How hindsight bias distorts history

An iconoclastic analysis of the Buncefield explosion – full version

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1 Introduction

"When the past no longer illuminates the future, the spirit walks in darkness"
Alexis de Tocqueville (1805 – 1859)

The purpose of this paper is to explain the concept of hindsight bias. Hindsight *bias* promotes the belief that adverse events are more foreseeable than they actually are. Moreover errors in the causal chain seem far more culpable with the knowledge of the consequences. I review the causes of the 2005 Buncefield Explosion where this bias, in my opinion, distorted perceptions of 'blameworthiness' and led to a failure to learn important lessons. I also discuss how hindsight bias may distort the findings of incident investigations generally, and how the bias can be minimised. This is covered in detail in section 4. It must be appreciated that learning from experience is essential for progress. But hindsight can never be wholly objective. The 'spirit' may walk *in the full light of day*, but sometimes in the wrong direction.

While hindsight is an accepted part of everyday discussion in the media and beyond, the concept is usually 'taken as read' and its implications are not debated or considered. It is not surprising that the media have not engaged directly on the issue due to its complexity. What is remarkable is that the safety movement, notably accident investigators, have neglected this vital field[1].

The diversity of adverse circumstances where hindsight bias may have played a part in investigations (and media reports) include: diagnostic errors by physicians; supervision of children at domestic risk; releases of prisoners on licence; failures to identify Soviet spies working in MI5 and MI6, and 'friendly fire' incidents. It is a commonplace that agencies and individuals are often made scapegoats following such events, in my view unfairly in most cases[2].

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1 Sidney Dekker, on whom I have relied heavily, seems, apart from my colleagues, to be to be a notable exception; see section 4.

2 Scapegoating individuals, albeit unfair, can sometimes change the course of history. In 1757 Admiral Byng was shot for cowardice (strictly, for failing to 'do his utmost') in the face of the enemy. This followed a flawed and biased court martial. Voltaire said that the execution was 'pour encourager les autres'. Indeed it did. The execution led to a sea-change in the fighting spirit of naval officers and was

Hindsight bias is often intimately linked with criminal and civil legal proceedings following serious incidents. It is sometimes, but only superficially, referred to in court by the defence in mitigation. But the fact that hindsight bias infects many prosecutions might be the basis for rebuttal. The cautions are that a rebuttal can only be sustained by secure scientific underpinning, and courts may not be impressed by a counter-intuitive argument. My interest in hindsight bias only began in 2009, despite my interest in modern history (reflected in some indulgent footnotes here) and despite having lectured for 20 years on the associated work of the seminal researchers. My belated perception was, as an expert witness, that prosecutions, supported by their experts, unwittingly overstated their cases – not in my experience to secure convictions, but rather to facilitate sharper criticisms of defendants. Equally, defences may be constrained unduly by their belief that their clients were more culpable than the objective reality.

Analysis by any of the parties (including myself) of the events leading up to adverse events, for example Buncefield, are bound to be biased by hindsight[3]. As has been stated, hindsight bias, *inter alia*, draws an over-sharp focus on errors or fallible decisions that appear far more culpable with the knowledge of what actually happened afterwards. Moreover, those who (quite sincerely) believe that they have 'factored out' hindsight in investigations are profoundly mistaken. Reason (2008) has summarised the issue as follows:

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a key factor in victories such as Trafalgar in 1805. Admiral Jellicoe's caution at Jutland in 1916 was and continues to be condemned. Though 'Jellicoe was the only man on either side who could lose the war in an afternoon' (Churchill, 1927) – and he didn't. Jellicoe did not 'do his upmost', but for compelling reasons. Incidentally the battle was a narrow tactical defeat as a result of dire communications between ships and violations of explosion-prevention procedures in Beatty's Battle Cruiser fleet. These factors bear an uncanny resemblance to those encountered in recent major industrial accidents. In any event the court martial of an admiral pre-dates by 250 years the modern view that senior managers and directors should be called to account when things go wrong on 'their watch'.

[3] I was an expert engaged to assist the court by Total UK Ltd. This is a source of bias to which readers should be alert, and there could of course be others. The opinions expressed here are wholly my responsibility and are not necessarily the views of any other organisation. I believe that almost everything stated here (apart from my own interpretation of events) is in the public domain (albeit exceptionally difficult to access in many cases). I apologise if any unwitting indiscretions cause delicacies.

> "There is a universal tendency to perceive past events as somehow more foreseeable and more avoidable than they actually were. Our knowledge of the outcome *unconsciously* colours our ideas of how and why it occurred. To the retrospective observer *all the lines of causality home in on the bad event;* but those on the spot, possessed only of foresight, do not see this convergence." [My emphases]

In the case of Buncefield, hindsight bias has particular resonance. None of the parties involved anticipated a cold petrol vapour explosion as a result of a storage tank overflow. In the aftermath, it now seems that here was an explosion waiting to happen. Thus inadequate measures taken by some of the participants to prevent an overflow appear dramatically more serious with the knowledge of the catastrophic consequences[4]. Moreover, Total UK Ltd, with the support of expert external auditors, had implemented good, and in some regards best, industry practice to promote and monitor safety at their (60% owned) subsidiary. But in the after light the fact that 'best practice' failed to detect the shortcomings in overflow prevention at plant level seems 'proof' that the systems were both inappropriate and too casually implemented.

There seems only one certain way to justify that one's opinions are not biased, post event, namely to provide uncontroverted evidence showing that the same opinions, or at least compatible opinions, were held beforehand[5]. In this context all the parties in a court case should disclose their pre-event opinions, including the regulator who might be part of the causal chain. Eventually the Competent Authority's (CA's)[6] prior role relating to Buncefield was disclosed to other parties, but too late to be of much assistance. I sought to complete a jig-saw puzzle of the events and causes via an Events and Causal Factors Analysis (ECFA) - to create a 'map' of the incident to assist the court, but vital pieces – key decisions of the CA - were missing.

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4 Of course, uncontrolled releases of flammable substances from storage tanks are highly undesirable on any terms. This is discussed further below.

5 This is my opinion. I have not encountered any comments in the literature on this, perhaps because it is self-evident.

6 The CA under the COMAH Regulations 1999/2005 comprises HSE and the Environment Agency (EA) working together. The CA acts as regulator, investigator and prosecutor. This is not an ideal arrangement. For example rail and air accidents are investigated by independent bodies.

Tozer (2011)[7] has drawn attention of the continuing failure of the MIIB to publish their promised final report on the prior roles of the CA[8]. It is now a year since the end of all legal proceedings. Perhaps the report will be published only when HSE is able to demonstrate that it has remedied the deficiencies identified in the report.

The effects of hindsight bias are uniformly adverse. But I also discuss in section 4 how hindsight (aiding understanding of the 'correct' lessons from what has happened) can better inform incident investigators about the future control of risks. Hindsight is a double-edged sword. Progress in every field depends on learning the salient lessons of experience: walking in the right direction, illuminated by the light of day.

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7 "Buncefield - An alternative review of the official story and why not to rely on a regulator".

