 119–127. <https://doi.org/10.1016/j.ssci.2018.07.001>
- Rae, A., Alexander, R., & McDermid, J. (2014). Fixing the cracks in the crystal ball: A maturity model for quantitative risk assessment. *Reliability Engineering & System Safety*, 125, 67–81. <https://doi.org/10.1016/j.ress.2013.09.008>
- Rela, M. Z., Madeira, H., & Silva, J. G. (1996). *Experimental evaluation of the fail-silent behaviour in programs with consistency checks* [Paper presentation]. Proceedings of Annual Symposium on Fault Tolerant Computing (pp. 394–403). IEEE. <https://doi.org/10.1109/FTCS.1996.534625>

- Ross, J. A., Deshotels, T. H., & Forsyth, C. J. (2016). Fantasy objects: The perception of safety of emergency shelter in place kits. *Deviant Behavior*, 37(6), 692–708. <https://doi.org/10.1080/01639625.2015.1062681>
- Royal Commission on the Pike River Coal Mine Tragedy. (2012). *Royal Commission on the Pike River Coal Mine Tragedy*. Government of New Zealand.
- Sanne, J. M. (2008). Framing risks in a safety-critical and hazardous job: Risk-taking as responsibility in railway maintenance. *Journal of Risk Research*, 11(5), 645–658. <https://doi.org/10.1080/13669870701715550>
- Sinkovics, R. R., & Alfoldi, E. A. (2012). Progressive focusing and trustworthiness in qualitative research. *Management International Review*, 52(6), 817–845. <https://doi.org/10.1007/s11575-012-0140-5>
- Snook, S. A. (2002). *Friendly Fire: The Accidental Shootdown of U.S. Black Hawks Over Northern Iraq*. Princeton University Press.
- Transcript of Hearing. (2011a). Royal Commission on the Pike River Coal Mine Tragedy, 5 December. <http://pikeriver.royalcommission.govt.nz/Phase-3-Hearing-Transcripts>
- Transcript of Hearing. (2011b). Royal Commission on the Pike River Coal Mine Tragedy, 7 December. <http://pikeriver.royalcommission.govt.nz/Phase-3-Hearing-Transcripts>
- Transcript of Hearing. (2011c). Royal Commission on the Pike River Coal Mine Tragedy, 8 December. <http://pikeriver.royalcommission.govt.nz/Phase-3-Hearing-Transcripts>
- Transcript of Hearing. (2012a). Royal Commission on the Pike River Coal Mine Tragedy, 8 February. <http://pikeriver.royalcommission.govt.nz/Phase-3-Hearing-Transcripts>
- Transcript of Hearing. (2012b). Royal Commission on the Pike River Coal Mine Tragedy, 13 February. <http://pikeriver.royalcommission.govt.nz/Phase-3-Hearing-Transcripts>
- Transcript of Hearing. (2012c). Royal Commission on the Pike River Coal Mine Tragedy, 14 February. <http://pikeriver.royalcommission.govt.nz/Phase-3-Hearing-Transcripts>
- U, S. Chemical Safety and Hazard Investigation Board. (2007). *Investigation Report—Refinery Fire and Explosion*. BP Texas City March 23, 2005. <http://www.csb.gov/>
- United States Department of the Interior. (2011). *Report Regarding the Causes of the April 20, 2010 Macondo Well Blowout*.
- Weichbrodt, J. (2015). Safety rules as instruments for organizational control, coordination and knowledge: Implications for rules management. *Safety Science*, 80, 221–232. <https://doi.org/10.1016/j.ssci.2015.07.031>
- Weick, K. E. (1995). *Sensemaking in organizations*. SAGE.

Appendix

Table A1. Key evidence associated with the artefact and claims analysis.

Artefact	Accident	Claim, assumption or belief	Physical reality
BP's Regional Oil Spill Response Plan (ROSRP)	Macondo	BP provided assurances to stakeholders that a worst-case oil discharge could be responded to using proven equipment and technology	The plan was said to have taken optimistic assumptions on worst-case discharge and recovery success, and inaccurately referred to animals, like walruses and sea otters, which are not found in the Gulf region Source: Deepwater Horizon Study Group (2011, p. 11), Associated Press (2010)
Workshop for underground fan placement	Pike River	Underground fan placement risk assessment workshop provided mechanism for downgrading risks	Some of the proposed controls never eventuated, e.g., explosion-proofing for the main underground fan was not installed, nor site the fans in rock Source: Royal Commission on the Pike River Coal Mine Tragedy (2012)
Requirement for standby vessel	Piper Alpha	There was a regulatory requirement for a standby vessel to be available for emergency assistance	Vessel was a converted trawler that was unsuitable for its task Source: Cullen (1990)
Fire intervention vessel	Piper Alpha	Fire-intervention vessel was employed, which was equipped with water cannons and other equipment for emergency response	Misperception of the vessel's ability to fight fires due to inadequacies in capabilities or equipment Source: Cullen (1990)
Visual displays	Buncefield	Emergency shutdown button provided on a visual display	Several supervisors were not aware that the emergency shutdown feature had never been fitted to the system Source: COMAH Competent Authority (2011)

(Continued)

Table A1. Continued.

