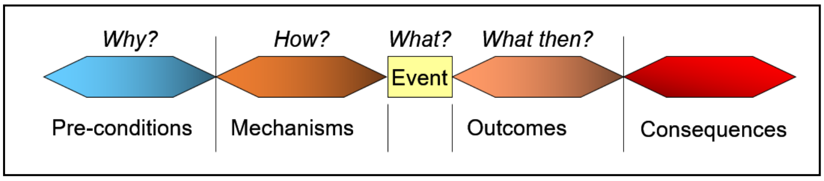
The Dimensions of Risk

In running any operation, the objective is normally "success", so any interruption, for whatever reason, is unwelcome. This can happen, when unexpected events, incidents and accidents occur. These are treated as "risks" that we run in everyday life in a chaotic complex environment. Risks then, present challenges or "hazards" to be overcome: where one cannot guarantee that everything will go exactly as planned. At a certain level of risk, the enterprise is deemed to be non-viable, or "unsafe". So a "risk analyst" is tasked with understanding how and why they occur and what to do about them; requiring an appreciation of the multifaceted dimensions of the phenomenon.

One dimensional approaches

Mostly these employ a hindsight perspective, "ensuring it can never happen again"; but it would obviously be more useful if we can predict and prevent it happening in the first place.



Learning from experience is a genetically pre - programmed, "natural" thing to do, a product of survival / adaptation / evolutionary pressures. Thus early approaches followed the classic process of observing the consequences and identifying the cause – and the cause of the cause, and the cause of that cause and so on, until we had satisfied ourselves that we had found the "root" cause. (A much quoted criticism of this as a formal methodology, is knowing when to stop?) This can be a bit like striving to reach infinity, or finding the square root of minus one, an impossible, or imaginary exercise?

In practice, the limit seems to be when we are satisfied that we have discovered something, or someone, we can identify, "blame", or conveniently fix, and can consider that our analysis is complete. We could call this a one dimensional approach.

But if we have identified what happens from a cause, we can then predict what will happen in the future if that cause occurs. Formulations of this approach can be seen in early methodologies, such as Event Causal Analysis, Taproot and Failure Modes and Effects analyses (FMEA).

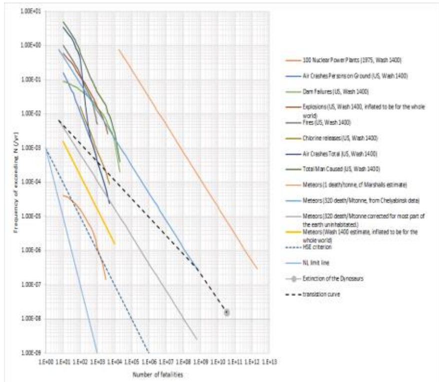
https://www.youtube.com/watch?v=eNxDgd3D_bU

If we can predict the chances of that cause occurring, we can quantify this as a likelihood of happening, which some use as a measure of the risk, or more positively, reliability.

The classic example of course is the flippant, but much quoted generalisation of the risk of being struck by lightning.

Even here, there should be an additional consequence dimension of the extent of the impact implied. This is usually dealt with by distinguishing between individual and societal risk. We seem to be much more averse to large consequence events. An example here could be assessing the risk of extinction from an asteroid hitting the earth.

http://www.livescience.com/26933-chicxulub-cosmic-impact-dinosaurs.html

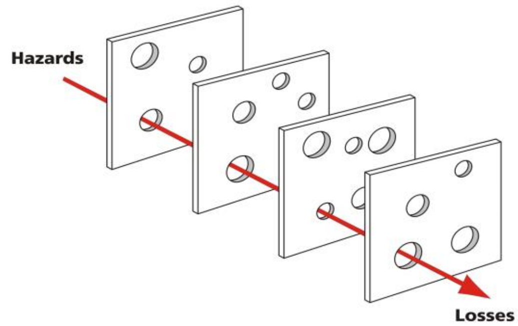


Two Dimensional Analysis

More sophisticated approaches have recognised that problems could arise from a combination, or sequence of causes.

https://www.videezy.com/free-video/domino-effect

The classic example is the Heinrich Domino model. Here there are a number of tiles, which have to fall sequentially, in order for the event to have the consequences we are trying to avoid. These events could be the failures of “Barriers” across the incident trajectory.



