Techniques of Accident & Incident Investigation

226302001-KM 03 KT 02

QCTO: Occupational Health, Safety Quality Practitioner Qualification – NQF Level 5

ISO NET (Pty) Ltd

Learner Guide

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Difference between accidents and incidents

Incidents and accidents are more than just words used to describe a situation in the workplace. While they may indicate the level of damage that results form a workplace situation, they also make up the basic logic for two of occupational health and safety's most common safety philosophies.

Defining Accidents and Incidents

The difference between accidents and incidents is like the difference between fingers and thumbs. Remember the old saying "All thumbs are fingers, but not all fingers are thumbs"? Well, incidents and accidents are kinda like that.

Accidents are defined as:

an unexpected event that may result in property damage, and does result in an injury or illness to an employee.

Incidents, on the other hand, are:

an unexpected event that may result in property damage, but does not result in an injury or illness. Incidents are also called, "near misses," or "near hits."

So both events are unplanned, both can present damage to places or things, but only accidents result in illness or injury to a person. Basically, by definition, all accidents are incidents, but not all incidents are accidents.

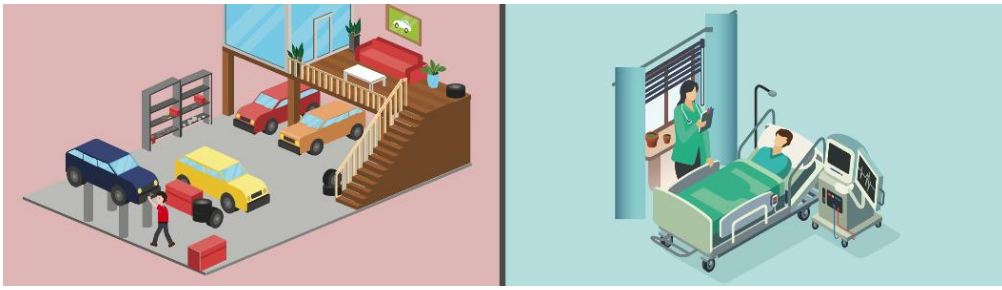
As a matter of fact, incidents (near misses/hits) are much more common in the workplace than accidents. According to Australian risk management consultancy IPM, accidents as defined above make up only 2% of all workplace incidents.

Now let's take those definitions a step further and put them in the context of two of the most common workplace safety philosophies.

Zero Accident Vision vs Accidents Happen

The OH&S world seems to be divided between *all accidents are preventable* and *accidents happen.* While many overseeing health and safety organizations around the world promote the all accidents are preventable approach to safety, many argue that it is impossible to foresee every possible "accident" and implement measures against them.

This has led to two schools of thought on how safety in the workplace should be practiced and both sides have passionate arguments as to why their preferred method is the right way of doing things.



Zero Accident Vision

Organizations who follow the all accidents are preventable philosophy, also known as Zero Accident Vision, will avoid using the word accident and be proactive in their safety approach.

Their core safety belief is that no one is injured in an accident. There may be flaws in a system or human error at play, but injuries and illnesses can be prevented by identifying and anticipating hazards before any harm occurs.

Policies and procedures are implemented based on either past incidents, incidents in similar workplaces, and most importantly, from near misses/hits in their own organization.

In an article for OHSonline.com, Larry Wilson suggests that zero accidents is not within the scope of human reality:

The problem with "All injuries can be prevented" is that in order for this statement to be true, everybody would have to be watching what they were doing and thinking about what they were doing *whenever* they were moving.

Because once they move or start to move, the only thing that tells them what they could be moving into is their eyes or their mind, with the exception of planes and ships that also use radar and sonar.

But most of us aren't using radar or sonar when we are walking, working, or driving; we're using our eyes and our minds, though none of us do it 100 percent of the time.

As much as we all like to think we have planned and prepared for every worst case scenario, the truth is that everyone overlooks something at some point. It is almost impossible to anticipate every single mistake or flaw that could lead to an illness or injury, regardless of how long organizations spend thinking of ways to make their workers safer.

Accidents Happen

Some organizations don't believe you can foresee every hazard or danger present in the workplace. Often, the cause of these accidents is said to be a fluke, a one in a million chance of equipment failure or wrong place at the wrong time.

These incidents lead to the creation or improvement of safety procedures and policies which are intended to stop the same scenario from playing out again in the future.

It also means that management teams are looking to reduce the number of injuries or illnesses that occur, not trying to prevent them outright.

An accident is the opposite of the fundamental intentions of a safety program, which is to find hazards, fix hazards, and prevent incidents. When we accept that accidents have no cause, we assume that they will happen again.

It is argued that the word "accident" implies that the event was related to fate or chance. When the root cause is determined, it is usually found that many events were predictable and could have been prevented if the right actions were taken - making the event not one of fate or chance (thus, the word incident is used).

It is easy to feel as though this way of thinking is the wrong one. While the goal to reduce the number of accidents that occur acknowledges that they can do better, the hard truth is that these organizations are still planning for some accidents to inevitably take place.

What feels right to you

The world of OH&S is full of debates, and like any other, you probably already have an idea of which side of the fence you stand on.

Whether you stand by the Zero Accident philosophy, or you believe that Accidents Happen no matter how many controls are put in place, the important thing to remember is that no one WANTS to see anyone get hurt at work.

Keep doing what feels right for you and your company. You never know which side of the fence you will end up on down the road.

Interrelationship of accidents and incidents

Accidents, Incidents and Near Misses

According to estimates by the International Labour Organisation (ILO), the number of jobrelated accidents and illnesses, which annually claim more than two million lives, appears to be rising because of rapid industrialisation in some developing countries.

An assessment of workplace accidents and illness indicates that the risk of occupational disease has become the most prevalent danger faced by people at their jobs, accounting for 1.7 million annual work related deaths and out pacing fatal accidents by four to one.

Relationship Between Accidents, Incidents and Near Misses

Activities at work often give rise to incidents. The outcome of these incidents may (but not necessarily do) cause harm to people as well as loss. Accidents are a particular type of incident and these result in loss, personal (minor) injury, serious injury or death. Where no such outcome results, the incident is classified as a near miss.

Evolution of models of accident causation

The history of accident models to date can be traced from the 1920s through three distinct phases (Figure 1):

- Simple linear models
- Complex linear models
- Complex non-linear models. (Hollnagel, 2010). Each
- type of model is underpinned by specific assumptions:
- The simple linear models assume that accidents are the culmination of a series of events or circumstances which interact sequentially with each other in a linear fashion and thus accidents are preventable by eliminating one of the causes in the

linear sequence.

- Complex linear models are based on the presumption that accidents are a result of a combination of unsafe acts and latent hazard conditions within the system which follow a linear path. The factors furthest away from the accident are attributed to actions of the organisation or environment and factors at the sharp end being where humans ultimately interact closest to the accident; the resultant assumption being that accidents could be prevented by focusing on strengthening barriers and defences.
- The new generation of thinking about accident modelling has moved towards recognising that accident models need to be non-linear; that accidents can be thought of as resulting from combinations of mutually interacting variables which occur in real world environments and it is only through understanding the combination and interaction of these multiple factors that accidents can truly be understood and prevented. (Hollnagel, 2010).

Figure 1 portrays the temporal development of the three types of model and their underpinning principle. The types of model, their evolution, together with representative examples are described in the following sections.

