Models of Causation: Safety

Core Body of Knowledge for the Generalist OHS Professional

Safety Institute of Australia Ltd

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The OHS Body of Knowledge for Generalist OHS Professionals has been developed under the auspices of the **Health and Safety Professionals Alliance**

The Technical Panel established by the Health and Safety Professionals Alliance (HaSPA) was responsible for developing the conceptual framework of the OHS Body of Knowledge and for selecting contributing authors and peer-reviewers.
The Technical Panel comprised representatives from:

The Safety Institute of Australia supported the development of the OHS Body of Knowledge and will be providing ongoing support for the dissemination of the OHS Body of Knowledge and for the maintenance and further development of the Body of Knowledge through the Australian OHS Education Accreditation Board which is auspiced by the Safety Institute of Australia.

Synopsis of the OHS Body of Knowledge

Background

A defined body of knowledge is required as a basis for professional certification and for accreditation of education programs giving entry to a profession. The lack of such a body of knowledge for OHS professionals was identified in reviews of OHS legislation and OHS education in Australia. After a 2009 scoping study, WorkSafe Victoria provided funding to support a national project to develop and implement a core body of knowledge for generalist OHS professionals in Australia.

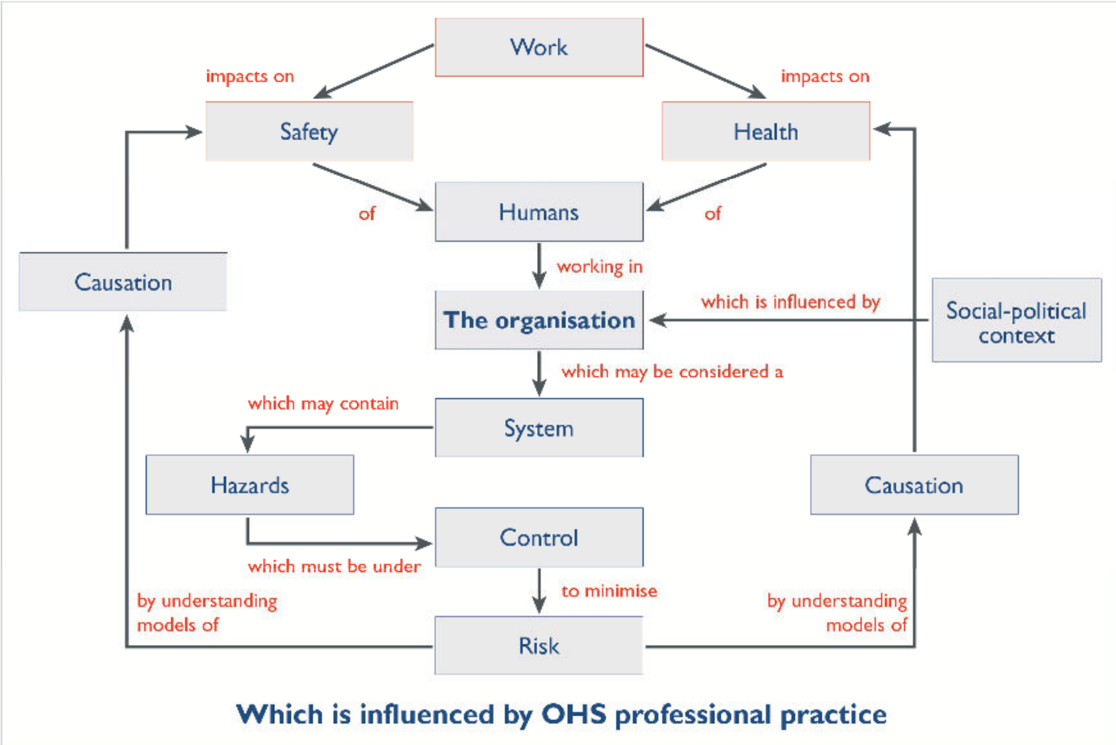
Development

The process of developing and structuring the main content of this document was managed by a Technical Panel with representation from Victorian universities that teach OHS and from the Safety Institute of Australia, which is the main professional body for generalist OHS professionals in Australia. The Panel developed an initial conceptual framework which was then amended in accord with feedback received from OHS tertiary-level educators throughout Australia and the wider OHS profession. Specialist authors were invited to contribute chapters, which were then subjected to peer review and editing. It is anticipated that the resultant OHS Body of Knowledge will in future be regularly amended and updated as people use it and as the evidence base expands.