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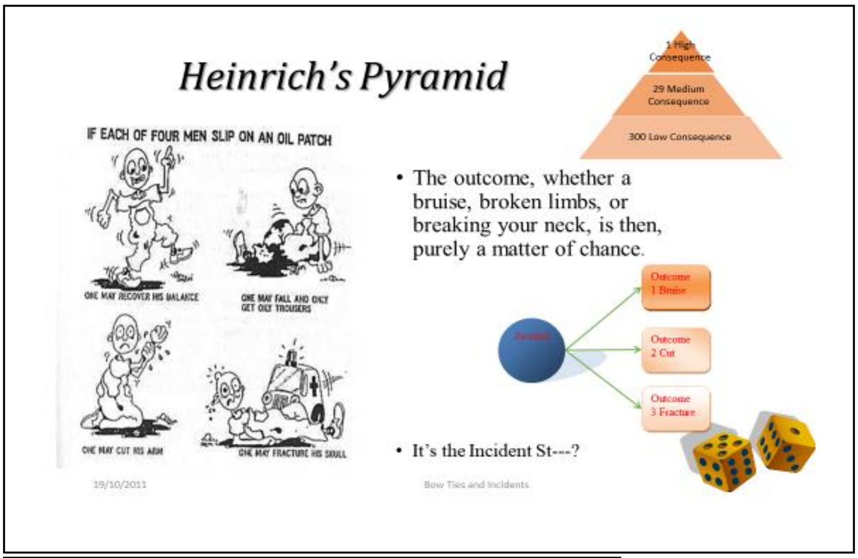
James Reason has helpfully and memorably compared them to Swiss cheese slices in which holes line up to allow the fatal trajectory to penetrate.

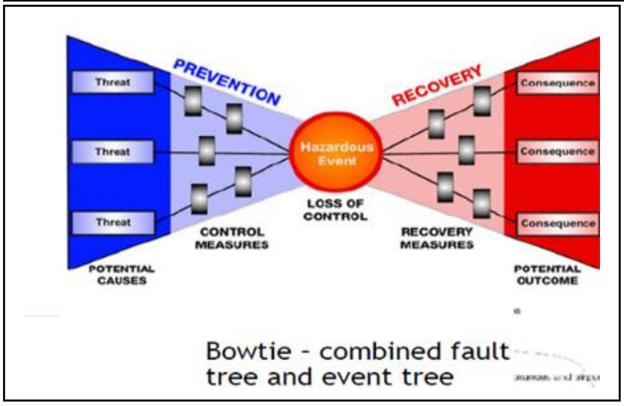
Heinrich also highlighted the variability of outcomes given the same cause, in his famous accident triangle.

Kletz’s favourite example of this was slipping on an oil patch. The consequences can range essentially randomly, (hence the logarithmic distribution?), from irritation, to breaking your neck. Here the “barriers” that can mitigate the consequences, if they are effective, are things like nonslip soles, better housekeeping, padded joints and hard hats. Similarly the current “barriers” in cars include ABS and air bags.

Again this approach can be quantified as to the probability of occurrence using Layers of Protection Analysis (LOPA), if the permeability of the cheese is known, or available from historical records. Then it is termed the System “integrity”.