8 MIIB (unpublished) "The Report of the Buncefield [MIIB] into the policy and procedures of the [HSE's] and the [EA's] role in regulating the activities on the Buncefield site under the COMAH Regulations".

2 Research background

"We learn from history that we never learn anything from history"
GWF Hegel (1770 – 1831)

It is not that we fail to learn anything from history; the challenge is that we sometimes draw the wrong conclusions[9].

The point of departure for studies of hindsight bias derives from a factor in research on perceptions of risk, namely the concept of 'availability' introduced by Tversky & Kahneman (1974) though with a longer ancestry. "The bias of availability refers to the greater role played in the … assessment of probability by information that is regarded as important and salient. This means that people are more influenced by events which have happened recently or frequently or which are particularly vivid" (Hale & Glendon, 1987). It is a commonplace that people's perceptions of risk increase sharply following a serious event (an air crash, nuclear incident or terrorist attack, for example), but gradually decay at a rate affected by the frequency and potency of reminders of the incident, such as newspaper reports, television documentaries and prosecutions.

The psychologist Fischoff with colleagues studied hindsight bias and published papers that now carry uncontested authority[10]. The following necessarily full quotations from Fischoff (1975) (some quotes from the separate commentary on the paper re-published in 2003) indicate the nature and consequences of the phenomenon [My emphases throughout]:

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9 Moreover there is a tendency to presume (by politicians in particular) that a new challenge exactly matches a previous experience. Prime Minister Eden's presumption that Colonel Nasser was a reincarnation of Mussolini led to the Suez fiasco in 1956 (Eden, 1960). On the other hand Barbara Tuchman's book (Tuchman, 1962) describing the muddles and misunderstandings that led to the Great War was widely read in Washington DC. The influential lessons helped President Kennedy avert the outbreak of World War 3 during the 1962 Cuban missile crisis. The book was published by Macmillan. Prime Minister Macmillan was a director.

10 Fischoff with Slovik & Lichtenstein also carried out the seminal work on public perceptions of risk. Their key conclusion was that the public do not rely on statistical risk data to inform their judgements; rather they are most influenced by their dread of an adverse event and whether the people responsible for prevention are perceived as competent and their spokespeople worthy of trust. After a serious incident risk perceptions are bound to rise per Hale & Glendon (ibid) and also because an event may undermine perceptions of competency and trustworthiness.

> "The hindsight bias is a projection of new knowledge into the past accompanied by a denial that the outcome information has influenced judgment. Thus, subjects who learn of an outcome in a hindsight experiment typically claim that they 'would have known it all along.'"
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> "… it appears that what passes for the wisdom of hindsight often contains *heady doses of sophistry* - that the perceived inevitability of reported outcomes *is imposed upon*, rather than legitimately inferred from, the available evidence."
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> "Consider a decision maker who has been caught unprepared by some turn of events and who tries to see where he went wrong ... If, in retrospect, the event appears to have seemed relatively likely, he can do little more than *berate himself* for not taking the action which his knowledge seems to have dictated … *When second guessed by a hindsightful observer, his misfortune appears to have been incompetence, folly, or worse*."
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> "Given knowledge of outcome, reviewers will tend to simplify the problem-solving situation that was actually faced by the practitioner. … *Possessing knowledge of the outcome, because of the hindsight bias, trivializes the situation confronting the practitioners and makes the correct choice seem crystal clear*."

Dekker (2004) illustrates that while the concept of hindsight bias is well understood, there is research still to be done to find ways of eliminating its venomous effects:

> "Any random sample of accident reports will put the hindsight bias *on full display*. If we, besides monitoring and documenting the effect of hindsight, propose no psychological theory of *why* people disfigure history, we will come up short on solutions for keeping the hindsight bias in check, even if we all agree that it needs to be kept in check."

As mentioned already, I attempt some suggestions on how to combat hindsight bias in incident investigations (section 4), but as far as I know there has been no attempt yet on the psychological theory. But perhaps that does not matter if empirical (near) solutions are available, eg, the use of systematic incident investigation models. There is a substantial literature post Fischoff on hindsight bias experiments where proposals are made to mitigate its effects. Some of these proposals (discussed in detail in section 4) essentially involve seeking to understand the mindset and environment in which practitioners, for example physicians, carry out their hazardous tasks, eg, Wears & Nemeth (2007).

I now turn to how hindsight bias distorted the lessons of Buncefield, and particularly how it discredited the good practice safety management procedures adopted by Total UK Ltd.

3 The Buncefield Explosion

"We can be almost certain of being wrong about the future, if we are wrong about the past"
GK Chesterton (1874 – 1936)

We are wrong about the past in two respects: first inappropriate lessons may be learnt. Secondly some people do not act on any lessons at all, often because they do not see that an adverse event is relevant to them. This section focuses mainly on the first challenge, though the second seems equally important.

The Buncefield explosion occurred at 06.01 on Sunday 11 December 2005 at Hertfordshire Oil Storage Ltd (HOSL). It followed an overflow of 37 tanker-loads (250,000 litres) of petrol from Tank T912 into the surrounding bunded area. The source of ignition was a spark from the fire pump electric motor when the emergency shutdown was belatedly activated. The explosion destroyed the Oil Storage Depot (OSD) site and caused substantial off-site damage and pollution[11], but by extraordinary good fortune nobody was fatally injured.

HOSL was owned as a joint venture partnership (JVP) by Total UK Ltd and the Chevron Corporation. Total held 60% of the equity and appointed three directors, and Chevron 40% with two directors but the latter could veto 'majority' Board decisions. Total employed all but one of the seventeen HOSL personnel and were responsible for safety under the terms of the JVP. HOSL was one of a number of OSDs on the Buncefield site (MIIB, 2008).

The issues considered in this section are the:

- The events leading to the explosion;
- The prosecution of Total and the adequacy of their safety regime at HOSL;
- Perceptions of the foreseeability of cold petrol vapour explosions, and their impact on overflow precautions;
- Underlying and root causes.

[11] Largely ground pollution as a consequence of 'fire water' resulting from the decision taken by government that the tank fires should be extinguished, rather than allowed to burn out.

The events leading to the explosion

The overflow was a result of a failure of an endemically unreliable automatic tank gauge (ATG) level indicator/alarm together with the non-operation of an apparently functioning independent high level (supply cut-off) switch (IHLS) but which had a crippling *latent* defect.

A very experienced night-shift pipeline supervisor, with multiple other tasks and concerns, including frequently-amended product schedules and a domestic emergency, misunderstood which tank was being filled and from which pipeline. He thought the tank being filled was from a low-flow-rate 'Chevron' pipeline (as was recorded in the day-shift log[12]). This was a result of a misunderstanding by the day-shift supervisor, and a cursory shift handover.

The night supervisor did not realize the ATG *alarm* had failed to operate or later that the tank was overflowing not wholly unaccountably as he presumed that the tank was far from full at the time. Earlier he did not monitor the *level* in the tank – not an essential check for him when the tank was (he believed) far from full. This would have revealed that the ATG had seized up, ie, the graph displayed on the VDU was 'flatlining' despite the tank filling up; but not of course the latent IHLS failure. The ATG filling graph was hidden behind other 'windows' on a 'System Control and Data Acquisition' (SCADA) VDU[13].