Conceptual structure

The OHS Body of Knowledge takes a

This can be represented as:



Audience

The OHS Body of Knowledge provides a basis for accreditation of OHS professional education programs and certification of individual OHS professionals. It provides guidance for OHS educators in course development, and for OHS professionals and professional bodies in developing continuing professional development activities. Also, OHS regulators, employers and recruiters may find it useful for benchmarking OHS professional practice.

Application

Importantly, the OHS Body of Knowledge is neither a textbook nor a curriculum; rather it describes the key concepts, core theories and related evidence that should be shared by Australian generalist OHS professionals. This knowledge will be gained through a combination of education and experience.

Accessing and using the OHS Body of Knowledge for generalist OHS professionals

The OHS Body of Knowledge is published electronically. Each chapter can be downloaded separately. However users are advised to read the Introduction, which provides background to the information in individual chapters. They should also note the copyright requirements and the disclaimer before using or acting on the information.

Models of Causation: Safety

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Abstract

Understanding accident causation is intrinsic to their successful prevention. To shed light on the accident phenomenon, over the years authors have developed a plethora of conceptual models. At first glance they seem as diverse and disparate as the accident problem they purport to help solve, yet closer scrutiny reveals there are some common themes. There are linear models which suggest one factor leads to the next and to the next leading up to the accident and there are complex non linear models which hypothesise multiple factors are acting concurrently and by their combined influence, lead to accident occurrence. Beginning with a look at the historical context, this chapter reviews the development of accident causation models and so the understanding of accidents. As this understanding should underpin OHS professional practice the chapter concludes with a consideration of the implications for OHS professional practice.

Key words

accident, occurrence, incident, critical incident, mishap, defence/s, failure, causation, safety

Note from the Body of Knowledge Technical Panel and the authors of this chapter:
The development of theories and modeling of accident causation is a dynamic field with the result that there is often a gap between the theoretical discussion and practice. This chapter has taken on the difficult task of collating a selection of models and presenting them in a format that should facilitate discussion among OHS professionals. It is considered 'version 1' in what should be a stimulating and ongoing discussion. It is anticipated that this chapter will be reviewed in the next 12 months.

Contents

1 Introduction

Accidents have been broadly defined as:

> a short, sudden and unexpected event or occurrence that results in an unwanted and undesirable outcome

2 Historical context

Perhaps the earliest well documented application of accident causation knowledge is that of the Du Pont company which was founded in 1802 with a strong emphasis on accident prevention and mitigation. Klein (2009), in a paper entitled linear models offered an easy visual representation of the

Figure 1: Summary of a history of accident modelling (Hollnagel, 2010, slide 7)

3.1 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

- 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).

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

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

3.1.2 Bird and Germain

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

3.2 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

Figure 5: The Energy Damage Model (Viner, 1991, p.43)

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)

3.2.2 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

Figure 6: Generalised Time Sequence Model (Viner, 1991, p.58)

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)

3.2.3 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

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

The term became more widely known as

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[3] 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

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

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 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

3.3 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 non complex linear models. Key researchers in this approach have been Perrow, Leveson and Holnagel. The implications of recent discussions on complexity and because Leveson

- 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

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). .

