Who moved my (Swiss) cheese?
The (r)evolution of human factors in transport safety investigation

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Abstract

When it comes to incidents and accidents, the popular template adopted for human factors investigations has been Reason's 'Swiss cheese' model (e.g., Reason, 1990; 1997). One of the main implications of this has been the tenacious and dogmatic search for latent conditions leading up to the incident. Overzealous implementation of the theoretical model has led to an illusion of management responsibility for *all* errors. While this may very often be the case for major accidents, in other cases the retrofit seems contrived and untenable. This paper reviews a variety of prominent case studies to illustrate the contention that human action at the sharp end can play a more significant role than we have recently assumed. A critique of Reason's organisational accident model is presented, with a focus on the problem of identifying latent conditions in hindsight. In conclusion, we believe that the focus on latent factors such as management and regulation has gone too far, and perhaps we should redress some of our efforts back to the human in control.

The evolution of accident causation

Transport disasters, such as the Tenerife runway collision in 1977, or the Glenbrook rail crash in 1999, are mercifully rare. However, public concern over such events is inversely proportional to their frequency and probability of harm (Singleton, 1989). Oft-quoted statistics reveal that more than two-thirds of these accidents involve 'human error' as a major contributory factor (e.g., Boeing, 1996; Dekker, 2002; Hawkins, 1993; IATA, 1993; Wiegmann and Shappell, 1999), and the popular press puts this quotient closer to 90%.

Data such as these have been instrumental in raising the profile of human factors, within training, research, and investigations (e.g., the laudable movement towards Crew Resource Management, or CRM). In response, we have been driven to determine why humans are so fallible, and the discipline of human factors has grown from modelling individual cognitive failure to investigating the organisational contribution to accidents (e.g., Perrow, 1999; Reason, 1990; 1997). The popularisation of this way of thinking is largely thanks to the work of James Reason (ibid.), whose 'Swiss cheese' model of accident causation is now adopted as a model for investigation in many industries. Indeed, in aviation, it has become the accepted standard as endorsed by organisations such as the Australian Transport Safety Bureau (ATSB) and the International Civil Aviation Organisation.

Reason's (ibid.) distinction between the active, operational errors and the latent, organisational conditions effectively makes human error a contributory factor in 100% of accidents and incidents. Reason asserts that these latent conditions are the true causes of disasters – typically, the operator merely inherits a defective system, and active errors are seen as the consequence, rather than the cause of the accident chain. The term 'operator error' became taboo, and it thus became the duty of incident investigators to look at the psychopathology of organisations in the search for clues.

Pathogens in the cheese

As a momentary aside, the story, 'Who Moved My Cheese?' (Johnson, 1998), is a simple parable about adapting to change. In the story, four characters (two mice and two 'littlepeople') live in a maze and look for cheese to nourish them and make them happy. 'Cheese' is a metaphor for a goal in life – a job, relationship, health, peace of mind, or perhaps accident prevention. The 'maze' is where you look for it. The story shows what happens to the characters one day when the cheese has been moved to another part of the maze. Some are prepared for it and adapt. Others are surprised by it and have a difficult time, for instance always looking in the same place for the cheese. The 'cheese' within the 'maze' of accident investigation, then, may not always be found in the same place.

To apply the metaphor, one of the main implications of the organisational approach has been the often tenacious search for latent conditions leading up to the incident. However, we believe that some high-profile accident investigations have revealed flaws in such prescriptive implementation. Whilst the importance of analysing human factors throughout the accident sequence is not in question, the dogmatic insistence on identifying the latent conditions could and should be challenged in cases where active errors have played a major part.

Interestingly, in two separate aviation human factors conferences in late 2003, Reason (2003a, b) himself stated some concerns with the ever-widening search for the upstream or 'remote factors' in safety investigation. The main points were as follows:

- they have little causal specificity,
- they are outside the control of system managers, and mostly intractable,
- their impact is shared by many systems,
- the more exhaustive the inquiry, the more likely it is to identify remote factors,
- their presence does not discriminate between normal states and accidents; only more proximal factors do that.

While acknowledging the significant contributions of the organisational approach, Reason (2003a, b) suggested that we might be reaching the point of diminishing returns with regard to prevention. Significantly, he stated, '…*perhaps we should revisit the individual* (the heroic as well as the hazardous acts). History shows we did that rather well' (emphasis added).