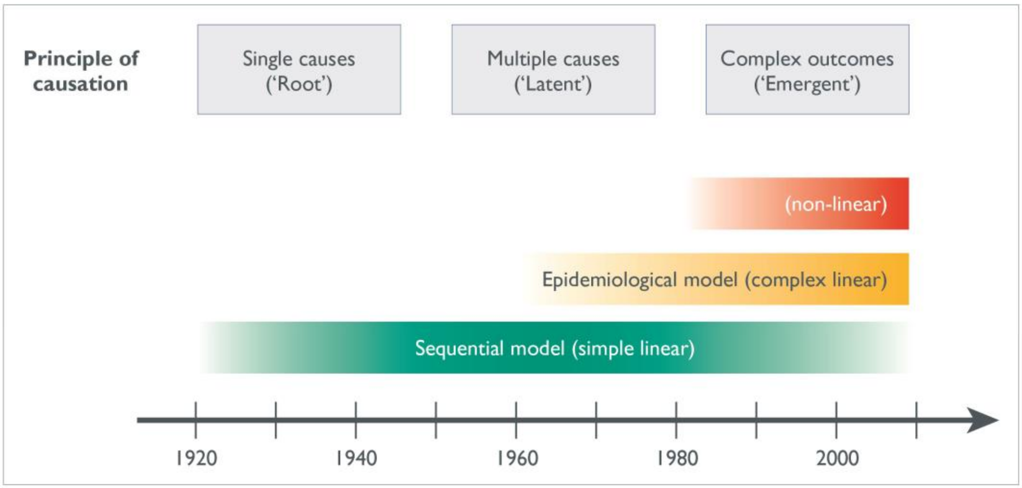


Figure 1: Summary of a history of accident modelling (Hollnagel, 2010)

Simple sequential linear accident models

Simple sequential accident models represent the notion that accidents are the culmination of a series of events which occur in a specific and recognisable order (Hollnagel, 2010) and now represent the "commonest and earliest model of accident research ... that describing a temporal sequence" where the "accident is the overall description of a series of events, decisions and situations culminating in injury or damage .. a chain of multiple events" (Surry, 1969).

Heinrich's Domino Theory

The first sequential accident model was the 'Domino effect' or 'Domino theory' (Heinrich, 1931). The model is based in the assumption that:

the occurrence of a preventable injury is the natural culmination of a series of events or circumstances, which invariably occur in a fixed or logical order … an accident is merely a link in the chain.

This model proposed that certain accident factors could be thought of as being lined up sequentially like dominos. Heinrich proposed that an:

… accident is one of five factors in a sequence that results in an injury … an injury is invariably caused by an accident and the accident in turn is always the result of the factor that immediately precedes it. In accident prevention the bull's eye of the target is in the middle of the sequence – an unsafe act of a person or a mechanical or physical hazard

Heinrich's five factors were:

- Social environment/ancestry
- Fault of the person
- Unsafe acts, mechanical and physical hazards
- Accident
- Injury.

Extending the domino metaphor, an accident was considered to occur when one of the dominos or accident factors falls and has an ongoing knock-down effect ultimately resulting in an accident.

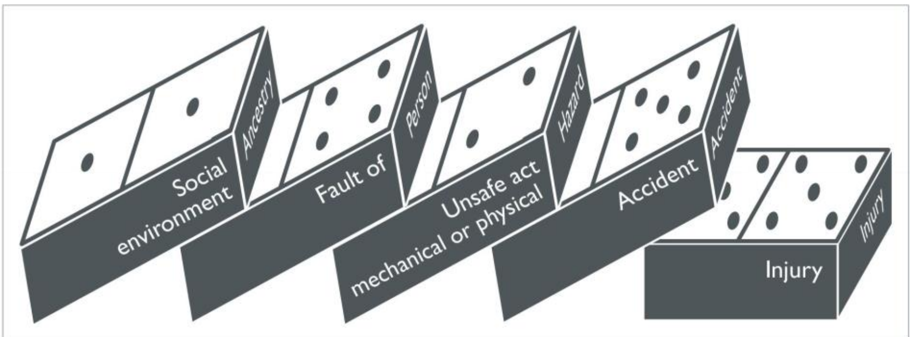


Figure 2: Domino model of accident causation (modified from Heinrich, 1931)

Based on the domino model, accidents could be prevented by removing one of the factors and so interrupting the knockdown effect. Heinrich proposed that unsafe acts and mechanical hazards constituted the central factor in the accident sequence and that removal of this central factor made the preceding factors ineffective.

He focused on the human factor, which he termed "Man Failure", as the cause of most accidents. Giving credence to this proposal, actuarial analysis of 75,000 insurance claims attributed some 88% of preventable accidents to unsafe acts of persons and 10% to unsafe mechanical or physical conditions, with the last 2% being acknowledged as being unpreventable giving rise to Heinrich's chart of direct and proximate causes

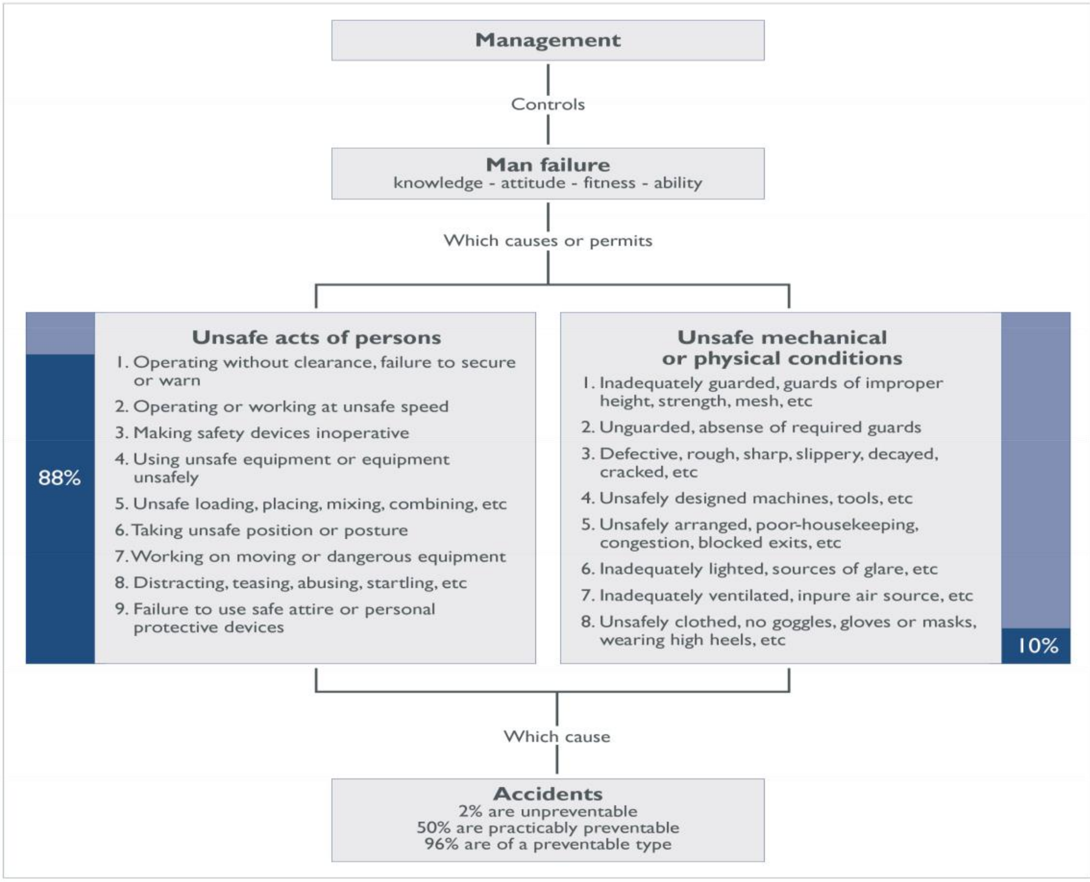


Figure 3: Direct and proximate accident causes according to Heinrich (1931)

<u>Bird and Germain's Loss Causation model</u>

The sequential domino representation was continued by Bird and Germain (1985) who acknowledged that the Heinrich's domino sequence had underpinned safety thinking for over 30 years.

They recognised the need for management to prevent and control accidents in what were fast becoming highly complex situations due to the advances in technology. They developed an updated domino model which they considered reflected the direct management relationship with the causes and effects of accident loss and incorporated arrows to show the multi-linear interactions of the cause and effect sequence.