3.3.3 Complexity and accident modelling

While the FRAM model begins to address complexity of organisation and the relationship with accident causation Dekker (2011) takes the discussion of complexity further to challenge the notion of accident modelling and the predictive ability of accident models. In describing complexity of society and technology Dekker considers that:

> The growth of complexity in society has got ahead of our understanding of how complex systems work and fail. Our technologies have got ahead of our theories. Our theories are still fundamentally reductionist, componential and linear. Our technologies, however are increasingly complex emergent and non-linear. Or they get released into environments that make them complex, emergent and non-linear. (2011, p.169)

Accidents occur in these complex systems by a

> representing alternative mindsets in order to spark the imagination and creativity required to solve the accident risk problem. (Hovden et al., 2010, p. 954)

The Model of OHS Practice[5] highlights the role of a conceptual framework in underpinning professional practice. An understanding of the evolution of accident, or occurrence, modelling is vital grounding for the OHS professional in developing their conceptual framework or mental model of accident causation. This chapter has considered a number of models for causation of accidents but which on initial reading may leave the OHS professional asking

5 Summary

Hovden et al., provide six uses for accident causation models:

- Create a common understanding of accident phenomena through a shared simplified representation of real-life accidents.
- Help structure and communicate risk problems.
- Give a basis for inter-subjectivity, thus preventing personal biases regarding accident causation and providing an opening for a wider range of preventive measures.
- Guide investigations regarding data collection and accident analyses.
- Help analyse interrelations between factors and conditions.
- Different accident models highlight different aspects of processes, conditions and causes. (p.955)

Accidents are complex events and that complexity has made understanding how accidents occur problematic. Beginning in the 1930s there has been an evolution in thinking about accident causation. While there has been significant overlap in the development phases, and a number of the models have enduring application in certain circumstances. The evolution has progressed from simplistic

Cacciabue, P. C., Holnagel, E. (1995). Simulation of Cognition: Applications. In J.M. Hoc, P.D. Cachiabue & E. Holnagel, (Eds.), *Expertise and Technology*, New Jersey: Lawrence Erlbaum and Associates.

DeBlois, L. A. (1915), *The Application of Safety Devices*, Hagley Museum and Library, Wilmington, DE

Dekker, S. (2011). Drift into Failure: From Hunting Broken Components to Understanding Complex Systems. Surry: Ashgate.

Gates and Partners (2011), Aviation and the Implications of Criminalisation, Gates and Partners Solicitors, http://alae.org/downloads/legal/accidents.pdf

Gibson, J.J. (1961). The contribution of experimental psychology to the formulation of the problem of safety

Leveson, N. (2004). A new accident model for engineering safer systems. *Safety Science*, 42, 237-270.

Luxhøj, J. T., Maurino, M. (2001). An aviation system risk model (ASRM) case study: Air Ontario 1363. *The Rutgers Scholar*, 3.

Michaelidis-Mateou S. and Mateou A. (2010), *Flying in the Face of Criminalisation*, Ashgate

Newbold, E. M. (1926). *A contribution to the study of the human factor in causation of accidents.* British Industrial Health Research Board.

Osborne, E. E., Vernon, H. M., &Muscio, B. (1922). *Two contributions to the study of accident causation.* British Industrial Fatigue Research Board.

Perrow, C. (1984). *Normal Accidents: Living with High-Risk Technologies*. New York: Basic Books Inc.

Purswell, J. J., &Rumar, K. (1984). Occupational accident research: Where have we been and where are we going? *Journal of Occupational Accidents*, 6, 219-228.

Qureshi, Z. H. (2007). A review of accident modelling approaches for complex socio-technical systems. Paper presented at the 12th Australian Workshop on Safety Related Programmable Systems (SCS'07). http://crpit.com/confpapers/CRPITV86Qureshi.pdf

Rasmussen, J. (1981). Models of mental strategies in process plant diagnosis. In J. Rasmussen & W. Rouse (Eds.), *Human Detection and Diagnosis of System Failures*. New York: Planum.

Rasmussen, J. (1982). Human errors: A taxonomy for describing human malfunction in industrial installations. *Journal of Occupational Accidents*, 4(311-335).

Rasmussen, J. (1986). *Information Processing and Human-Machine Interaction*. Amsterdam: North-Holland.