In the control room there was a not uncommon over-reliance on warning systems, and therefore the presumption was, despite incomplete knowledge of recent ATG failures[14], that both devices were working correctly. The pipeline supervisor could not have

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[12] Shortcomings in shift record keeping and shift handovers were key causal factors in the explosion on Piper-Alpha (1987), and at Longford (1998), Port Talbot (2001) and Texas City (2005).

[13] The prosecution, later supported by Judge Calvert-Smith when sentencing, criticised the use of 'windows' displays. He agreed that each key variable should be shown on a separate screen. I suspect that if 'windows' displays (or others with multiple data screens available) were 'banned' the decision would result in consternation in the industry. My own impression is that access to all relevant parameters on one VDU has significant benefits.

[14] On the tank that overflowed the ATG had actually failed 14 times in the previous three months.

known about the IHLS latent inoperability as no-one knew about it. The endemic ATG unreliability was poorly communicated generally (and to the HOSL maintenance manager in particular). Despite frequent 'call-outs' by control room supervisors, Motherwell Control Systems (MCS), who were contracted to carry out maintenance, failed to grapple effectively with the problem – sometimes because the ATGs started working again before they arrived, or had already been rectified by the supervisors themselves from the control room. But the IHLS failure to cut off the supply to the tank was the immediate cause of the overflow[15]. MCS who also installed and maintained the IHLS were I believe primarily responsible for the overflow, though not of course for the amount of petrol released. Total/HOSL have been criticised for not 'rumbling' MCS regarding the ATG failures, a serious error with hindsight. But as will be explained below, MCS's errors in the installation of the IHLSs could not reasonably have been detected.

HOSL managers were under a lot of pressure. Paradoxically some were completing the COMAH Safety Report and supporting documents. But pressure was exacerbated by managers (who were Total employees) being sent to 'troubleshoot' at Total's OSD at Colnebrook. This was an unfortunate decision and belies the initial argument by Total that while 16 HOSL staff (of 17) were Total employees they were on permanent secondment to the JVP. However a decision was made to postpone the introduction of the environmental management standard (ISO14001) to reduce the load on senior staff. Nonetheless two senior HOSL staff were at the end of their tether in the weeks preceding the explosion[16].

HOSL supervisors appear to have been reasonably meticulous in defect reporting – a cause for isolated congratulation. Prosecution evidence lacked grace in this regard. HOSL supervisors were criticised for crying wolf too often and that the real issues for

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[15] Strictly an IHLS is exclusively a 'safety device', whereas an A TG is a 'process control' device (with lower reliability standards). Of course ATG failures very substantially degrade the system.

[16] One manager submitted his resignation at the time. This is a rare example where a person had pre-event incontrovertible evidence to show that his opinions were not biased later.

MCS were hidden by the noise of their unnecessary call outs. The so called 'unnecessary' call outs properly reflected the belief of supervisors that all faults, whatever happened later, merited reporting.

The pipeline supervisor has been scapegoated for not checking the ATG level. In fact he was doing his best in challenging conditions[17], and his behaviour seems consistent with the prevailing culture of the HOSL control room. A nuance of hindsight bias is the presumption that personnel should have spent their time exclusively addressing the issues that only subsequently emerge as critical.

In fact the errors which led to the defective installation of the IHLS also by MCS were dramatically more culpable. Primary responsibility for the faulty IHLS (and ATG) lay with MCS and here some prosecution criticisms of HOSL/Total were based on counsels of perfection, without acknowledging normal practice in the industry sector as described by Toone (2006)[18]. Even if HOSL had been the most 'intelligent customer' they would still have needed extraordinary insight to counter the (now obviously bizarre) opinion of MCS engineers that padlocks, in fact *essential* as an IHLS balancing device, were merely an *optional* security provision.

After installation MCS engineers simply deposited the padlocks in the HOSL control room. It is perhaps the best example of hindsight bias in the whole case that HOSL staff were expected to deduce that a 'security' padlock was in fact crucial to the operability of IHLSs. In a uni-causal world (see section 4) the padlock misunderstanding by MCS staff leading to their non-fitment was the seminal error (an unsafe *act* by MCS that served as an unsafe *condition* for HOSL). MCS staff installed IHLSs at several sites without even seeing the installation instructions. The instructions were written by TAV, the manufacturer. While the TAV design appears suitable, the company should have issued instructions as a matter of course and free of charge. It was not appropriate that they

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17 These included the news during the shift that one his children had been injured in a car crash.

18 Nick Toone was the HSE inspector responsible for Buncefield. In the aftermath he completed an MSc at Cranfield University. The findings of his dissertation largely contradict a part of the prosecution's case. The dissertation was available on Cranfield's web site in March 2010. It is no longer there.

made a charge for supplying them. TAV *sales* literature was anyway ambiguous as to the role of the padlocks.

The IHLS latent defect could only have been detected by an in-situ fully-realistic test (though perhaps using water, not petrol). But such a test (in principle highly desirable) was opposed for plausible reasons by all parties; including HSE (on safety grounds), BPA, and Chevron whose concern (noting the substantial outages involved, particularly if water was used) was the effects on throughput. An MCS engineer advocated a full test, but this was not company policy. A test involving the removal of IHLSs from tanks was eventually judged sufficient. Again, a well-considered decision based on a wide-ranging review looks badly flawed with hindsight.

The prosecution argued that a full COMAH review of the new IHLS design should have been made by HOSL, citing the Flixborough explosion in 1974 as a wholly inappropriate precedent. In fact the regulation only calls for reviews of significant plant changes, not like-for-like up-grading of safety devices. Incidentally the prosecution's assertion that *no one* had *applied their minds* to whether the chosen test method was adequate is fatuous, and is wholly inconsistent with the evidence available. But yet again it shows hindsight bias rampant, relying on post hoc knowledge of the outcome, and also the presumption that all those involved 'should have known' that the IHLSs suffered a latent defect only discoverable by fully-realistic testing. As Fischoff (ibid) states (see above):

> "Possessing knowledge of the outcome … trivializes the situation confronting the practitioners and makes the correct choice seem crystal clear".
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> "… it appears that what passes for the wisdom of hindsight often contains *heady doses of sophistry* - that the perceived inevitability of reported outcomes *is imposed upon*, rather than legitimately inferred from, the available evidence."

The latter quote describes the effects of hindsight bias at their most corrupting.

A paradox is that the petrol being pumped into Tank 912 belonged to Chevron, supplied by 'their' pipeline over which HOSL staff had no direct control[19]. In contrast HOSL supervisors could manage pro-actively deliveries from the Total pipeline. But in the aftermath, Total's *best* practice systems were the foundation for criticisms of 'Chevron's' arrangements. Incredibly, Total were blamed for the alleged shortcomings of approved (though far from ideal) systems. All this might form the plot for a 'Kafkaesque' novel.

