OHS Body of Knowledge

An Introduction to User-Centred Safe Design

Core Body of Knowledge for the Generalist OHS Professional

Second Edition, 2019

34.2

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The chapter supports the capability action area of the Australian Work Health and Safety Strategy 2012-2022, specifically the strategic outcome that “those providing work health and safety education, training and advice will have appropriate capabilities.” Thus, the chapter contributes to the vision of “healthy, safe and productive working lives.”

Bibliography

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An Introduction to User-Centred Safe Design

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An Introduction to User-Centred Safe Design

Abstract

This chapter emphasises the importance of user-centred control and safe design within a framework of participatory ergonomics, and considers the roles that generalist OHS professionals can take in the workplace design and control process. Key concepts of ergonomics/human factors, user-centred design, risk management and participatory approaches to control, and safe design are described, with an emphasis on methods of infusing safe design with a user-centred perspective. The chapter provides an example of a user-centred safe design tool – Safety in Design Ergonomics (SiDE) – that employs a task-based approach to develop effective user-centred controls in the mining industry. Also, safe design procurement and manual-task risk management are considered. Designer duties and regulations are summarised, including standards for user-centred control and safe design, and the chapter concludes with some implications for OHS practice.

Keywords

safe design, participatory ergonomics, end users, human factors, user-centred control

Contextual reading

Readers should refer to 1 *Preliminaries* for a full list of chapters and authors and a synopsis of the OHS Body of Knowledge. Chapter 2, *Introduction* describes the background and development process while Chapter 3, *The OHS Professional* provides a context by describing the role and professional environment.

Terminology

Depending on the jurisdiction and the organisation, Australian terminology refers to 'Occupational Health and Safety' (OHS), 'Occupational Safety and Health (OSH) or 'Work Health and Safety' (WHS). In line with international practice this publication uses OHS with the exception of specific reference to the Work Health and Safety (WHS) Act and related legislation.

Jurisdictional application

This chapter includes a short section referring to the Australian model work health and safety legislation. This is in line with the Australian national application of the *OHS Body of Knowledge*. Readers working in other legal jurisdictions should consider these references as examples and refer to the relevant legislation in their jurisdiction of operationas examples and refer to the relevant legislation in their jurisdiction of operation.

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1 Introduction

Ron McLeod, previously the global discipline lead for human factors at Royal Dutch Shell, proposed that: "People are probably the most resilient and robust element of any socio-technical system, capable of immense feats of adaptation, working around problems and finding creative solutions to novel, unforeseen and unexpected difficulties” (2015, p. 5). The reliability of people at work can be enhanced through: (i) providing an organisational culture that values safety and encourages, supports and reinforces safe behaviours; (ii) ensuring workers are fit for work and have the appropriate technical and non-technical skills; and (iii) providing working environments, equipment, tools and systems that are compatible with human strengths and limitations (McLeod, 2015). However, the last of these three strategies offers the greatest potential to enhance human reliability, and is the focus of this chapter.

One of the seven action areas of the *Australian Work Health and Safety Strategy 2012-2022* is ‘healthy and safe by design.’ This action area supports achievement of two strategic outcomes by 2022:

- Structures, plant and substances are designed to eliminate or minimise hazards and risks before they are introduced into the workplace.
- Work, work processes and systems of work are designed and managed to eliminate or minimise hazards and risks. (SWA, 2012, p. 9).

These outcomes can be achieved with the application of the principles of ‘user-centred design’ and ‘safe design.’ While access to specialist ergonomic advice is essential in complex situations, generalist Occupational Health and Safety (OHS) professionals should have a working knowledge of these principles.

The need for this *OHS Body of Knowledge* chapter was identified at the 2012 national conference of the Human Factors and Ergonomics Society of Australia (HFESA). Chapter development was overseen by a topic-specific technical panel (TSTP), and feedback on the initial draft was obtained from workshop participants at the 2013 HFESA conference, and from invited Australian and international OHS design and safety specialists. This chapter extends and complements chapter *34.1 Control: Prevention and Intervention*, which addresses workplace hazard and risk control and introduces the control strategy of safe design, and chapter *16 Biomechanical Hazards*, which provides a ‘participative ergonomics’ framework for developing controls. This chapter introduces the concept of user-centred safe design and control, and the role of the generalist OHS professional in that process. While this chapter acknowledges the breadth of roles that generalist OHS professionals may take in the design and control process (see Table 1) the *OHS Body of Knowledge* chapter, *34.3 Health and Safety in Design* provides a detailed analysis of the safety in design process and the associated role of the OHS professional.

Within a participatory-ergonomics framework, user-centred control and safe design strategies can be applied to the design/modification of workplace equipment, tools, structures and work processes; as controls for previously identified hazards; or to ensure safe work systems and layouts for end users. The general philosophy advocated throughout this chapter is that obtaining end-user input can be vital to revealing design deficiencies and to identifying effective control solutions. After introducing key concepts, the chapter reviews the development of safe design methodologies, provides some specific examples in mining and procurement, and considers the legislative obligations of designers. The chapter concludes with some implications for OHS practice.