Rasmussen, J. (1990). Human error and the problem of causality in analaysis of accidents. Paper presented at the Human Factors in Hazardous Situations. *Proceedings of a Royal Society Discussion Meeting*.

Rasmussen, J., Jensen, A. (1974). Mental procedures in real-life tasks: A case study of electronic troubleshooting. *Ergonomics*, 17, 193-307.

Reason, J. T. (1975). How did I come to do that? *New Behaviour*, 24.

Reason, J. T. (1976).Absent minds.*New Society*, 4(November).

Reason, J. T. (1979). Actions not as planned: The price of automatization. In G. Underwood & R. Stevens (Eds.), *Aspects of Consciousness* (Vol. 1). London: Wiley.

Reason, J. T. (1984a).Lapses of attention.In R. Parasuraman& R. Davies (Eds.), *Varieties of Attention*. New York: Academic Press.

Reason, J. T. (1984b).Absent-mindedness and cognitive control.In J. Harris & P. Morris (Eds.), *Everyday Memory, Actions and Absent-Mindedness*. London: Academic Press.

Reason, J. T. (1984c).Order of output in category generation. Paper presented at the Cognitive Section, British Psychological Society, Oxford.

Reason, J. T. (1987).The Chernobyl Errors. *Bulletin of the British Psychological Society*, 40, 201-206.

Reason, J. T. (1990).*Human Error*. Aldershot: Ashgate.

Reason, J. T. (1997).*Managing the Risks of Organisational Accidents*. Aldershot: Ashgate.

Reason, J.T. (2008). *The Human Contribution: Unsafe Acts, Accidents and Heroic Recoveries.* Surrey: Ashgate.

Roelen, A. L. C., Lin, P. H., & Hale, A. R. (2011). Accident models and organisational factors in air transport: The need for multi-method models. *Safety Science*, 49, 5-10.

Rouse, W. B. (1981). Models of human problem solving: Detection, diagnosis and compensation for system failures. Paper presented at the Proceedings of IFAC Conference on Analysis, Design and Evaluation of Man-Machine Systems., Baden-Baden, FRG.

Sundstrom, G.H., Hollnagel, E. (2011). The Importance of Functional Interdependence in Financial Services Systems. In E. Hollnagel, J Pariés & D.D. Woods (Eds.), *Resilience Engineering in Practice: A Guide Book.* Ashgate.

Surry, J. (1969). *Industrial Accident Research: A Human Engineering Appraisal*. Toronto, Ontario: Labour Safety Council, Ontario Department of Labour.

Svenson, O. (1991). The accident evolution and barrier function (AEB) model applied to incident analysis in the processing industries. *Risk Analysis*, 11(3), 499-507.

Svenson, O. (2001). Accident and incident analysis based on accident evolution and barrier function (AEB) model. *Cognition, Technology & Work*, 3(1), 42-52.

Tenner, E. (1996). *Why things bite back*. London: Fourth Estate Limited.

Trogeler M. (2010), Criminalisation of air accidents and the creation of a Just Culture, European Air Law Association, http://www.eala.aero/library/Mildred%20Trgeler%20EALA%20prize.pdf

Vernon, H. M. (1919). *The influence of hours of work and of ventilation on output in tinplate manufacturing.* British Industrial Fatigue Research Board.

Vernon, H. M. (1920). *Fatigue and efficiency in the iron and steel industry.* British Industrial Fatigue Research Board.

Vernon, H. M., Bedford, T., & Warner, C. G. (1928). *A study of absenteeism in a group of 10 collieries.* British Industrial Fatigue Research Board.

Viner, D. (1991), *Accident analysis and risk control*, Derek Viner Pty Ltd, Melbourne.

Woods, D. D., Johannesen, L. J., Cook, R. I., &Sarter, N. B. (1994). Behind Human Error: Cognitive Systems, Computers, and Hindsight. Dayton, Ohio;Dayton University Research Institute.