Total were wholly responsible for safety at HOSL but Chevron (with Shell, see below) were de facto at least an equal partner in production scheduling. Chevron's throughput increased by 50% between 2001 and 2005. This was a significant causal factor in the challenges facing the control room supervisors (and maintenance staff), and promoted rule-violations. (Total's throughput increased by less than 8% over the same period). The reason for the increase was that Shell closed their OSD at Buncefield and three vital storage tanks were dismantled. They transferred their operations to HOSL via a contract with Chevron. Shell were therefore a key player in HOSL throughput scheduling. Moreover, supervisors encountered increasing problems with the reduction in storage capacity. Shell's place in the causal chain seems to have got lost in the post-accident investigations. As usual it is necessary to explain that my oblique or overt criticisms of the prior roles of Chevron and Shell (and of course HSE) are magnified by hindsight bias. Being part of the causal chain is not the same as being culpable. And this applies to Total as well.

A mantra of safety professionals is that any incident 'could have been worse'. That one of the largest explosions in peacetime for 100 years could have been even more catastrophic[20] is a lesson of general applicability to the chemical process industry notably when conducting risk assessments. Details of the 'worst' case scenario are essential data. But even where the worst case is barely credible, good practice reliable physical

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19 Chevron's products were delivered by two pipelines owned by BPA – a Shell & BP JVP.

20 An adjacent heavily damaged office block was unoccupied over the weekend.

precautions, and procedures rigorously implemented, prevent adverse events (such as an overflow) whatever the magnitude of the consequences.

The prosecution of Total and the adequacy of their safety regime at HOSL

Hindsight bias may distort the findings of accident investigations generally. In the context of Buncefield hindsight bias is on full display – several examples have already been given. Apart from the question of the foreseeability of the explosion, discussed in detail below, a key issue was the suitability of Total UK Ltd's safety oversight of the JVP (HOSL). A vital element was the engagement of DNV (Det Norske Veritas, an industry leader) to carry out safety audits at 'Total's' OSDs[21]. HOSL also were certificated to the ISO9001 quality management system and had been successfully audited for compliance in 2005.

Incidentally, there were also unfortunate misinterpretations of the daunting quantity of evidence gathered for the prosecution. The prosecution's primary expert witness's authoritative and comprehensive report taught me a great deal. But in important areas I believe he was mistaken and prone to 'gold-plating' good safety practices to take account of 'what was at stake'. My impression is that his report was not subject sufficiently to peer review[22]. This will become more important with the changes in the law proposed by the Law Commission relating to the reliability of expert reports.

HSE were under enormous pressure carrying out an enquiry of unprecedented complexity. While the quality of the interviews carried out by HSE inspectors (drafted in for this purpose) left much scope for improvement, the pressure they were under - interviewing for weeks on end – was intense. But their challenge does not wholly excuse the fact that one HOSL manager was obliged, in an interview transcribed onto *182 pages*, to question the accuracy of a *15 page* summary statement, prepared by the prosecution, of

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[21] At Total's request their OSDs were audited with the DNV International Small Site Safety Rating System (ISSSRS). Total's refineries were audited with the International Safety Rating System (ISRS). ISRS was developed originally by the US International Loss Control Institute (ILCI).

[22] For example any reviewer would question a statement to the effect that HOSL supervisors 'cried wolf' when reporting ATG failures to MCS, see above.

his previous interview. Personnel in the causal chain were profoundly traumatised by their experience, and this was not helped by their being interviewed under caution – necessarily for days in some cases. Hindsight bias makes participants believe that their actions were more reprehensible than the objective reality[23] leading them in turn to blame others unduly for their part, often in exasperation. When cherry picked relentlessly by the prosecution (as was too prevalent with all the evidence) such comments when quoted in isolation may present a far more austere picture than the witnesses intended.

The failure of Total's 'high level' management systems to detect and address the incompetence of safety device suppliers[24], and inadequate control room procedures, now leads to a range of hindsight biases. The prosecution argued mistakenly that the audits by DNV (an internationally highly-respected company) were critical of HOSL's safety systems, when they *were actually very positive*. Moreover Total/HOSL were criticised for not taking the DNV audits seriously. In fact the audits were thoroughly reviewed (with full minutes) and acted upon. A (Total) director of HOSL was intimately involved. He contributed some perceptive observations. HOSL scored 94.7% in the audit section most relevant to the causal factors of the overflow. Incidentally, with hindsight, HOSL's determined efforts at the time to improve safety in tanker loading and hot work precautions seem almost a misdirection of effort.

But the DNV industry best practice audits commissioned by the parent company did not engage, as it emerged, sufficiently on day-to-day *operational* pressures and practices. Thus a key learning point was masked in the prosecution evidence.

The previous paragraph is important. Prosecutors may focus only on the 'reprehensible' deficiencies of the accused, not on the potentially causal involvement of third parties (eg,

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[23] "If, in retrospect, the event appears to have seemed relatively likely, he can do little more than *berate himself* for not taking the action which his knowledge seems to have dictated …" (Fischoff, ibid)

[24] While HOSL's management of the ATG failure epidemic was deficient, they had no reason to suspect the IHLS. Relying on MCS was though the basis of a 'common mode' failure, namely that a then well-regarded company appears to have been in operational and technical disarray at that time.

DNV, Chevron & Shell – and HSE). In-house representatives in turn may down-play or attribute to others deficiencies that might facilitate prosecutions or civil claims.

The DNV audit reports were actually models of their kind. Prosecution criticisms of the audit protocol (in terms of its selection by Total) were largely founded on the seriously-mistaken belief that a US process industry protocol should have been used, despite that standard's clear preliminary statement that it did not apply to flammable liquid storage at ambient temperatures and pressures. It should be noted that the DNV audits did engage on safety procedures at the grass roots. HSE did not demur at the audit system (included in the COMAH report) pre-event. My opinion is that Total/HOSL would have fared pretty well even in terms of the more demanding process-specific US standard.

Perhaps an important lesson from Buncefield is that good/best practice in the safety oversight of subsidiary companies may be deficient generally. The historical learning point is that Total had every reason to believe that their systems were sufficiently robust to ensure safety at HOSL. They were adopting good, and in important regards, what at the time was considered to be best practice, including appropriate review at HOSL Board meetings. But the 'reach' of their systems was deficient. This is a disquieting reflection that challenges the conventional wisdoms in major hazard industries.

Total would have had to 'micromanage' HOSL's safety and operational systems to uncover and address their well-disguised long-standing but unacceptable local working practices. But micromanagement of subsidiaries is rightly anathema in the business community. Auditors should consider afresh the scope of their audits of subsidiaries to uncover such problems, even at the risk of promoting micro-management, albeit temporarily.

Total pleaded guilty to charges under sections 2(1) & 3(1) of the Health and Safety at Work Etc Act 1974. While it is my opinion that Total had principled reasons for pleading not guilty, they were unlikely to find favour with the court. Juries are not immune to hindsight bias, and anyway Total were not 'bullet proof'. A 95% rebuttal of

a prosecution's case is no rebuttal at all. Moreover mitigation based on arguments that appear to constitute a defence is likely to irritate a judge.