This model became known as the *Loss Causation Model* and was again represented by a line of five dominos, linked to each other in a linear sequence

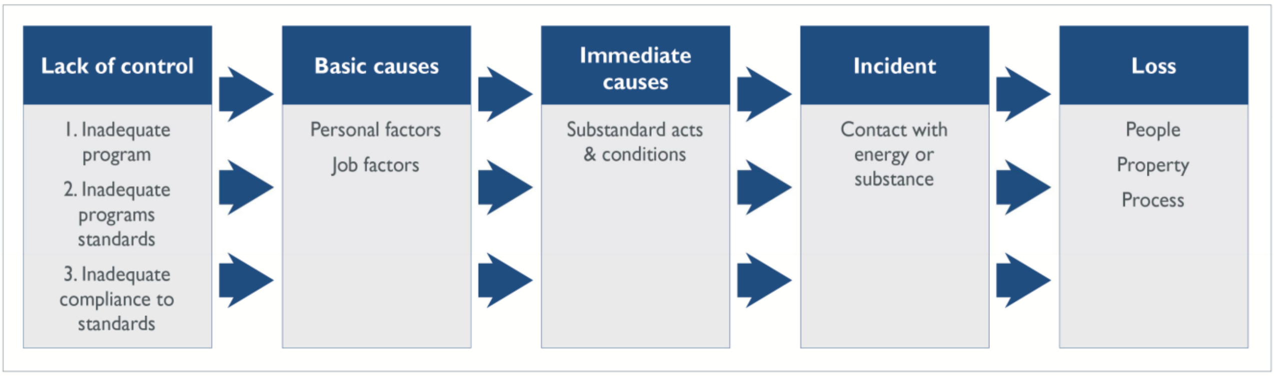


Figure 4: The International Loss Control Institute Loss Causation Model (modified from Bird and Germaine, 1985)

Complex linear models

Sequential models were attractive as they encouraged thinking around causal series. They focus on the view that accidents happen in a linear way where A leads to B which leads to C and examine the chain of events between multiple causal factors displayed in a sequence usually from left to right.

Accident prevention methods developed from these sequential models focus on finding the root causes and eliminating them, or putting in place barriers to encapsulate the causes. Sequential accident models were still being developed in the 1970's but had begun to incorporate multiple events in the sequential path. Key models developed in this evolutionary period include energy damage models, time sequence models, epidemiological models and systemic models.

Energy-damage models

The initial statement of the concept of energy damage in the literature is often attributed to Gibson (1961) but Viner (1991, p.36) understands it to be a result of discussions between Gibson, Haddon and others.

The energy damage model (figure 5) is based on the supposition that "Damage (injury) is a result of an incident energy whose intensity at the point of contact with the recipient exceeds the damage threshold of the recipient".

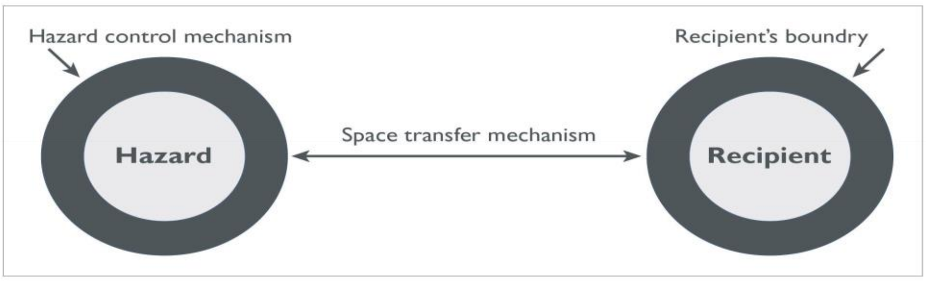


Figure 5: The Energy Damage Model (Viner, 1991)

In the Energy Damage Model the *hazard* is a source of potentially damaging energy and an accident, injury or damage may result from the loss of control of the energy when there is a failure of the *hazard control mechanism.*

These mechanisms may include physical or structural containment, barriers, processes and procedures. The *space transfer mechanism* is the means by which the energy and the recipient are brought together assuming that they are initially remote from each other. The *recipient boundary* is the surface that is exposed and susceptible to the energy. (Viner, 1991)

Time sequence models

Benner (1975) identified four issues which were not addressed in the basic domino type model:

1. the need to define a beginning and end to an accident;
2. the need to represent the events that happened on a sequential time line;
3. the need for a structured method for discovering the relevant factors involved; and
4. the need to use a charting method to define events and conditions.

Viner's Generalised Time Sequence Model is an example of a time sequence model that addresses Benner's four requirements.

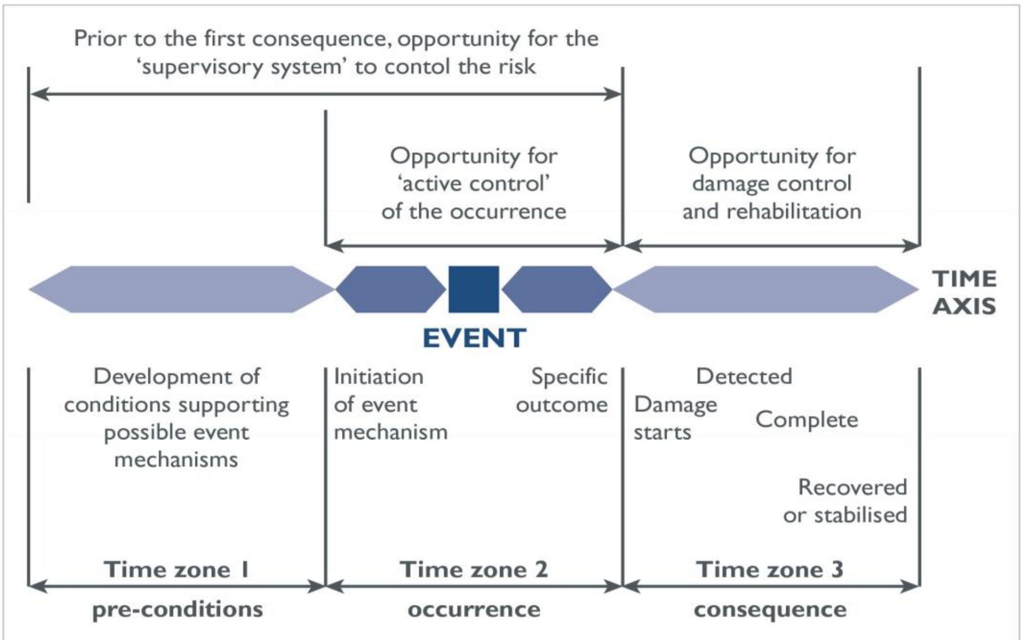


Figure 6: Generalised Time Sequence Model (Viner, 1991)

Viner considers that the structure for analysing the events in the occurrence-consequence sequence provided by the time sequence model draws attention to counter measures that may not otherwise be evident.

In Time Zone 1 there is the opportunity to prevent the event occurring. Where there is some time between the event initiation and the event, Time Zone 2 offers a warning of the impending existence of an event mechanism and the opportunity to take steps to reduce the likelihood of the event while in Time Zone 3 there is an opportunity to influence the outcome and the exposed groups. (Viner, 1991)

While Viner takes a strictly linear approach to the time sequence Svenson (1991; 2001) takes a more complex approach in his Accident Evolution and Barrier Function (AEB) model.

The AEB model analyses the evolution of an accident as a series of interactions between human and technical systems and is visualised as a flow chart. Svenson considers that the required analysis can only be performed with the simultaneous interaction of human factors and technical experts. (Svenson, 2001)

Epidemiological models

Epidemiological accident models can be traced back to the study of disease epidemics and the search for causal factors around their development. Gordon (1949) recognised that "injuries, as distinguished from disease, are equally susceptible to this approach", meaning

that our understanding of accidents would benefit by recognising that accidents are caused by: a combination of forces from at least three sources, which are the host – and man is the host of principal interest – the agent itself, and the environment in which host and agent find themselves.

Recognising that doctors had begun to focus on trauma or epidemiological approaches, engineers on systems, and human factors practitioners on psychology Benner (1975); considered these as only partial treatments of entire events rather than his proposed entire sequence of events.

Thus Benner contributed to the development of epidemiological accident modelling which moved away from identifying a few causal factors to understanding how multiple factors within a system combined. These models proposed that an accident combined agents and environmental factors which influence a host environment (like an epidemic) that have negative effects on the organism (a.k.a. organisation). See for example Figure 7.