In the present paper, we take this statement as licence to pass a critical eye over the application of Reason's (1990, 1997) organisational model to incident investigations. When viewed in this light, textbook case studies display a continuum of latent and active failures. With the *Challenger* space shuttle, for instance, is a classic Reason-esque organisational accident. Latent conditions were traced back nine years before the event, and there was nothing the shuttle crew could do to prevent the explosion. The capsize of the *Herald of Free Enterprise*, on the other hand, can be seen as having significant contributions from both latent conditions and active failures. Finally, the nuclear accident at Chernobyl highlights the salient contribution of active failures to a disaster. In a disastrous series of active errors, the reactor was not shut down, and all safety systems were disconnected as they arose to ensure continuance of an experiment. It is also notable that all of the Inquiry recommendations were, in one way or another, aimed at reducing the possibility of active errors.

The above discussion leads us to question whether the focus on latent errors has become too strong, and whether we should redress some of our efforts back to the human at the sharp end. It should be made clear at the outset that this is in no way an effort to reapportion blame or change the focus of investigations (i.e., to prevent future accidents). Rather, it is in direct keeping with such philosophy that we are trying to elucidate all of the relevant causes of an accident. We now go on to examine a recent aviation incident in order to demonstrate that the front-line operator can often hold the answer.

Bangkok – a disorganisational accident

On 23rd September 1999, a Boeing 747 aircraft overran a runway while landing at Bangkok International Airport in Thailand. 'The overrun occurred after the aircraft landed long and aquaplaned on a runway which was affected by water following very heavy rain. The aircraft sustained substantial damage during the overrun, but none of the three flight crew, 16 cabin crew or 391 passengers reported any serious injuries. … These events and conditions can be described in many different ways, the most common being the model of organisational accidents as outlined by James Reason and others.' (ATSB, 2001; p. v, xii).

Although this investigation was conducted in accordance with standard practice by adopting the organisational model, it is our contention that the assumptions and conclusions of this investigation were flawed, primarily because the Bangkok accident *did not fit the Reason model*. The most critical event in the accident sequence was, arguably, an active and 'irrational' error. That this was not sufficiently acknowledged in the investigation report, and so the rest of the findings were distorted.

The critical event referred to is the Captain's late and incorrectly handled cancellation of the go-around. Due to a troubled final approach, the aircraft was just about to land when the Captain instructed the First Officer to go-around. This was a perfectly normal decision and corresponds with required flight procedures. The next action by the Captain was not normal. Some four seconds later, the Captain retarded the thrust levers '…because he decided to continue the landing rather than go around. The Captain gave no verbal indication of this action or of his intentions and did not take control of the aircraft from the First Officer' (ATSB, 2001; p. 9).

In assessing the decision to go around, the report states: 'It is very widely accepted that a decision to conduct a go-around should not be reversed. … The Captain's rejection of the go-around appeared to be a considered but rapid response to a unique situation' (ATSB, 2001; p.

44). It is not clear why the report concluded that the Captain's actions were 'considered', and the situation only became unique when the aircraft ran off the end of the runway.

That there were latent factors at work in this accident is not in question. The investigation report (ATSB, 2001) identified deficiencies in company procedures and training for landing on waterlogged runways. However, these latent conditions pale in significance when contrasted with the events at the sharp end. The key point of the inquiry should have been in determining why the Captain acted as he did in cancelling the go-around. This action was contrary to the pilot's training and experience. More importantly, this single act precipitated the whole event. If one accepts that an irrational act occurred then none of the latent failures are relevant. Every organisation can be investigated and there will always be room for improvement. This, however, does not necessarily contribute to incidents, which is implied by the report's use of the term 'latent failures'. The point is that the inquiry attempted to force this accident into the Reason model when it was probably inappropriate given the evidence.

Needless to say, there were clearly reasons why the Captain acted in this manner, and the aim of the investigation should have been in uncovering those in order to prevent a recurrence. Whilst the identification (and presumed rectification) of latent conditions undoubtedly served to improve the safety health of the organisation, it is hard to see how these conditions had a significant influence on the ultimate active error.

Railway accidents – the one true pathogen?

In addition to aviation and nuclear power, the Reason model has been adopted in railway industries around the world as a template for incident investigations. Whilst we maintain that such use of the model could still fall prey to an excessive focus on latent conditions, a review of major railway accidents reveals that this industry may actually exemplify the organisational model better than any other. The key systemic deficiencies contributing to railway accidents would appear to lie in design and maintenance. Some of the most high profile fatal accidents in the UK of recent years have been a result of inadequate track or signal maintenance (e.g., Clapham Junction, Hatfield, Potters Bar).