For impenetrable reasons the legal advisers to HOSL (as a JVP involving Chevron) pleaded not guilty, in the end unsuccessfully. Their defence was essentially that Total were wholly responsible for everything that HOSL did, including 'ownership' of the HOSL COMAH Safety Report. MCS (for technical reasons) and TAV also pleaded not guilty, without success[25]. At the risk of hyperbole, Total, a French company, were the 'fall guys'. All the opprobrium fell on them. While their guilty plea was based on a realistic appraisal, they thereby lost the opportunity to challenge the evidence of other defendants, notably that of HOSL, at the trial. Moreover, while it would have been wholly inappropriate to have prosecuted Chevron, Shell and others, their 'failings' were laid at Total's door.

As just stated, the CA has explicit duties under COMAH. The CA were part of the causal chain that led to the Explosion, not just because of their belief (shared with others) that an overflow was not a MAH. The MIIB report on the policy and procedures of HSE and the EA in regulating the activities on the Buncefield site has still not been published (Tozer, 2011), see above. The essential point is that the prosecution asserted, *inter alia,* that all the problems at HOSL should have been identified by Total (as the employer), skating over the fact that the CA itself did not address these problems despite their inspection of OSDs and their regulatory expertise generally.

In the counter-factual case where the CA was not exempt from prosecution and there was an independent prosecutor, the latter would, I presume, have examined the CA's possibly culpable role in the causal chain.

It is my opinion that the CA did not comply with their duties under the COMAH Regulations. The CA's quasi-statutory regulatory regime was honoured in the breach, largely because of staff shortages. Moreover HSE guidance, with hindsight, was badly

[25] BPA pleaded guilty to a charge under environmental legislation as did Total.

flawed. HSG176 "The storage of flammable liquids in tanks" HSE (1998) only *recommends* the fitment of an ATG alarm, and states that an IHLS *may* also be fitted[26]. HSE (1999/2006) guidance states:

> "An occurrence will be a major accident if it meets the following conditions:
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> (a) it results from uncontrolled developments at an establishment to which the Regulations apply; and
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> (b) it leads to serious danger to people or to the environment, on or off site; and
>
> (c) it involves one or more dangerous substances defined in the Regulations, irrespective of the quantity involved."

An overflow of flammable liquid from a storage tank, even if small quantities are involved, seems to meet these criteria.

The regulator's belief was that overflows were not critical events illustrated by HSE (1998) and despite HSE (1999), and this is the matter to which I will now turn in detail.

Perceptions of the foreseeability of cold petrol vapour explosions, and their impact on overflow precautions

I have mentioned already that the oil 'majors' in common with HSE believed that a cold petrol vapour explosion from an overflow was not reasonably foreseeable. The worst scenario was seen by them as a fire contained within a bund. As a result overflow from tanks was not judged to be a major accident hazard (MAH) under the site's COMAH regime, despite HSE (1998). This was perhaps an important causal factor of the overflow on 11 December 2005.

A quantitative risk assessment was not completed as it was not required for the COMAH Safety Report. Overflow prevention was not included in (otherwise very appropriate) COMAH training. The safety challenges for control room staff associated with substantially increased throughput & reduced storage capacity, and the impact of penalty charges, were barely considered. The need for documented procedures (though

[26] But if automated devices are fitted they must be highly reliable as operator vigilance can no longer be relied upon (Kletz, 2009).

in fact based on 'golden rules') for pipeline and storage operations was not engaged upon. 'Turf wars' with other OSDs on the site continued unabated. Two overflows at another OSD were reported to HSE without follow-up. There was no compelling impetus to deal effectively with the shortcomings in the ATGs referred to above. Crucially the need to test the IHLSs in situ, though fully considered by all parties, led to the mistaken conclusion that the test was not necessary. This was despite a mid-2003 overfill causing tank damage that had resulted from an ATG failure and an IHLS (of an earlier design) that operated late. The paradox was that as a result of the incident a new contract was made with MCS to increase their maintenance work on site, thereby placing further reliance on that company.

As has already been stated, releases of flammable substances from storage tanks are highly undesirable on any terms. The point here is that this important issue went 'below the radar' when the focus was on MAHs and the completion of the COMAH Safety Report. It is well-established that where personnel confront major hazards their perception of the seriousness of other adverse events is diminished, eg, HSC (1993).

It is now clear that a number of well-documented incidents in the 1980s-90s demonstrated that cold petrol vapour *could* explode in circumstances not dissimilar from Buncefield (Kletz, 2009), but the industry and its regulators had simply forgotten or overlooked these events. So no one of the parties involved anticipated an explosion as a result of a tank overflow[27]. The myopia is easily explained by the 'availability' concept (Tversky & Kahneman, ibid).

The Major Incident Inquiry Board (MIIB, 2008) acknowledged that an explosion (and certainly not one of the most violent explosions in peace-time Europe for a century) was not 'realistically credible'. Recommendation 1 of MIIB (ibid) reads:

> "Operators of Buncefield-type sites should review their emergency arrangements to ensure they provide for all reasonably foreseeable emergency scenarios arising out of credible major hazard

[27] As an example the local authority approved a business park built right up to HOSL's boundary.

incidents, including vapour cloud explosions and severe multi-tank fires *that, before Buncefield, were not considered realistically credible.*" [My emphasis]

This italicised observation was scorned by Kletz (ibid). The conventional wisdoms of an industry may not be influenced sufficiently by incident experiences that may appear at first sight to be of little direct relevance, and this is another lesson of Buncefield. The challenge of factoring out hindsight bias is sometimes dwarfed by failures to begin to engage on the findings of major incidents or indeed near misses.

HSE has had a substantial influence on HOSL (and other) COMAH Safety Reports[28]. For example HSE generic reliability data were used to assess the likelihood of safety system failures. Such data may be almost meaningless averages of high reliability components, and devices (or batches) with dire durability. At Buncefield the ATGs and IHLSs installed and maintained by MCS fell into the latter category[29] and average industry reliability figures were therefore misleading. As was the case in the Port Talbot explosion, control room personnel and their managers unwisely 'worked round' these deficiencies for significant periods (Booth, 2006).

HSE are taking important initiatives to review their COMAH compliance regimes, see HSE (2010). My impression is that they too recognise that the 'reach' of their compliance regimes (parts analogous to independent audits) may be insufficient. I hope that a new version of HSG176 will be published to consolidate HSE's 'emergency' technical responses to the explosion.

Prosecutions, while in the public interest, involving austere criticisms of defendants (discussed above) may reduce the impact of HSE's initiatives. If an employer (Total) is prosecuted for failing to oversee the safety of a subsidiary where the key argument is that they were incompetent, HSE has difficulty in cautioning that well-motivated parent

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[28] This is not a criticism of HSE. It is the regulator's duty to guide duty holders, relying on the best evidence available. The downside of a 'safety report' compliance regime is that regulatory approval may become the pre-eminent objective.

[29] The use of HSE data may ensure regulatory approval, but what also matters is the local experience of safety device reliability.

companies (in my opinion including Total) using good practice safety oversight arrangements may still be highly vulnerable to shortcomings in site operational practices. HSE (2011), generally a well-balanced account, goes some way to dealing with this (though DNV's role seems not to have been worthy of mention).