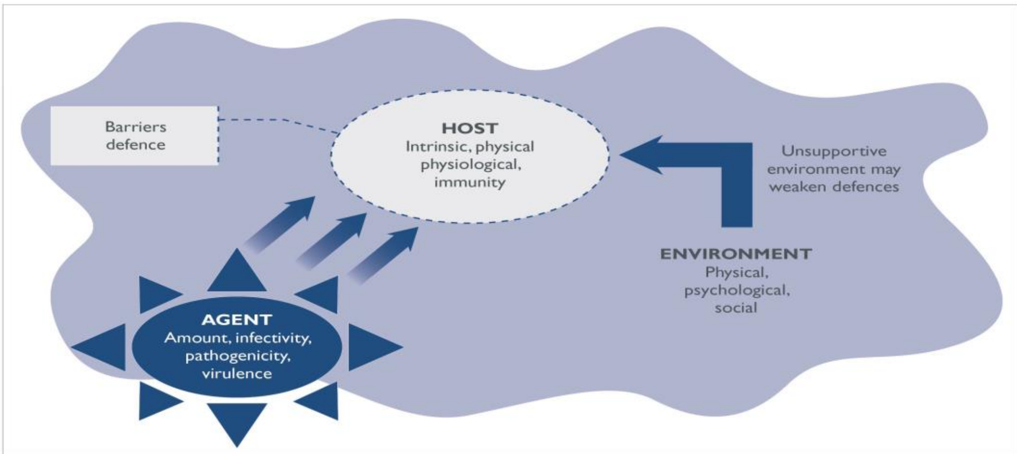


Figure 7: A generic epidemiological model (modified from Hollnagel, 2004)

Reason (1987) adopted the epidemiological metaphor in presenting the idea of 'resident pathogens' when emphasising:

the significance of causal factors present in the system before an accident sequence actually begins and all man-made systems contain potentially destructive agencies, like the pathogens within the human body.

The term became more widely known as 'latent errors', then changed to 'latent failures' evolving further when the term 'latent conditions' became preferred (Reason, 1997).

Accident prevention methods matching an epidemiological accident model focus on performance deviations and understanding the latent causes of the accident. These causes might be found in deviations or unsafe acts and their suppression or elimination can prevent the accident happening again.

Errors and deviations are usually seen by OHS professionals in a negative context, and programs such as 'safe behaviour' methodologies attempt to ensure that strict rules and procedures are always followed. However safety prevention thinking is moving to an understanding that systems should be resilient enough to withstand deviations or uncommon actions without negative results.

Systemic models

By the 1980s OHS researchers realised that previous accident models did not reflect any realism as to the true nature of the observed accident phenomenon. As noted by Benner:

one element of realism was non-linearity models had to accommodate non-linear events. Based on these observations, a realistic accident model must reflect both a sequential and concurrent non- linear course of events, and reflect events interactions over time.

This was supported by Rasmussen (1990) who, whilst quoting Reason's (1990) resident pathogens, acknowledged that the identification of events and causal factors in an accident are not isolated but "depend on the context of human needs and experience in which they occur and by definition ... therefore will be circular".

Systemic accident models which examined the idea that systems failures, rather than just human failure, were a major contributor to accidents (Hollnagel, 2004) began to address some of these issues (but not non-linear concepts) and recognised that events do not happen in isolation of the systemic environment in which they occur.

Accident models also developed with further understanding of the role of humans, and in particular the contribution of human error, to safety research. A skill-rule-knowledge model of human error was developed in the earlier work of Rasmussen & Jensen (1974) and has remained a foundation concept for understanding of how human error can be described and analysed in accident investigation.

Research by Rouse (1981) contributed to the understanding of human memory coding, storage and retrieval. Cognitive science came to the fore in accident research, and further work by Rasmussen (1981; 1986) and Reason (1979; 1984a; 1984b; 1984c) saw the widespread acceptance and recognition of the skill- based, rule-based and knowledge-based distinctions of human error in operations.

Rasmussen (1990) wrote extensively on the problem of causality in the analysis of accidents introducing concepts gleaned from philosophy on the linkage between direct cause-effect, time line and accident modelling.

Rasmussen explored the struggle to decompose real world events and objects, and explain them in a causal path found upstream from the actual accident where latent effects lie dormant from earlier events or acts.

At this stage, Rasmussen recognised that socio-technical systems were both complex and unstable. Any attempt to discuss a flow of events does not take into account:

closed loops of interaction among events and conditions at a higher level of individual and organizational adaption … with the causal tree found by an accident analysis is only a record of one past case, not a model of the involved relational structure"

In calling for a new approach to the analysis of causal connections found in accident reports Rasmussen heralded in a more complex approach to graphically displaying accidents and understanding and capturing the temporal, complex system and events surrounding accident causation.

Reason's early work in the field of psychological error mechanisms (Reason 1975; 1976; 1979) was important in this discussion on complexity of accident causation. By analysing everyday slips and lapses he developed models of human error mechanisms (Rasmussen 1982). Reason (1990) went on to address the issue of two kinds of errors: active errors and latent errors.

Active errors were those "where the effect is felt almost immediately" and latent errors "tended to lie dormant in the system largely undetected until they combined with other factors to breach system defences".

Reason, unlike Heinrich (1931) and Bird and Germain (1985) before him, accepted that accidents were not solely due to individual operator error (active errors) but lay in the wider systemic organisational factors (latent conditions) in the upper levels of the organisation. Reason's model is commonly known as the Swiss Cheese Model (see Figure 6).

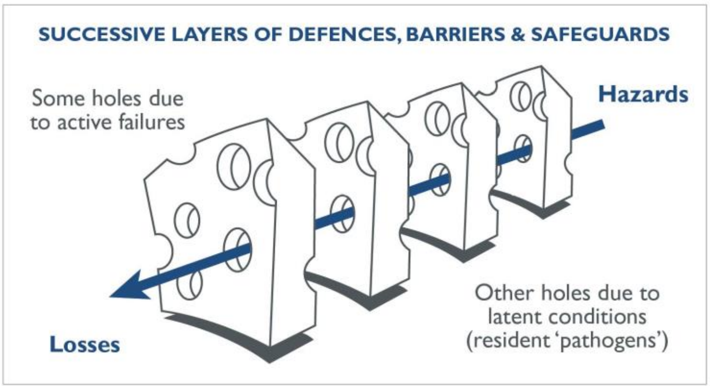


Figure 6: Reason's 'Swiss Cheese' Model (modified from Reason, 2008 p.102)

Unlike the modelling work of Heinrich (1931) and Bird and Germain (1985), Reason did not specify what these holes represented or what the various layers of cheese represented.

The model left the OHS professional to their own investigations as to what factors within the organisation these items might be. The "Swiss Cheese" model was only one component of a more comprehensive model he titled the *Reason Model of Systems Safety* (Reason 1997) (Figure 7).

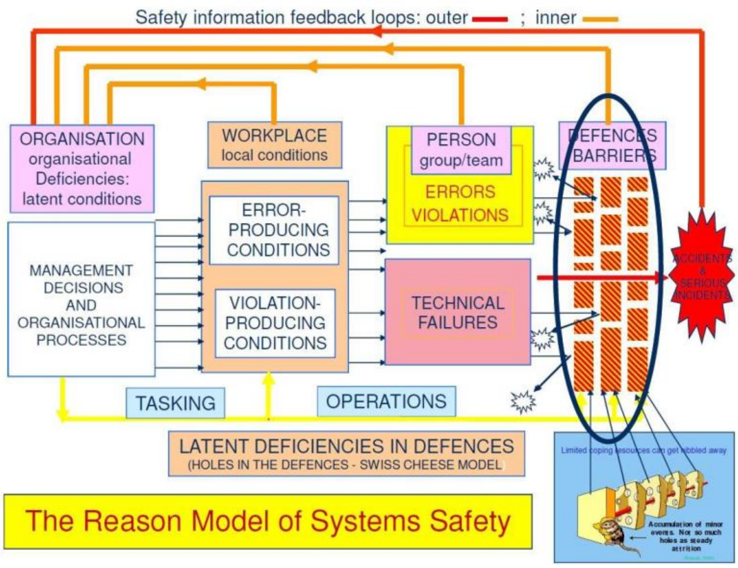


Figure 7: The Reason Model of System Safety (Reason, 1997)

Reason had a major impact on OHS thinking and accident causation in that he moved the focus of investigations from blaming the individual to a no-blame investigation approach; from a person approach to a systems approach; from active to latent errors; and he focused on hazards, defences and losses.