The most recent major fatal rail accident in Australia can also be attributed to latent failures, this time in the design of the train protection systems. The Waterfall inquiry (Ministry of Transport, 2003) found the design of the deadman system to be deficient, in that the weight of the driver's legs was sufficient to maintain the footpedal in the suppressed position. Further evidence uncovered at the inquiry revealed that some drivers (although not the driver of the Waterfall train) had been deliberately circumventing the system by forcing a handsignaller's flagpole into the footwell, thereby keeping the pedal suppressed. This suggests that the design was not only deficient in failing to achieve its intended purpose, but also in being a hindrance to drivers such that they felt the need to commit a 'necessary' violation (in Reason's terms).

Although these brief case studies have focused on the most pertinent latent conditions involved, there were undoubtedly further organisational failings underlying the errors in each case. However, the point is that there was nothing that the drivers of any of the trains involved could have done to prevent the accidents. That is, in terms of occurring in close temporal and spatial proximity to the event, there were no identifiable active errors.

Not all rail crashes fall into this category either though. The increased public and media concern with SPADs lately has inevitably been the result of fatal accidents caused by trains passing signals at danger. In the UK, the collisions at Southall in 1997 and at Ladbroke Grove two years later were both the result of drivers passing a red light. Again, there were clear organisational problems in each case – most notably concerning the train protection systems and driver training – resulting in an extensive set of recommendations from the joint inquiry of Professor Uff and Lord Cullen. The accident at Glenbrook in 1999 was partly the result of verbal communication failures when the signaller (correctly) authorised the driver to pass a failed red light.

Clearly, SPADs are another category of accidents for which active errors are a necessary and sufficient component in the accident chain. This is not to say that there were no organisational failures at Southall, Ladbroke Grove, or Glenbrook, nor that any of the drivers were necessarily 'at fault', but that a key error on the front line was essential to complete the accident chain.

Moving the Swiss cheese

In light of the above cases, the remainder of this paper asks whether the organisational accident model is still valid for describing, investigating, and preventing accidents, or whether the approach to safety investigation needs to evolve further rather than revolve.

It is indisputable that the ultimate and necessary (though not always singly sufficient) cause of all technological disasters relates to human actions – i.e., error. Reason (e.g., Maurino et al., 1995) contends that an error can consist of mostly latent failures, mostly active failures, or a combination of both. As we have argued through the various case studies above, though, the accident without a significant contribution from active failures is a relatively rare event (Challenger being one such example, and the rail industry providing a generic exception). Accidents occur due to varying proportions of predisposing factors and precipitating events, and many require an active 'trigger' to keep the window of accident opportunity open.

Most major accidents are rife with errors of commission, including Three Mile Island and Chernobyl. Such extraneous actions were brought into focus in the early 1990s, but did not receive the kind of attention they deserve, except at surface level. Kirwan (1994) notes that the problem with such errors is twofold. First, extraneous actions are difficult to predict, being rooted in misconceptions, knowledge inadequacies or misleading indications. Predicting what people could fail to do (errors of omission) based on a task analysis is much easier than identifying what *else* people could do. Second, such errors can have a dramatic impact. Reason (1990) noted the difficulties faced in detecting mistakes. The person making the error can often only detect it from the adverse consequences, since before that point everything is going according to plan, which happens to be faulty.

A more contentious issue concerns the ironic susceptibility of Reason to his own 'hindsight bias' in many of the case studies he presents. In the analysis of the BAC 1-11 windscreen accident (Maurino et al., 1995; ch. 4), the authors cite a series of latent failings – such as insufficient stocks and poor labelling of stock drawers – which formed the accident chain. Similarly, an emergency landing by a Boeing 737 at Daventry in 1995 (Reason, 1997; ch. 2) occurred as a result of understaffing and communications errors during maintenance activities. Whilst these may well be organisational failings, the establishment of causality is only really evident in hindsight at best (Dekker, 2002), and even then subject to interpretation – as Reason (2003a, b) himself has recently noted.

Top-down investigations (as advocated by Maurino et al., 1995 and Reason, 1997), working retrospectively from the event outcome, could easily be influenced by knowledge of the consequences. Latent conditions are often present all the time anyway, and it is only the unfortunate occurrence that reveals their pathogenic status (Boston, 2003). Instead, a bottom-up approach, investigating the contextual factors and working forward along the timeline towards the event (cf. Dekker, 2002), might give a more unbiased view of the relevant factors. Many of these factors would doubtless seem insignificant to the actors – or even the industry regulators, whom Reason (1997) also criticises (see footnote 1) – in the pre-event scenario, and it is therefore harsh to judge them as latent failures *post mortem*.