Underlying and root causes

Strictly the pathway from underlying to root causes is a continuum. Creating boundaries between these terms is artificial. Underlying causes for the purpose of this paper are those that relate directly to errors in the full sequence of events leading to an incident. For example the error made in the shift log on 10 December was associated with an underlying cause - namely that shift record keeping was less than adequate generally. But the root causes emerge from asking 'why' – perhaps several times. In this case the root causes included mistaken perceptions of the importance of record keeping by the control room supervisors and poor communications – part of their embedded culture. Many of the causal factors at Buncefield have a long ancestry. Inadequate shift logs and handovers in particular have been significant issues in many major incidents as has already been mentioned. The effectiveness of initiatives to improve for example record keeping and communications may depend on the efforts made to change deeply entrenched beliefs (and behaviours) in the organisation.

Taylor & Rycraft (2004) in a study of five major incidents demonstrated not only that there was a pattern of underlying causes, but also a pattern of root causes such as those just described:

> It has become increasingly clear that these types of events have deep-seated, organizational and cultural root causes …"

They described the causal factors of one major incident, relying on Hopkins (2000), as follows:

> "A series of *local plant level* shortfalls occurred. These included failure to carry out systematic risk assessments …; poor communication, particularly at *shift handover; a lack of management and operator awareness of the safety issues,* demonstrated by inadequate procedures and training; the acceptance

of *informal rule-violating practices* to get the job done *(e.g. response to alarms);* and the *buildup of maintenance backlogs*." [My emphases]

There are two important learning points; first that this account describes the causes of the *Longford Explosion* in 1999. It could equally apply to Buncefield without the need for significant amendment. Secondly that the appropriate regimes for promoting, securing and monitoring safety by a parent company of a subsidiary may be deficient in 'reach' (a recurring theme), namely in identifying *plant level* operational deficiencies.

Suitable methodologies for determining peoples' attitudes to risk and related matters have been used for 15 years or so, see eg BS18004 (BSI, 2008), though there is conflicting evidence as to the best techniques to adopt. My opinion is that 'cultural' methods, including questionnaires and focus groups, should at least provide a useful indication of the cultural root causes that companies need to address. As an example, such surveys might reveal that endemic rule-violations are condoned by managers. An alternative method (though best used in combination) is 'Behavioural Safety' (BS) where staff are observed at work with immediate feedback of concerns, see BSI (ibid). This technique has become something of a panacea solution in the chemical industry world-wide regrettably focussing only on the reduction of 'industrial' accidents, rather than on the day-to-day observation of eg control room behaviours. This is another example of safety initiatives having insufficient 'reach'. Both methods have worked well in some organisations. Survey methods falter when managements fail to take action on the findings. Effective BS depends on the organisational preparedness of the company and the selection of the behaviours meriting observation (Horbury & Wright, 2000; Brown, 2009).

I have referred already to the fact that the underlying causes of recent incidents, such as inadequate control room procedures, have a long ancestry. Put another way, there have been repeated failures to learn from, and implement, precautions to combat these causal factors. There seems to have been a state of corporate myopia of breath-taking proportions in the international chemical process community – of which Total are a part.

One remedy is that details of adverse events should be widely disseminated. The presumption of the recipients must be that an external adverse event is relevant even where some of the causal factors may not apply. Someone asked me: what was the key message of Buncefield? My not wholly flippant response was that Kletz (2009) should be made obligatory reading in the chemical process industry[30].

[30] "What Went Wrong? Case Histories of Process Plant Disasters". I might have added books by Reason, eg, Reason (1990 and/or 1997). Certainly his models of human failures (latent and active; slips & lapses; mistakes; fallible decisions; and routine, situational & exceptional violations) should be used in incident investigations. A conclusion that an accident was 'caused' by human error is as useful as saying that a fall from a scaffold was due to gravitational forces; an aphorism told to me by Kletz.

4 Hindsight bias and incident investigation

"History, as the study of the past, makes the coherence of what happened comprehensible by reducing events to a dramatic pattern and seeing them in a simple form"
Johan Huizinga (1872 – 1945)

All the foregoing is predicated on the fact that hindsight bias is a malign influence notably in incident investigation and legal proceedings. But if bias is minimised the simplifications of hindsight captured by Huizinga (quoted above) and by Reason (2008) (in section 1): "To the retrospective observer all the lines of causality home in on the bad event" *is actually an advantage*. The sequence of events and conditions leading up to the bad outcome are still the important issues even if people, such as 'practitioners', are blamed unduly for their part. The targeted investigation approach, if it explores underlying and root causes, provides a coherent, comprehensible but simple (but not simplistic) explanation that can be used to devise appropriate precautions to minimise repetitions, and more. But there are considerable challenges that stand in the way of this ideal outcome. The obstacles are of course linked to hindsight bias. They are covered in the following sub-sections:

- the heightened perceptions of risk of investigators immediately after a serious incident;
- perceptions of the rationality of the behaviour of incident participants;
- experience of investigators and their beliefs of causation.

The final sub-section addresses the value of analytical methods, notably Events & Causal Factors Analysis (ECFA), in structuring and thereby maximising lessons learnt from incidents, and to minimise bias.

Heightened perceptions of risk

Figure 1 shows how perceptions of risk increase dramatically immediately after a major incident and then gradually decay. This was mentioned early on in section 2 in the context of 'availability'. An incident investigation naturally takes place when perceptions are close to their peak. At this point hindsight bias exaggerates the

likelihood and perhaps the severity of a repetition. And the mantra of the investigators and the public is that 'this accident must never happen again'.

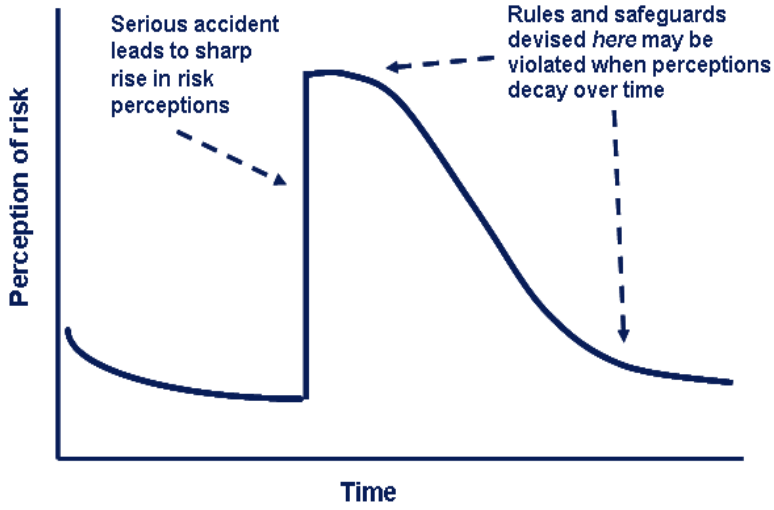

Figure 1 Perceptions of risk following a serious accident (from Booth (2000))

The primary purpose of incident investigations, in addition to determining the causal factors down to root causes and reviewing the safety management systems, should be to introduce proportionate controls to prevent repetitions of causally-related events.