Reason's Swiss Cheese and Systems Safety models were an attempt to reflect these changes.

To understand the role of James Reason in changing the thinking about accidents it is important to see his work in the historical context that his work followed closely the accepted work of Rasmussen on human error (see Rasmussen, 1982) and Reason's 1987 work in this area gave him initial credibility in the safety arena.

However, by 1997 he wanted accident investigation to move away from blaming the individual at the sharp end of the system towards a no-blame approach, as had been an underpinning tenet of professional air safety investigators for many years (ICAO 1970 & USNSC 1973).

In focusing on hazards, defences and losses Reason (1997) wanted to convey the message that organisational accidents were a result of a failure to recognise the hazards in the system and the need to establish a variety of defences to prevent their adverse effects. The holes in the Swiss cheese represented a lack of strong, air-tight defences which ultimately let the accident sequence happen.

Reason continued to discuss human error, but from an error management perspective, requiring organisations to again put in place barriers for errors rather than trying to eradicate them as he recognised total eradication as an impossible task.

These models, whilst becoming highly recognisable and favoured, were criticised for a number of reasons including their lack of definition of what the holes in the barriers represented.

The Reason model, in its current form, fails to provide the detailed linkages from individual to task/environment to organization beyond a general framework of line management deficiencies and psychological precursors of unsafe acts" (Luxhøj & Maurino, 2001, p. 1).

Also, the model did not allow for the variation in organisational and individual working:

Reason's model shows a static view of the organisation; whereas the defects are often transient, i.e. the holes in the Swiss cheese are continuously moving … the whole socio-technical system is more dynamic than the model suggests (Qureshi, 2007,"Epidemiological Accident Models" par.2)

While Reason's models achieved a change in thinking about accidents recognising the complexity of causation he was also part of the move away from the heavy human error emphasis (Reason, 1990) towards a no blame or "just culture" approach (Reason, 1997).

The "just culture" approach recognised that human error was not only a normal operating mode but a normal occurrence allowing humans to learn as part of their natural path of development and function. Woods, Johannesen, Cook & Sarter (1994) describe this scenario as "latent failures [that] refer to problems in a system that produce a negative effect but whose consequences are not revealed or activated until some other enabling condition is met"

By recognising that latent conditions require a trigger in the form of an interaction, usually with a human, it can be seen that the study of humans in the accident trajectory moves away from what the human did wrong to the study of normal

While this has now largely been accepted across industry, the recent emergence of the criminalisation of aircraft accidents has the real potential to undermine the effort and adversely impact the successfulinvestigation of future accidents (Michaelidis and Mateou, 2010; Trogeler, 2010; Gates and Partners, 2011).

Human behaviour and decision making based on the environment in which they are functioning and the knowledge and technology available for decision making at the time. The study of humans in the system moves from the individual to groups of individuals embedded in a larger system (Woods et al 1994). This is represented in Woods et al., depiction of the sharp and blunt end of large, complex systems (Figure 8.)

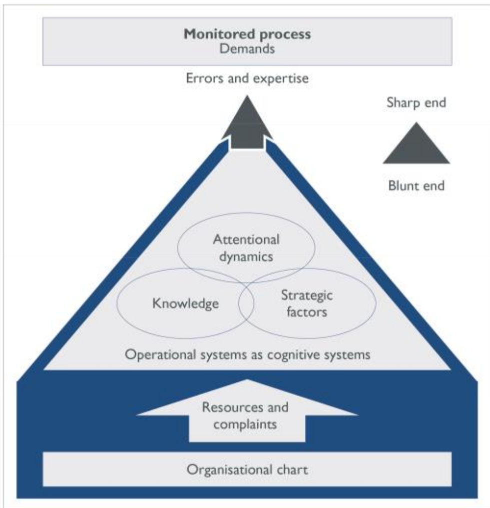


Figure 8: The sharp and blunt ends of a large complex system (Woods et al., 1994)

In 1984 Purswell and Rumar reviewed the progress of accident research in recent decades and in particular accident modelling. They noted the continuing discussion around the suitability of one accident model over another with the resolution that at this time "no universally accepted approach which is unique to occupational accident research" had yet emerged.

They cautioned against the apparent dangers of trying to obtain uniformity in the methodology of accident investigation with the dilemma being "the prospect of the model driving the problem definition, rather than the problem generating the appropriate model to be used" (p. 224). This observation and concern was still appropriate a decade later.

Complex non-linear accident models

As shown in Figure 1 there has been considerable overlap in the development of the various conceptual approaches to accident causation. In parallel with the development of thinking around epidemiological models and systemic models the thinking around the complexity of accident causation led to noncomplex linear models.

Key researchers in this approach have been Perrow, Leveson and Holnagel. The implications of recent discussions on complexity and 'drift' are briefly considered.

In the early 1980s Perrow began to argue that technological advances had made systems not only tightly coupled but inheritably complex, so much so that he termed accidents in these systems as being "normal". Perrow's normal accident theory postulated that tightly coupled systems had little tolerance for even the slightest disturbance which would result in unfavourable outcomes.

Thus tightly coupled systems were so inherently unsafe that operator error was unavoidable due the way the system parts were tightly coupled. (Perrow, 1984) Components in the system were linked through multiple channels, which would affect each other unexpectedly, and with the complexity of the system meaning that it was almost impossible to understand it (Perrow, 1984; Tenner, 1996).

Two new major accident models were introduced in the early 2000s with the intention of addressing problems with linear accident models (Hovden, et al., 2009):

- The Systems-Theoretic Accident Model and Process (STAMP) (see Leveson, 2004).
- The Functional Resonance Accident Model (FRAM) (see Hollnagel, 2004)

Systems-Theoretic Accident Model and Process (STAMP)

Leveson's model considered systems as "interrelated components that are kept in a state of dynamic equilibrium by feedback loops of information and control" (2004, p. 250). It emphasised that safety management systems were required to continuously control tasks and impose constraints to ensure system safety.

This model of accident investigation focused on why the controls that were in place failed to detect or prevent changes that ultimately lead to an accident. Leveson developed a classification of flaws method to assist in identifying the factors which contributed to the event, and which pointed to their place within a looped and linked system. Leveson's model expands on the barriers and defences approach to accident prevention and is tailored to proactive and leading safety performance indicators (Hovden, et al., 2009).

However this model has had little up take in the safety community and is not widely recognised as having a major impact on accident modelling or safety management generally. Roelen, Lin and Hale (2010, p.6) suggest that this may be because Leveson's model does "not connect to the current practice of safety data collection and analysis" making it less favourable than event chain models such as Reason's.

Functional Resonance Accident Model (FRAM)

Erik Holnagel is one of the more forward thinking researchers in the area of accident modelling and the understanding of causal factors. While Hollnagel's early published work (Cacciabue & Hollnagel 1995; Hollnagel 1993; 1998) centred on human/cognitive reliability and human/machine interface his more recent work *Barriers and Accident Prevention* (2004) challenged current thinking about accident modelling.

He introduced the concept of a three dimensional way of thinking about accidents in what is now known to be highly complex and tightly coupled socio-technical systems in which people work. He describes systemic models as tightly coupled and the goals of organisations as moving from putting in place barriers and defences to focusing on systems able to monitor and control any variances, and perhaps by allowing the systems to be (human) error tolerant.

Hollnagel's Functional Resonance Accident Model (FRAM) (Figure 9), is the first attempt to place accident modelling in a three-dimensional picture, moving away from the linear sequential models, recognising that "forces (being humans, technology, latent conditions, barriers) do not simply combine linearly thereby leading to an incident or accident" (Hollnagel, 2004, p. 171).

FRAM is based on complex systemic accident theory but considers that system variances and tolerances result in an accident when the system is unable to tolerate such variances in its normal operating mode. Safety system variance is recognised as normal within most systems, and represents the necessary variable performance needed for complex systems to operate, including limitations of design, imperfections of technology, work conditions and combinations of inputs which generally allowed the system to work.

Humans and the social systems in which they work also represent variability in the system with particular emphasis on the human having to adjust and manage demands on time and efficiency (p.
168).