The revolution in accident prevention?

The point we are trying to make here is not that Reason's Swiss cheese model is irrelevant or outdated – indeed, it has clearly revolutionised incident and accident investigations worldwide and put human factors well and truly on the map. However, it may be the case now that industries and organisations have latched on to the model in a far too rigid and dogmatic fashion. As a consequence, investigations based on the Reason model can easily turn into a desperate witch-hunt for the latent offenders when, in some cases, the main contributory factors might well have been 'human error' in the traditional sense.

Considering these as 'irrational acts', then, we can be even more revolutionary and focus on the emotive influences on behaviour, which have been neglected in human factors to date. Various performance-shaping factors such as stress and fatigue can exacerbate these cognitive errors. Emotion, however, is hardly a word in the human factors nomenclature. Just to illustrate, a search of human factors literature in Ergonomics Abstracts Online (accessed May 2004) revealed 266 hits on emotive *or* affective, versus 5224 hits on the word cognitive, and 139 hits on the word emotion versus 636 hits on the word cognition. This is a crude comparison, but is illustrative of the focus in the literature. Many in the human factors community simply seem not know where to start when it comes to emotion. One of the present authors had experience in developing an incident investigation tool, and was warned against including classification terms that hinted at emotion or motivation.

It may be that emotion is simply seen as uncontrollable, unpredictable and unfathomable. Indeed, many models often used in the study of human performance make no mention of emotional factors (e.g., Endsley, 1995; Norman, 1986; Reason, 1990; Wickens, 1992). Again, it seems that the paradigm pendulum has swung too far, extending the computer metaphor of the human beyond acceptability. Attempts to find references to 'panic' in NTSB reports have come up with little (Wheeler, 2003), although one would intuitively think that panic must play a role *sometimes*. The Captain at Bangkok must have been under stress, he was almost certainly fatigued, and perhaps his cancellation of the go-around was to some extent a panic response. Should we consider such emotional acts to be 'irrational', or can we as psychologists address this very human side of behaviour too?

Conclusion: the 'human' in human factors

In summary, the position in this paper is not that Reason's Swiss cheese model should be discarded as a model for accident and incident investigations, despite the seemingly negative tone. On the contrary, since it has clearly proven value in a range of high-risk industries – and perhaps holds most validity in the railways. Our argument is simply that it is sometimes not as applicable as has been thought, and that it can be misapplied in some cases as a prescriptive investigation technique, rather than a theoretical model. The fixation on latent conditions can then result in the sidelining of active errors, which may have had much more direct implications for the outcome. Even in those cases, the search for latent conditions has resulted in recommendations that undoubtedly improve the safety health of the organisations concerned, despite these conditions arguably having only tenuous connections to the actual event.

As we noted earlier, these thoughts have been aired by James Reason himself at two recent conferences (Reason, 2003a; b). Even in his book, Reason (1997) gives fair acknowledgement to the role of active errors, but still argues that 'identifying and eliminating latent conditions proactively still offer the best routes to improving system fitness' (p. 237). Again, we cannot argue with this point. Looking only at active errors is a symptomatic approach, and the symptoms of emotional or 'irrational' acts are difficult to decipher.

The aim of this paper has not been to criticise James Reason, or to throw his Swiss cheese to the mice. We would just like to see an increased awareness amongst investigators of the spirit of the model, rather than following the letter of Reason's 'bibles' so dogmatically. Without wanting to return to the dark ages of 'human error' being the company scapegoat for all accidents, there is a balance to be redressed in accounting for the role of active errors. Latent conditions may be significant, but occasionally people really do just slip up.

Footnotes

(1) Reason (1997) does, though, make the very valid point that industry regulators have suffered from goal conflicts in the past. The Australian Civil Aviation Authority was implicated in the crash of a Piper Chieftain at Young, New South Wales in 1993, being at the time part financed by its stakeholders. This led to the formation of the Civil Aviation Safety Authority. However, a similar situation has recently emerged in the UK with the formation of the Rail Safety and Standards Board, which is wholly funded by its members, the industry stakeholders. As a consequence, all new safety standards and interventions are subject to consultation by the entire industry – so the Board must beware not to rock the commercial boat while trying to improve safety.

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