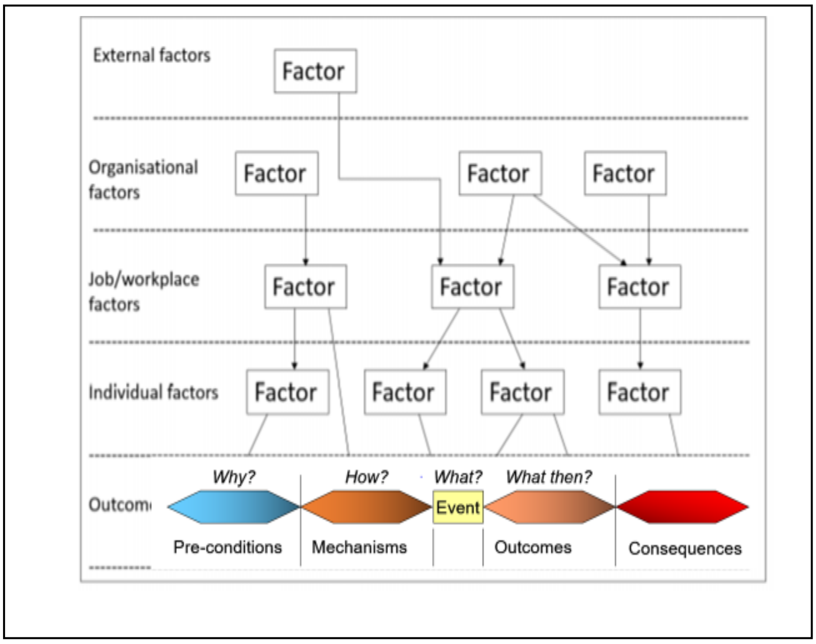


A more formal approach was pioneered in the Nuclear Industry, which mapped out comprehensively causal sequences, using Boolean logic trees (Fault Trees) and stochastic probabilistic event Trees. These yielded reassuring predictions of reliability, transparently and quantitatively; and were much employed to demonstrate the "safety" of these systems. These logic trees had the added advantage in that in a significantly large enough population of very similar systems, accident reports could be mapped on to a relatively small set of standard FTA/ET templates, yielding more reliable predictions to be made of implications of future events and incidents.



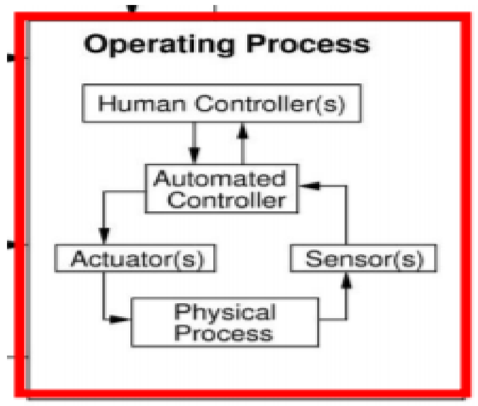
Nowadays the vestiges of this approach can be seen in the currently popular Bow Tie visualisation approaches and their variations (e.g. TRIPOD).

Three Dimensional Analysis



Rasmussen was probably the first to formalise the notion that "there are more things in heaven and earth, Horatio, than" -- Fault Trees, Event Trees and Barriers. In his "Accimap" approach, he set out to identify and link / assess, the importance of "higher level" influences on such causes and failures. These included things like the effectiveness of supervision, the Regulatory Environment and Cultural complications.

An example much quoted is the application by Hopkins, which highlighted the full implications of the Longford Gas Plant explosion in Australia. As these are essentially qualitative, their use is normally illustrative.



After Levenson in her STAMP papers

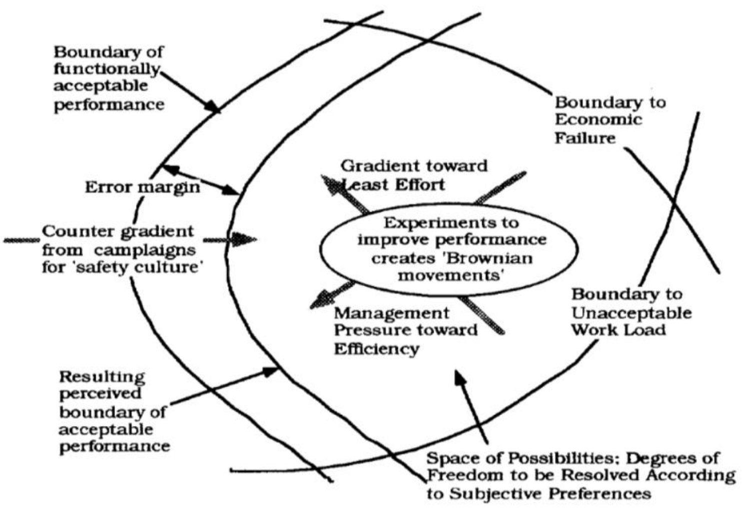
A more recent development of this third dimension, has been Levenson's appreciation that these external influences can be thought of as controls on the progress of these events, an appealing analogy for engineers. Separate control loops can then be identified and could even perhaps be quantified using control Theory?

Examples include applications highlighting the organisational causes of high profile NASA accidents.

The Fourth Dimension

Implicit in the simple one-dimensional event causal analysis approach, is that there is a sequential time sequence. But also implicit, is an acceptance that this linear sequence is fixed and predetermined. Similarly, the two and three dimensional models assume a common fixed geometry to the models, which can then highlight pre-existing but not emerging anomalies.