Hollnagel's (2005) theory of efficiency-thoroughness trade-off (ETTO) expanded on these demands on the humans, where efficiency was often given more priority to thoroughness and vice versa. Hollnagel recognised that complex systems comprise a large number of subsystems and components with performance variability usually being absorbed within the system with little negative effect on the whole. Four main sources of variability were identified as:

- Humans
- Technology
- Latent conditions
- Barriers (p. 171).

Holnagel proposed that when variables within the system became too great for the system to absorb them; possibly through a combination of these subsystem variables of humans, technology, latent conditions and barriers; the result will be undetectable and unwanted outcomes. That is a 'functional resonance' results, leading to the system being unable to cope in its normal functioning mode. (Figure 9)

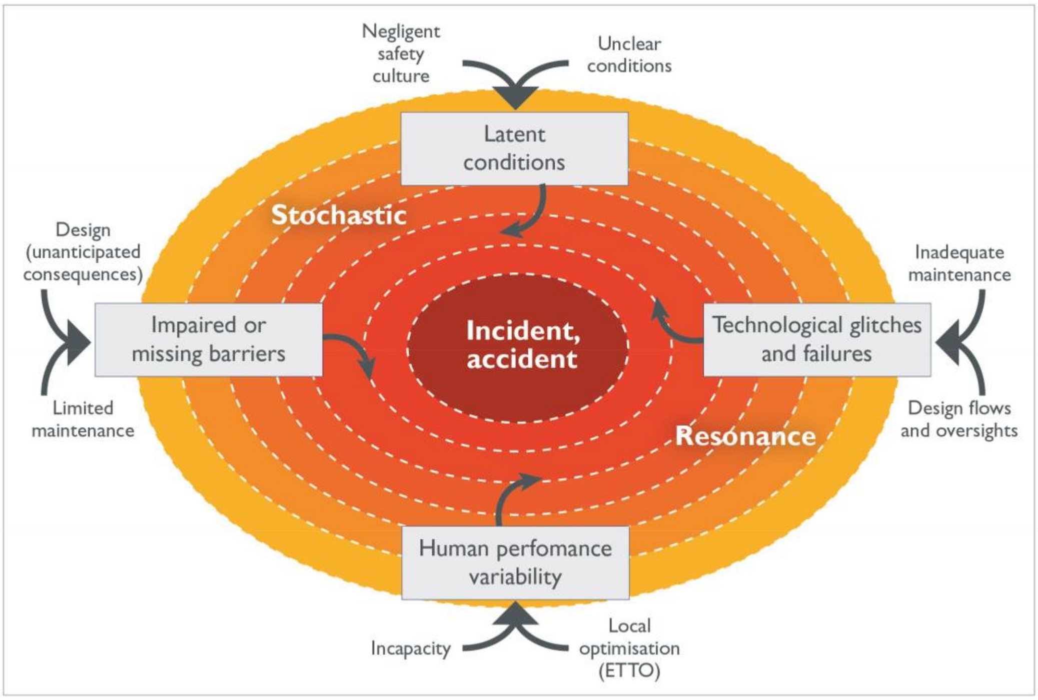


Figure 9: Functional Resonance as a System Accident Model (Holnagel, 2004)

Hollnagel’s FRAM model presents a view of how different functions within an organisation were linked or coupled to other functions with the objective of understanding the variability of each of the functions, and how that variability could be both understood and managed.

The functions are categorised as inputs, outputs, preconditions, resources, time and control. Variability in one function can also affect the variability of other functions. In 2010 Hollnagel launched a web site in support of the growing cohort of researchers and OHS professionals interested in using the model as a tool for understanding and managing accidents and incidents.

While the Functional Resonance Accident Model provided a theoretical basis for thinking about accident causation Hollnagel clearly differentiated between models that aided thinking about accident causation and methods of analysing accidents as part of investigations.

The Functional Resonance Analysis Method evolved from the conceptual thinking embodied in the model which was highlighted by retaining the FRAM acronym. A detailed description of the method is given in Sundstrom & Hollnagel (2011)

Legal requirements to investigate and report on all accidents and incidents

Reporting an incident is an important part of an effective occupational health and safety program. It helps identify work related health and safety hazards, risks and dangers. The purpose is to identify the causes of incidents.

Appropriate controls can then be put in place to prevent further occurrences of such events. In other words an incident investigation is normally performed to find out what happened, why it happened, and to prevent it from happening again.

The same innovative approach is demonstrated through the stipulations of the Occupational Health and Safety Act. According to the Act, the employer or user of machinery should formally investigate all section 24 incidents as well as any other incident where more medical treatment than the normal first aid is required.

Section 24 incidents that should be reported and investigated include the following types of incidents:

- When a person dies
- When a person becomes unconscious
- Suffers the lost of a limb or part of a limb
- Is injured or becomes ill, or is likely to die or suffer permanent physical defect

- Unable to work for 14 days or longer because of a work related incident
- When a ''major incident'' occurs

(Based on Legislation in section 24(a) and (b), *of the Occupational Health and Safety Act)* Section 1 of the Occupational Health and Safety Act defines it as ''an occurrence of catastrophic proportions, resulting from the use of plant or machinery, or from activities at a work place.''

The following occurrences must also be reported to the Provincial Director. When lives were endangered by:

- Dangerous spilled substances
- Uncontrolled release of a substance under pressure
- Flying, falling, uncontrolled moving object
- Machinery that ran out of control

(Based on Legislation in section 24(c), *of the Occupational Health and Safety Act)*

Procedure for reporting:

The above mentioned incidents; Section 24(a); (b) and (c) occurrences; should be reported immediately to the Provincial Director. It should be done by telephone, fax, or similar means of communication. They should also be reported to the Provincial Director within 7 days using the WCL 1 or WCL 2 forms.

If the injured person dies after notice the employer or user shall notify the Provincial Director of the death by fax or similar means of communication. *(Based on Legislation in* GAR 8, *of the Occupational Health and Safety Act.)*

The prescribed recording and investigation of incidents:

The employer or user should keep record of all section 24 incidents and any other incident where medical treatment or first aid is involved. This must be done in the form of the prescribed ''Annexure 1'' form. (Example attached to this document) Take note that records need to be kept for a period of at least three years. *(Based on Legislation in* GAR 9, *of the Occupational Health and Safety Act.)*

The incident site may not be disturbed without the consent of an inspector in the case where a person:

- Dies
- Loss of limb or part of limb
- Likely either to die

You may however:

- Remove injured or dead
- Rescue persons from danger

This shall not apply to:

- Traffic accident on a public road

- Incident at a private household
- Accidents according to the Aviation Act

The investigation should be performed by one the following persons:

- The employer or user of machinery
- A person appointed by the employer to investigate the incident
- The health and safety representative of the work area
- A member of the health and safety committee

The investigation should officially start within a period of 7 days and finalised as soon as is reasonably practicable, or within the contracted period in the case of contracted workers. An employer must ensure that the incident (record) be examined by the health and safety committee. *(Based on Legislation in* GAR 9, *of the Occupational Health and Safety Act.)*

Incident Investigation

What is an incident and why should it be investigated?

The term incident can be defined as an occurrence, condition, or situation arising in the course of work that resulted in or could have resulted in injuries, illnesses, damage to health, or fatalities.

The term "accident" is also commonly used, and can be defined as an unplanned event that interrupts the completion of an activity, and that may (or may not) include injury or property damage. Some make a distinction between accident and incident.

They use the term incident to refer to an unexpected event that did not cause injury or damage that time but had the potential. "Near miss" or "dangerous occurrence" are also terms for an event that could have caused harm but did not.

Please note: The term incident is used in some situations and jurisdictions to cover both an "accident" and "incident". It is argued that the word "accident" implies that the event was related to fate or chance.

When the root cause is determined, it is usually found that many events were predictable and could have been prevented if the right actions were taken - making the event not one of fate or chance (thus, the word incident is used). For simplicity, we will now use the term incident to mean all of the above events.

The information that follows is intended to be a general guide for employers, supervisors, health and safety committee members, or members of an incident investigation team. When incidents are investigated, the emphasis should be concentrated on finding the root cause of the incident so you can prevent the event from happening again.