But as shown in the figure, all too frequently, controls put in place when perceptions are at their peak may be violated when perceptions decay and the new controls may be viewed as over-bureaucratic and disproportionate. Two points emerge: first that investigators should recognise that their perceptions (and those of the public) are heightened and this may affect their recommendations. Secondly that the chosen precautions should be re-evaluated in (say) a year's time, when passions have cooled, listening to those who have to comply with them, with a view to dismantling some of the

unduly austere new rules. It is a commonplace that investigators (and regulators) having identified rule violations propose yet further rules – exacerbating the challenge[31].

Perceptions of the rationality of behaviour

As has been mentioned briefly already, the purpose of the seminal research on hindsight bias was to determine how people can learn better from experience. Dekker (ibid) observes that in order to understand incidents it is essential to understand the environments in which people are working and the rationality of their decisions in these circumstances:

> "A key commitment of the new view to human error [references omitted] is to understand why it made sense for people to do what they did. A premise is that system goals and individual goals overlap; that people do not come to work to do a bad job. Behaviour is rational within situational contexts." …
>
> "Jens Rasmussen points out that if we cannot find a satisfactory answer to questions such as 'how could they not have known?' then *this is not because these people were behaving bizarrely* [reference omitted]. It is because we have chosen the wrong frame of reference for understanding their behaviour. *The frame of reference for understanding people's behaviour is their own normal, individual work context, the context they are embedded in and from which point of view the decisions and assessments made are mostly normal, daily, unremarkable, perhaps even unnoticeable*[32]. A challenge is to understand how assessments and actions that from the outside look like 'errors' become neutralised or normalised so that from the inside they appear- non-remarkable, routine, normal." [My emphases]

Wears & Nemeth (2007) state pithily: "We do not learn much by asking why the way a practitioner framed a problem turned out to be wrong. We do learn when we discover why that framing seemed so reasonable at the time."

All this counters bias predicated on the fact that blameworthiness is magnified if investigators think that acts were not only unsafe but also inexplicable and/or irrational.

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[31] The mining industry where many major disasters from 1907 added to the already over-prescriptive legislation, has led to endemic rule violations becoming institutionalised. This partly explains the appalling fatal accident rate in the now emasculated industry.

[32] Violations that are routine for control room supervisors and condoned or approved by their immediate managers may be particularly difficult for safety auditors to detect. Moreover potential 'whistle-blowers' may not see such issues as meriting disclosure.

Note that I have not explored the mind-sets and decision-processes that led MCS to believe that IHLS padlocks were for security only. A review of the evidence might show that what looks an inexplicable decision was actually rational in the minds of those involved – and why. A full review (which I should have done) *might* have tempered my austere criticisms of MCS, though not of course the salience of the issue in the causal chain.

In a more recent case the defendants argued that the actions of the deceased person (DP) were bizarre (thereby excusing the overall lack of precautions in the company). I sought to explain the DP's behaviour (rational to him) underpinned by the principles enunciated in the above quotations.

Dekker's and Rasmussen's comments serve to emphasise that incident investigation must take into consideration the historical, social and cultural context in which the decisions, errors *or practices* that apparently contributed to the event were made or became the norm. Interpretations of the emerging data must be anchored to what was 'normal' knowledge and practice within the industry and organisation when critical contributing decisions were made or actions taken. Whilst the passage of time might have made those decisions or actions appear out-of-date they would have been judged as reasonable at the time. For example, within my memory, drinking and driving was considered reasonable behaviour. Moreover the independent inquiry report on the Flixborough Explosion (HSE, 1975) was untroubled by evidence that safety management was dire and that breath-taking short cuts were taken to resume production (Atherley & Booth, 1975).

Experience, and beliefs on causation

A further difficulty for investigators is that their investigation and the application of hindsight bias are further prejudiced by which aspects of 'hindsight' are applied. As Braybrooke & Linbolm (1970) indicate (in the context of evaluating policy) investigations "always begin somewhere, not ab nihilo ..." The human mind is incapable of starting

with a complete blank canvass and investigators come to the investigation with information which they have derived from "historical experience, from contemporary experience in other societies or locations and from imagination stimulated by experience ..." and this unwittingly is the filter through which they examine the emerging facts and draw conclusions. The investigator begins with the familiar, with what they think they know or have experienced, and then incrementally try to relate the incident data to it. Those 'facts' that are attuned with the familiar frequently form the selected starting point, and influence the thought patterns and the judgement as to what data is important. Not all of the developing hindsight will have equal weight or influence in the conclusions or subsequent improvement recommendations. The malignancy of hindsight bias is in its selective nature.

Braybrooke & Linbolm's view that investigators come to an investigation with pre-conceptions is illustrated in its simplest form in Figure 2. Here the sum of the pre-conceptions divides into two views of causation. (Both mind-sets presume that accidents are uni-causal).

The difference is that some investigators believe that accidents are 'caused' by unsafe acts, others that accidents are 'caused' by unsafe physical conditions[33]. As can be seen in the figure this leads *either* to new rules *or* to technical changes.

[33] These are of course not the only potential pre-conceptions. From the beginning of time accidents and natural disasters have been attributed to divine retribution for moral wrong-doing. More prosaically, naval defeats in the 17th Century were attributed to corruption. Samuel Pepys, Naval Secretary, a meticulous and principled man for his time, was incarcerated in the Tower of London for this reason. But he only accepted bribes (in cash or kind) after assuring himself that suppliers' products met the most exacting quality standards.

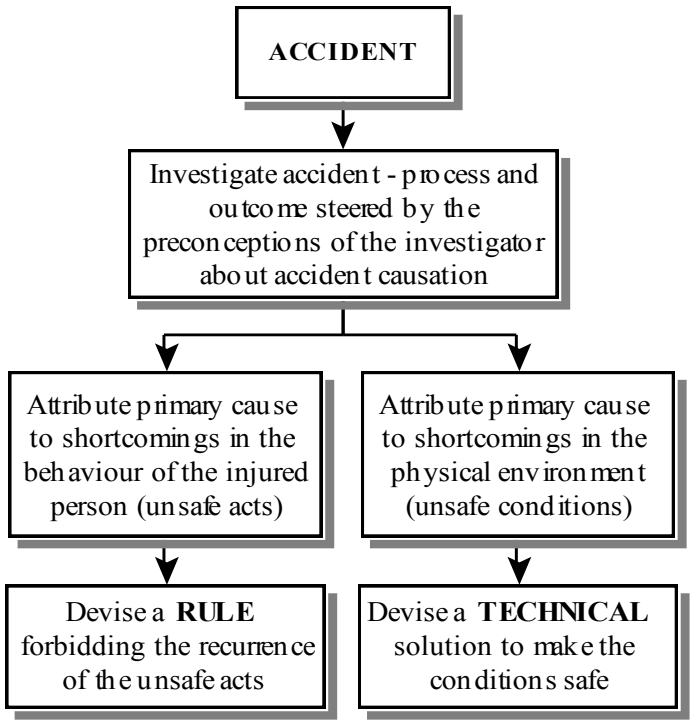

Figure 2 **Traditional accident investigations – perceptions of cause** (from Booth & Lee (1995), reproduced from HSC (1993))

The diagram in fact illustrates long-standing but still current perceptions of very many people, not just investigators. Indeed it is captured by Rasmussen's 'stop rule' where investigators halt investigations as soon as they have found either a human error or a technical shortcoming that in their opinion sufficiently explains what has gone wrong. Rasmussen (1990) states:

> "In an analysis to explain an accident, the backtracking will be continued until a cause is found that is familiar to the analysts. … [extended omission] … In one case, a design or manufacturing error, in the other, an operator error will be accepted as an explanation."