But in the real world outside the immediate system being studied, there are always variations in conditions, which are not necessarily predictable and can affect how sequences develop in practice.

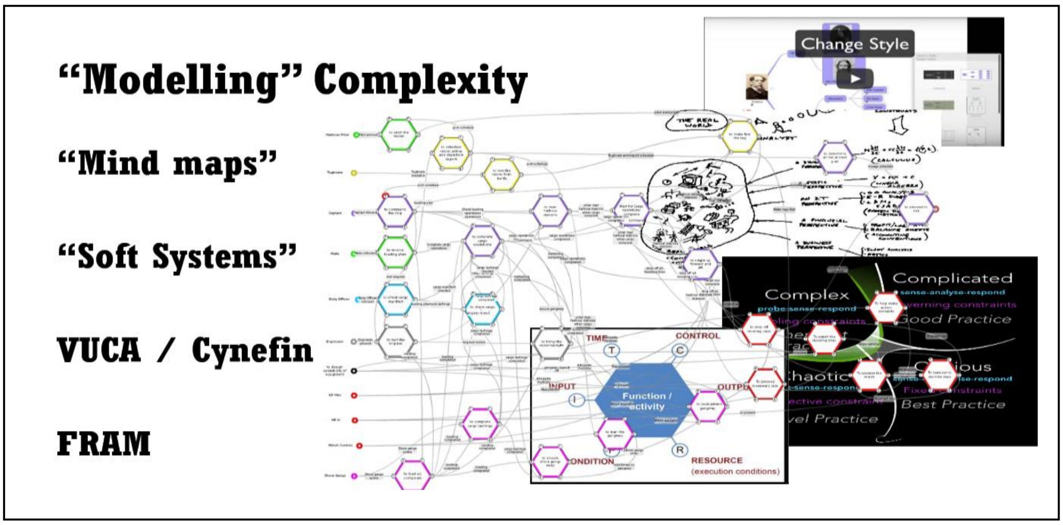


After Rasmussen

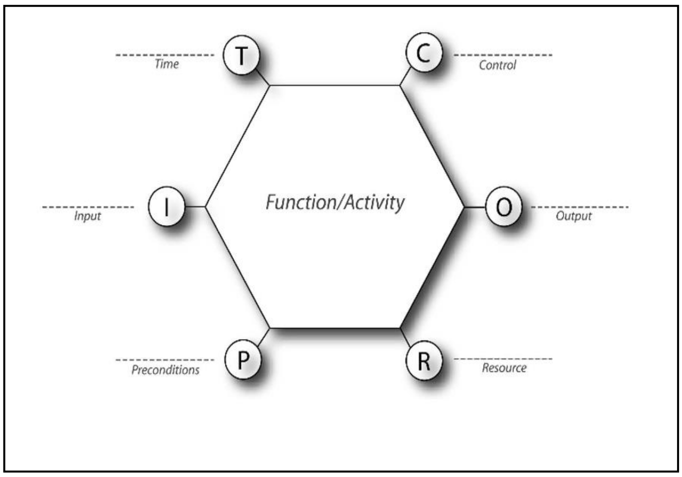
The Rasmussen insights do acknowledge the potentially perturbing effects of this external environment, but again the models highlight intended influences, which are known prior to the incident and either present /effective or not. As with any of these barriers, they cannot be assumed to be necessarily unconnected and independent, spatially or have properties that are fixed temporally (the fourth dimension). Given that in reality there is no such thing as complete isolation from the three dimensional interdependencies of factors that govern how incidents develop; and that developing situations can change their effectiveness, or influences, it is clear that a more rigorous approach is needed to include this fourth dimension; and additionally identify these time dependent interactions.

Including effects from the real world is particularly challenging, in today's increasingly more complex and less transparent systems. Producing an accurate, comprehensive and comprehensible "picture", or engineering diagram of what's happening, or supposed to happen, is a major problem. This is why the more abstract representations such as Bow Ties, Accimaps and STAMP, are meeting a real need at the moment, in the risk analysis world.

There are also a number of "softer" approaches available to model these complex systems that are omnipresent in reality.