The purpose is to find facts that can lead to corrective actions, not to find fault. Always look for deeper causes. Do not simply record the steps of the event.

Reasons to investigate a workplace incident include:

- most importantly, to find out the cause of incidents and to prevent similar incidents in the future

- to fulfill any legal requirements
- to determine the cost of an incident
- to determine compliance with applicable regulations (e.g., occupational health and safety, criminal, etc.)
- to process workers' compensation claims

The same principles apply to an inquiry of a minor incident and to the more formal investigation of a serious event. Most importantly, these steps can be used to investigate any situation (e.g., where no incident has occurred ... yet) as a way to prevent an incident.

Who should do the investigating?

Ideally, an investigation would be conducted by someone or a group of people who are:

- experienced in incident causation models,
- experienced in investigative techniques,
- knowledgeable of any legal or organizational requirements,
- knowledgeable in occupational health and safety fundamentals,
- knowledgeable in the work processes, procedures, persons, and industrial relations environment for that particular situation,
- able to use interview and other person-to-person techniques effectively (such as mediation or conflict resolution),
- knowledgeable of requirements for documents, records, and data collection; and
- able to analyze the data gathered to determine findings and reach recommendations.

Some jurisdictions provide guidance such as requiring that the incident must be conducted jointly, with both management and labour represented, or that the investigators must be knowledgeable about the work processes involved.

Members of the team can include:

- employees with knowledge of the work
- supervisor of the area or work
- safety officer
- health and safety committee
- union representative, if applicable
- employees with experience in investigations
- "outside" experts
- representative from local government or police

Note: In some cases, other authorities may have jurisdiction, such as if a serious injury or fatality occurred. Your organization should establish, implement, and maintain a procedure to coordinate managing incidents with the authority having jurisdiction (e.g., police, OH&S inspectors, etc.). This coordination may include the authority taking control of the incident scene.

Should the immediate supervisor be on the team?

The advantage is that this person is likely to know most about the work and persons involved and the current conditions. Furthermore, the supervisor can usually take immediate remedial action. The counter argument is that there may be an attempt to gloss over the supervisor's shortcomings in the incident.

This situation should not arise if the incident is investigated by a team of people, and if the worker representative(s) and the investigation team members review all incident investigation findings and recommendations thoroughly.

Why look for the root cause?

An investigator or team who believe that incidents are caused by unsafe conditions will likely try to uncover conditions as causes. On the other hand, one who believes they are caused by unsafe acts will attempt to find the human errors that are causes. Therefore, it is necessary to examine all underlying factors in a chain of events that ends in an incident.

The important point is that even in the most seemingly straightforward incidents, **seldom, if ever, is there only a single cause**. For example, an "investigation" which concludes that an incident was due to worker carelessness, and goes no further, fails to find answers to several important questions such as:

- Was the worker distracted? If yes, why was the worker distracted?
- Was a safe work procedure being followed? If not, why not?
- Were safety devices in order? If not, why not?
- Was the worker trained? If not, why not?

An inquiry that answers these and related questions will probably reveal conditions that are more open to correction.

What are the steps involved in investigating an incident?

First:

- Report the incident occurrence to a designated person within the organization.
- Provide first aid and medical care to injured person(s) and prevent further injuries or damage.

The incident investigation team would perform the following general steps:

- Scene management and scene assessment (secure the scene, make sure it is safe for investigators to do their job).
- Witness management (provide support, limit interaction with other witnesses, interview).
- Investigate the incident, collect data.
- Analyze the data, identify the root causes.
- Report the findings and recommendations.

The organization would then:

- Develop a plan for corrective action.
- Implement the plan.
- Evaluate the effectiveness of the corrective action.
- Make changes for continual improvement.

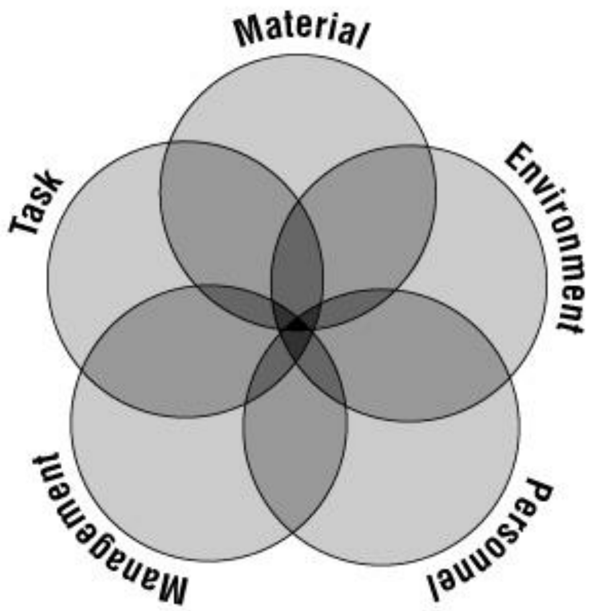
As little time as possible should be lost between the moment of an incident and the beginning of the investigation. In this way, one is most likely to be able to observe the conditions as they were at the time, prevent disturbance of evidence, and identify witnesses. The tools that members of the investigating team may need (pencil, paper, camera or recording device, tape measure, etc.) should be immediately available so that no time is wasted.

What should be looked at as the cause of an incident?

Causation Models

Many models of causation have been proposed, ranging from Heinrich's domino theory to the sophisticated Management Oversight and Risk Tree (MORT).

The simple model shown in Figure 1 attempts to illustrate that the causes of any incident can be grouped into five categories - task, material, environment, personnel, and management. When this model is used, possible causes in each category should be investigated. Each category is examined more closely below. Remember that these are sample questions only: no attempt has been made to develop a comprehensive checklist.



Incident Categories

Task

Here the actual work procedure being used at the time of the incident is explored. Members of the investigation team will look for answers to questions such as:

- Was a safe work procedure used?
- Had conditions changed to make the normal procedure unsafe?
- Were the appropriate tools and materials available?
- Were they used?
- Were safety devices working properly?
- Was lockout used when necessary?

For most of these questions, an important follow-up question is "If not, why not?"

Material

To seek out possible causes resulting from the equipment and materials used, investigators might ask:

- Was there an equipment failure?
- What caused it to fail?
- Was the machinery poorly designed?
- Were hazardous products involved?
- Were they clearly identified?
- Was a less hazardous alternative product possible and available?
- Was the raw material substandard in some way?
- Should personal protective equipment (PPE) have been used?
- Was the PPE used?
- Were users of PPE properly educated and trained?

Again, each time the answer reveals an unsafe condition, the investigator must ask **why** this situation was allowed to exist.

Work Environment

The physical work environment, and especially sudden changes to that environment, are factors that need to be identified. The situation at the time of the incident is what is important, not what the "usual" conditions were. For example, investigators may want to know:

- What were the weather conditions?
- Was poor housekeeping a problem?
- Was it too hot or too cold?
- Was noise a problem?
- Was there adequate light?
- Were toxic or hazardous gases, dusts, or fumes present?

Personnel

The physical and mental condition of those individuals directly involved in the event must be explored, as well as the psychosocial environment they were working within.

The purpose for investigating the incident is **not** to establish blame against someone but the inquiry will not be complete unless personal characteristics or psychosocial factors are considered.

Some factors will remain essentially constant while others may vary from day to day:

- Did the worker follow the safe operating procedures?
- Were workers experienced in the work being done?
- Had they been adequately educated and trained?
- Can they physically do the work?
- What was the status of their health?
- Were they tired?
- Was fatigue or shiftwork an issue?
- Were they under stress (work or personal)?
- Was there pressure to complete tasks under a deadline, or to by-pass safety procedures?

Management

Management holds the legal responsibility for the safety of the workplace and therefore the role of supervisors and higher management and the role or presence of management systems must always be considered in an incident investigation.

These factors may also be called organizational factors. Failures of management systems are often found to be direct or indirect causes. Ask questions such as:

- Were safety rules or safe work procedures communicated to and understood by all employees?
- Were written procedures and orientation available?
- Were the safe work procedures being enforced?
- Was there adequate supervision?
- Were workers educated and trained to do the work?
- Had hazards and risks been previously identified and assessed?
- Had procedures been developed to eliminate the hazards or control the risks?
- Were unsafe conditions corrected?
- Was regular maintenance of equipment carried out?
- Were regular safety inspections carried out?
- Had the condition or concern been reported beforehand?
- Was action taken?