The gross simplifications just described (together with new precautions that may be wholly inappropriate) may be countered by incident investigation training founded on multi-causality. Contemporary causation models should be the foundation for such training, though they can become an investigative straight jacket, in contrast to ECFA and FTA (see below).

Analytical methods for incident investigations

Dekker (ibid) makes the case for analytical models to simplify and thus to make sense of the past as the foundation for future actions:

> "The linearisation and simplification that happens in the hindsight bias may be a form of abstraction that allows us to export and project our and others' experiences onto future situations. Future situations can never be predicted at the same level of contextual detail as the new view encourages us to explain past situations. Predictions are possible only because we have created some kind of 'model' for the situation we wish to gain control over, not because we can exhaustively foresee every contextual factor, influence, data point. This model - any model - is an abstraction away from context, an inherent simplification. The model we create … after past events with a bad outcome inevitably becomes a model of binary choices, bifurcations and unambiguous decision moments. *That is the only useful kind of model we can take with us into the future if we want to guard against the same type of pitfalls and forks in the road.* [My emphasis]

A key approach to minimising bias and promoting foresight is the adoption of structured incident analysis models, argued well by Dekker above. My preferences are to use Events & Causal Factors Analysis (ECFA) and Fault Tree Analysis (FTA), sometimes in combination.

While hindsight bias may make errors appear more culpable, they are nonetheless still crucial in understanding what happened and the preventive changes that need to be made. The argument is simply that the detailed analysis of an incident in linear stages provides a comprehensible structure – effectively a map - with which to chart a pathway to the future which would otherwise be even more opaque and unpredictable.

How then are Dekker's precepts to be implemented? Here are some immediate suggestions which seek to cover the insights contained in the above quotations and hindsight bias more generally:

i) The only way that hindsight bias can truly be eliminated is to have an investigation team that was not aware of the actual outcome. This is manifestly impracticable in almost all cases.

ii) Systematic modelling of the events and conditions leading to a bad outcome help to minimise bias and lead to an understanding of what went wrong, and why.

iii) Perhaps investigators *themselves* should create a detailed 'counter-factual' (fictitious but plausible) history of a satisfactory outcome, and investigate both with this, as far as possible, and the actual 'bad' outcome in mind[34].

iv) The creation of the counter factual outcome should be based in part on the recorded perceptions and beliefs of for example rule-violators (if available) taking into account Dekker's comment: 'Behaviour is rational within situational contexts'. Investigators anyway should not 'stop' until they have examined the case in terms of the challenges and perceptions of the principle parties when they made what were to them rational decisions[35, 36].

v) Investigation *training* would be relatively easy *and a deliverable in itself:* delegates might be presented with a 'bad outcome' fictitious case, perhaps a concatenation of several actual cases with bad outcomes, and asked to create a counter-factual good outcome and then carry out the investigation with the two outcomes, as outlined. There are simpler group exercises that might achieve the same purpose. If the training is effective then the inevitability and consequences of bias might at least be explicitly and coherently addressed in real investigations.

vi) Note that for investigators in the emergency services or where bravery is involved there is usually either a *dramatically good,* or a bad outcome. This means that emergency service investigators have to confront a 'double' bias - a particular challenge in assessing the appropriateness of rule violations to save lives. In contrast, for a shift supervisor whose failures led to an oil storage depot explosion,

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[34] The use of counter-factual analysis as a legitimate method of historical enquiry is described, with compelling examples, in 'Virtual History', Ferguson (1997).

[35] Note that rationally-made decisions may still be culpable. For example a shift supervisor might 'skip' shift handovers for personal reasons, but believing them to be a bureaucratic chore.

[36] My colleague Andrew Hale's mantra in accident investigation is "Go on collecting and analysing data until you feel that you too, in the given circumstances would have made the same decision which proved in practice to be wrong."

there is no good outcome. Or at least the 'good' outcome is merely that an overflow does not occur as a result of the 'required' level of vigilance, not a compelling comparison for balance, and thus the basis for apportioning undue blame.

5 Concluding comments

"History … is an analysis of the past in order that we may understand the present and guide our conduct into the future"
Sidney E Mead (1904 -1999)

Hindsight *bias* is uniformly a harmful influence in the evaluation of bad events. This has been demonstrated here, inter-alia by the extensive quotations, and by the Buncefield experience. The key issues are that participants in adverse events are unfairly blamed and that inappropriate lessons may be learnt from investigations. Moreover investigators who sincerely believe that they have 'factored out' hindsight bias are mistaken. Hindsight is 'Janus faced' noting its usual connotation of deceit[37]. In my opinion, a key root cause of the Buncefield explosion, namely the limited 'reach' of good/best practice safety systems, has been masked by the desire, promoted by hindsight bias, to rubbish in legal proceedings the efforts of Total, the JV partner responsible for safety at HOSL. HSE (2011) – a really useful review - nonetheless treats superficially the significance of the issues emphasised here.

An equally important conclusion is that while hindsight bias cannot be eliminated, hindsight is the essential means for learning from experience. Hindsight-rich bias-aware studies of the past where the facts are structured 'simplified' and made comprehensible, is the foundation for coherent efforts to prevent repetitions of adverse events. Incident investigation training courses embracing an analysis of hindsight bias together with the practical use of structured investigation models, if effective, may maximise the utility of looking at past events. Such training might both improve the efficacy of investigation recommendations, and lead to a more balanced view of blameworthiness. Moreover the training should also recognise that investigators' heightened risk perceptions my lead to 'gold plating' of new precautions which may subsequently be violated.

The most important message of this paper, though not discussed in detail, is that it provides yet further evidence that some key lessons of major adverse events are simply

[37] Paradoxically, in antiquity Janus's two faces were in fact a face looking at the past and the other to the future.

not being appreciated and certainly not applied in practice. The *underlying* causal factors of major incidents are repeated time and time again. The repetitions almost defy belief. They reflect badly on the competence of regulators, managements and safety professionals world-wide, and here the 'availability' bias seems not a valid excuse. Some of the key lessons of Buncefield though with important omissions have at least been widely disseminated in HSE (2011). But these are merely duplicates of the underlying lessons which should already have been learnt. It is however the root causes, mainly associated with organisational and group culture and conventional wisdoms that need to be addressed. For the root causes lead to the underlying causes, and these to the proximate and immediate events leading to potentially catastrophic incidents. The 'analysis of the past' by investigators has so far failed to take sufficient account of the need to combat deeply-rooted causal factors. Historically the 'stop rule' operated at the immediate causes. Good practice is often now equated with halting an investigation once the underlying causes (often perceived mistakenly as 'root' causes) are reached. But effective prevention depends on explicit programmes to address the ultimate root causes. This is what we have yet to learn fully from history.

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Responsibility for the views expressed here is mine alone.

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