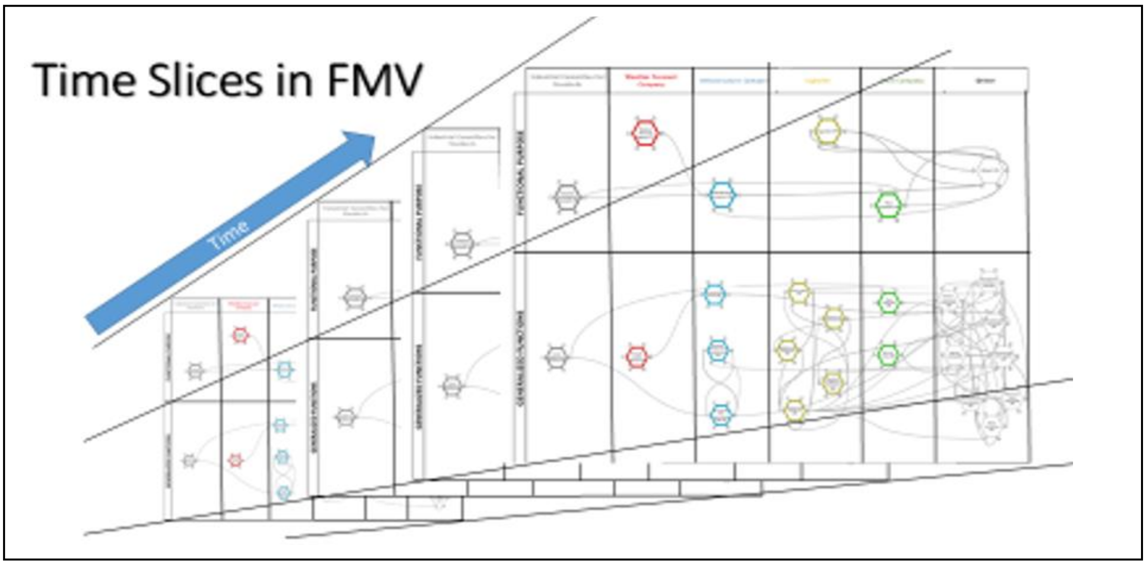
But to really address the issue, an approach must be able to track the development of unspecified, or non – predetermined, natural perturbations in real life conditions and predict outcomes and consequences that can "emerge" unexpectedly (off script). At present the only development which seems to offer the facility to do this, is Hollnagel's FRAM approach.



Here, as in Accimaps and STAMP, only the abstract "functions" involved are needed to be represented. Here though, as there is more formalisation of the interdependencies of functions, the specifications of couplings allow large and consistently labelled system pictures to be assembled. The FRAM function has been likened to a "Lego" brick, with which highly complex fractal-like structures can be built.

Note Hollnagel insists that these are not models, but visualisations of system interactions which can be probed formally for "resonances" (unexpected effects of random variations in couplings).The way that these functions have to / actually interact in the different stages of a system's operation, are then described as "instantiations".

These are successive "time slices" in a developing process, where the states of these functions are only defined by what has happened in the previous step. (The so-called Markowian condition). This means that the sequence is truly emergent and the states of any of the functions whether active (such as control), or passive (such as Barriers), also interact and emerge and can be very different with different implications, in different time steps.



Another major advantage of this way of representing systems as interdependent functions, is that these FRAM functions can be thought of as acyclic digraphs, or individual linked nodes in Bayesian Belief Nets, and thus can also be quantified. Strictly speaking, the time slices then should be treated as a set of emerging dynamic BBN's obeying the Markowian conditions. Thus the FRAM also has a major attraction in that quantitative estimates of "successful" couplings and overall performance can also be obtained. Applying Monte Carlo techniques can also highlight the coupling resonances, after which the methodology is named.

Conclusions

Simple linear, predetermined, sequential (unidimensional) models of incident development, have been essential and influential in the development of our thinking and approaches to analysing system risk, (and are still useful for simple systems). Modern complex systems and the recognition of the presence and influences of the natural variabilities in conditions and behaviours of the real world, however, demand a more accurate recognition of how these affect the behaviour of these systems. This is needed both to understand why they work well normally, as well as why, sometimes, things go wrong. So while there is nothing wrong with still using the simplified approaches, where appropriate and where their limitations are recognised, our increasingly risk averse society, with its increasingly opaque systems and non-human intelligences , or behaviours, requires the risk analyst to have the most advanced four dimensional tools available in his safety toolbox.
David Slater