Artefact	Accident	Claim, assumption or belief	Physical reality
Safety Management Systems	Esso Longford	Safety Management System intended to systematically manage asset integrity and safety	Safety Management System was said to be repetitive, complex and difficult to comprehend, hence distracting attention from practical issues Source: Longford Royal Commission (1999)
Permit to work	Piper Alpha	Expectation that management was supposed to seek out news whether critical systems were functioning	Management interpreted the lack of critical news as evidence that the system worked as intended Source: Cullen (1990)
Training process	Pike River	Training was considered important by several managers	Some training processes espoused as critical were given little focus Source: Royal Commission on the Pike River Coal Mine Tragedy (2012), Transcript of Hearing et al. (2012)
Training process	Piper Alpha	Safety handbooks, said to be the “passport to survival”, were issued to newcomers to the platform	Safety handbooks contained some inaccurate or misleading information, including inaccuracies around the permit to work process Source: Cullen (1990)
Start-up procedures	Texas City	Isomerisation start-up procedures developed in order to guide safe work	Start-up procedures did not adequately inform operators about serious safety implications, did not reflect current operating practices, and could be bypassed without penalties Source: U.S. Chemical Safety and Hazard Investigation Board (2007)
Risk assessment	Australian Home Insulation Program	Risk workshop facilitated by an external consultant intended to canvass program risks	Program members misunderstood the consultant’s role in the workshop; the consultant was not an expert in program risk Source: Hanger (2014)

(Continued)

Table A1. Continued.

Artefact	Accident	Claim, assumption or belief	Physical reality
Safety Management Systems	Esso Longford	Belief by some that the Safety Management System was developed from best international practice	While the guidelines were based on international best practices, the system was not operated in that manner and said to be repetitive, complex, and difficult to comprehend Source: Longford Royal Commission (1999)
Program standards	Australian Home Insulation Program	Installation guidelines referenced the building code and standards to guide program quality and safety	Some references in the program information referred to irrelevant building standards Source: Hanger (2014)
Program pocketbook	Australian Home Insulation Program	Pocketbook was distributed to installers to guide safe and effective install practices	Pocketbook referenced some irrelevant standards that did not inform on appropriate or safe installation methods Source: Hanger (2014)
Mine ventilation gas sensors and processes	Pike River	Gas sensors installed for monitoring mine gas levels as part of the methane explosion prevention program	Some gas monitors were not working or had 'latched', and no formalised process existed to alert the Mine Manager to these issues Source: Royal Commission on the Pike River Coal Mine Tragedy (2012), Transcript of Hearing et al. (2012)
Critical safety information flow	Pike River	Some stakeholders expected to be alerted to critical information, like incidents where more than 5% methane in the mine was detected	Formalised systems alerting managers to critical safety information did not exist, including exceedances of methane measurements Source: Royal Commission on the Pike River Coal Mine Tragedy (2012), Transcript of Hearing et al. (2012)

(Continued)

Table A1. Continued.

Artefact	Accident	Claim, assumption or belief	Physical reality
Ventilation management plan	Pike River	Ventilation management plan required the mine to have a tube-bundle gas detection system installed	Tube-bundle system was not installed, despite the plan being written as if it was a continuously running system at the mine Source: Royal Commission on the Pike River Coal Mine Tragedy (2012) Transcript of Hearing et al. (2011)
Safety Management System	Pike River	Safety Management System believed to be based on world-class standards	The Safety Management System at the time of the accident had a considerable number of documents in draft, lacked executive management commitment and many system elements were not followed in practice Source: Royal Commission on the Pike River Coal Mine Tragedy (2012)
ISOM start-up processes	Texas City	It is speculated that the start-up processes and system was not configured to deliver 'bad news', and hence, absence of news was taken as evidence that the system functioned as intended	Computerised data for start-up critical events were not effectively designed or monitored by management despite being readily available; this flaw also increased the challenge for operators to monitor feed into and out of the tower – affecting their ability to de-escalate the accident sequence Source: U.S. Chemical Safety and Hazard Investigation Board (2007, p. 76)