This model of incident investigation provides a guide for uncovering all possible causes and reduces the likelihood of looking at facts in isolation. Some investigators may prefer to place some of the sample questions in different categories; however, the categories are not important, as long as each question is asked.

Obviously there is considerable overlap between categories; this overlap reflects the situation in real life. Again it should be emphasized that the above sample questions do not make up a complete checklist, but are examples only.

How are the facts collected?

The steps in the investigation are simple: the investigators gather data, analyze it, determine their findings, and make recommendations. Although the procedures are seemingly straightforward, each step can have its pitfalls.

As mentioned above, an open mind is necessary in an investigation: preconceived notions may result in some wrong paths being followed while leaving some significant facts uncovered. All possible causes should be considered.

Making notes of ideas as they occur is a good practice but conclusions should not be made until all the data is gathered.

Physical Evidence

Before attempting to gather information, examine the site for a quick overview, take steps to preserve evidence, and identify all witnesses. In some jurisdictions, an incident site must not be disturbed without approval from appropriate government officials such as the coroner, inspector, or police.

Physical evidence is probably the most non-controversial information available. It is also subject to rapid change or obliteration; therefore, it should be the first to be recorded. Based on your knowledge of the work process, you may want to check items such as:

- positions of injured workers
- equipment being used
- products being used
- safety devices in use
- position of appropriate guards
- position of controls of machinery
- damage to equipment
- housekeeping of area
- weather conditions
- lighting levels
- noise levels
- time of day

You may want to take photographs before anything is moved, both of the general area and specific items. A later study of the pictures may reveal conditions or observations that were missed initially. Sketches of the scene based on measurements taken may also help in later analysis and will clarify any written reports.

Broken equipment, debris, and samples of materials involved may be removed for further analysis by appropriate experts. Even if photographs are taken, written notes about the location of these items at the scene should be prepared.

Witness Accounts

Although there may be occasions when you are unable to do so, every effort should be made to interview witnesses. In some situations witnesses may be your primary source of information because you may be called upon to investigate an incident without being able to examine the scene immediately after the event.

Because witnesses may be under severe emotional stress or afraid to be completely open for fear of recrimination, interviewing witnesses is probably the hardest task facing an investigator.

Witnesses should be kept apart and interviewed as soon as possible after the incident. If witnesses have an opportunity to discuss the event among themselves, individual perceptions may be lost in the normal process of accepting a consensus view where doubt exists about the facts.

Witnesses should be interviewed alone, rather than in a group. You may decide to interview a witness at the scene where it is easier to establish the positions of each person involved and to obtain a description of the events.

On the other hand, it may be preferable to carry out interviews in a quiet office where there will be fewer distractions. The decision may depend in part on the nature of the incident and the mental state of the witnesses.

Interviewing

The purpose of the interview is to establish an understanding with the witness and to obtain his or her own words describing the event:

DO...

- put the witness, who is probably upset, at ease
- emphasize the real reason for the investigation, to determine what happened and why
- let the witness talk, listen
- confirm that you have the statement correct
- try to sense any underlying feelings of the witness
- make short notes or ask someone else on the team to take them during the interview
- ask if it is okay to record the interview, if you are doing so
- close on a positive note

DO NOT...

- intimidate the witness
- interrupt
- prompt
- ask leading questions
- show your own emotions
- jump to conclusions

Ask open-ended questions that cannot be answered by simply "yes" or "no". The actual questions you ask the witness will naturally vary with each incident, but there are some general questions that should be asked each time:

- Where were you at the time of the incident?
- What were you doing at the time?
- What did you see, hear?
- What were the work environment conditions (weather, light, noise, etc.) at the time?
- What was (were) the injured worker(s) doing at the time?
- In your opinion, what caused the incident?
- How might similar incidents be prevented in the future?

Asking questions is a straightforward approach to establishing what happened. But, care must be taken to assess the accuracy of any statements made in the interviews.

Another technique sometimes used to determine the sequence of events is to re-enact or replay them as they happened. Care must be taken so that further injury or damage does not occur. A witness (usually the injured worker) is asked to re-enact in slow motion the actions that happened before the incident.

Other Information

Data can be found in documents such as technical data sheets, health and safety committee minutes, inspection reports, company policies, maintenance reports, past incident reports, safe-work procedures, and training reports.

Any relevant information should be studied to see what might have happened, and what changes might be recommended to prevent recurrence of similar incidents.

What should I know when making the analysis and recommendations?

At this stage of the investigation most of the facts about what happened and how it happened should be known. This data gathering has taken considerable effort to accomplish but it represents only the first half of the objective. Now comes the key question - why did it happen?

Keep an open mind to all possibilities and look for all pertinent facts. There may still be gaps in your understanding of the sequence of events that resulted in the incident. You may need to re-interview some witnesses or look for other data to fill these gaps in your knowledge.

When your analysis is complete, write down a step-by-step account of what happened (the team's conclusions) working back from the moment of the incident, listing all possible causes at each step. This is not extra work: it is a draft for part of the final report.

Each conclusion should be checked to see if:

- it is supported by evidence
- the evidence is direct (physical or documentary) or based on eyewitness accounts, or
- the evidence is based on assumption.

This list serves as a final check on discrepancies that should be explained.

Why should recommendations be made?

The most important final step is to come up with a set of well-considered recommendations designed to prevent recurrences of similar incidents. Recommendations should:

- be specific
- be constructive
- identify root causes
- identify contributing factors

Resist the temptation to make only general recommendations to save time and effort.

For example, you have determined that a blind corner contributed to an incident. Rather than just recommending "eliminate blind corners" it would be better to suggest:

- install mirrors at the northwest corner of building X (specific to this incident)
- install mirrors at blind corners where required throughout the worksite (general)

Never make recommendations about disciplining a person or persons who may have been at fault. This action would not only be counter to the real purpose of the investigation, but it would jeopardize the chances for a free flow of information in future investigations.

In the unlikely event that you have not been able to determine the causes of an incident with complete certainty, you probably still have uncovered weaknesses within the process, or management system. It is appropriate that recommendations be made to correct these deficiencies.

The Written Report

The prepared draft of the sequence of events can now be used to describe what happened. Remember that readers of your report do not have the intimate knowledge of the incident that you have so include all relevant details, including photographs and diagrams.

Identify clearly where evidence is based on certain facts, witness accounts, or on the team's assumptions.

If doubt exists about any particular part of the event, say so. The reasons for your conclusions should be stated and followed by your recommendations.

Do not include extra material that is not required for a full understanding of the incident and its causes such as photographs that are not relevant and parts of the investigation that led you nowhere.

The measure of a good report is quality, not quantity.

Always communicate your findings and recommendations with workers, supervisors and management. Present your information 'in context' so everyone understands how the incident occurred and the actions needed to put in place to prevent it from happening again.

Some organizations may use pre-determined forms or checklists. However, use these documents with caution as they may be limiting in some cases. Always provide all of the information needed to help others understand the causes of the event, and why the recommendations are important.

What should be done if the investigation reveals human error?

A difficulty that has bothered many investigators is the idea that one does not want to lay blame. However, when a thorough worksite investigation reveals that some person or persons among management, supervisor, and the workers were apparently at fault, then this fact should be pointed out. The intention here is to remedy the situation, not to discipline an individual.

Failing to point out human failings that contributed to an incident will not only downgrade the quality of the investigation, it will also allow future incidents to happen from similar causes because they have not been addressed.

However never make recommendations about disciplining anyone who may be at fault. Any disciplinary steps should be done within the normal personnel procedures.

How should follow-up be done

Management is responsible for acting on the recommendations in the investigation report. The health and safety committee or representative, if present, can monitor the progress of these actions.

Follow-up actions include:

- Respond to the recommendations in the report by explaining what can and cannot be done (and why or why not).
- Develop a timetable for corrective actions.
- Monitor that the scheduled actions have been completed.
- Check the condition of injured worker(s).
- Educate and train other workers at risk.
- Re-orient worker(s) on their return to work.

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