Table 1: Possible roles for generalist OHS professionals in the workplace design and control process

Role	Example Characteristics
Design-related	• Understanding work systems and hazards, and providing user-centred input into the design of equipment, tasks or workplaces at all lifecycle stages
	• Identifying parties who might use or be impacted by the design
	• Understanding user wants versus needs, and understanding special user groups (e.g. disabled or different-sized users)
	• Investigating events to identify design issues
	• Auditing of the workplace to get user input on current design and control issues
	• Using 'learning loops' and post-occupancy reviews of design/control processes
	• Using risk assessments to identify and prioritise design/control issues and improvement opportunities
Coordination and liaison	• Assisting with change management, the commissioning of new equipment, or the introduction of new tasks or workplace designs
	• Coordinating multiple inputs and viewpoints, especially of end users
	• Understanding political, economic, social and business drivers and barriers
	• Interacting and engaging with project managers and other relevant stakeholders
	• Developing relevant workplace policies and influencing design standards/processes
General	• Undertaking or assisting with cost-benefit / return on investment (ROI) analysis
	• Developing a procurement process to include user-centred safe design considerations, including the improved procurement process in assurance
	• Understanding when to call in specific expertise (e.g. ergonomists)
	• Achieving organisational recognition and support for strategic investment in user-centred safe design of tasks, equipment and workplaces

2 Key concepts

2.1 Ergonomics/human factors and user-centred design

As defined by the Council of the International Ergonomics Association in 2000:

> Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being, and overall system performance (as cited in IEA, 2019).

Or, as the vision statement of the Human Factors and Ergonomics Society of Australia puts it, "People-centred environments, products and systems for all" (HFESA, 2014). The relevance to OHS is clear.

As well as being a scientific field and profession, human factors is a way of looking at the world that focuses on the capabilities, limitations, motivations, behaviours and preferences of people. The aim is to maximise efficiency, effectiveness, quality, comfort, safety and health by ensuring that work systems are designed in such a way that human interaction with them is consistent with individuals' capabilities, limitations, motivations, behaviours and preferences (Horberry, Burgess-Limerick & Steiner, 2010). The essence of human factors is design from the perspective of the user; the systems approach to ergonomics typically considers interactions between the person, the tasks being performed, the tools/equipment being used, the environment in which the work takes place, how the work is organised and 'wider' issues such as the culture of the company (Horberry et al., 2010). The emphasis is on changing work systems to suit people, rather than requiring people to adapt to work systems. As such, user-centred design aims to meet the needs and capabilities of end users.

2.2 Risk-management and participatory approaches to control

As observed by Burgess-Limerick (2011, 2018), a risk-management framework is frequently adopted to guide the application of ergonomics/human factors principles to risk-control or design problems. The process starts with understanding the broader context in which the work takes place before undertaking hazard identification and risk assessment. If the outcome of the risk assessment is that preventative action is required, the risk-control phase incorporates identifying and evaluating potential control options prior to implementation and ongoing review. The risk-control emphasis is on elimination or reduction of risk through design controls rather than focusing excessively on administrative controls such as training, selection or personal protective equipment (Burgess-Limerick, 2011).

Perhaps most importantly for the generalist OHS professional, this risk-management process places heavy emphasis on consultation. This consultation is fundamental to participatory ergonomics; the people involved are assumed to be the 'experts' who must be involved at each stage of the risk-management cycle if the process is to be executed successfully (Burgess-Limerick, 2011). Participatory approaches take on the challenge of effectively engaging with and tapping into the insight of end users. This often involves a 'task analysis' in which operational tasks are studied from the user's perspective (Kirwan & Ainsworth, 1992; see section 4.2). In an occupational-injury-management context, this implies that workers and management participate in hazard identification, risk assessment, risk control and review steps of the risk-management cycle.[1] There is evidence that demonstrates the effectiveness of such approaches across many industries (see, for example, Burgess-Limerick, Straker, Pollock et al., 2007; Torma-Krajewski, Steiner & Burgess-Limerick, 2009; Pazell, Burgess-Limerick, Horberry & Davidson, 2016). Also, a participatory approach can increase productivity and work efficiency by improving equipment design, procedures and training.

2.3 Safe design

Less-than-adequate design is a major contributory factor in many work incidents. For example, Safe Work Australia (2018a) reported that "Of 639 work-related fatalities from 2006 to 2011, one-third (188) were caused by unsafe design or design-related factors contributed to the fatality [and] of all fatalities where safe design was identified as an issue, one fifth (21%) was caused by inadequate protective guarding for workers" (SWA, 2018a; see also Creaser, 2008; Driscoll, Harrison, Bradley & Newson, 2008).[2]

> In sum, many incidents, accidents and avoidable downtime are due in part to equipment design inadequacies, either in maintainability or operability, and are therefore theoretically preventable (Horberry, 2014, p. 6).

Largely as a result of such design-related incidents, one of the key action areas of the *Australian Work Health and Safety Strategy 2012-2022* is 'healthy and safe by design' (SWA, 2012). One increasingly high-profile strategy for achieving this goal is 'safe design' (sometimes referred to in the UK as 'safety in design' and in the US as 'prevention through design') (Horberry et al., 2010). As the name suggests, this involves safety by design and not safety by procedure, retrofit or trial and error (Horberry et al., 2010). Whereas in the past the term has been applied narrowly to products and equipment (rather than to work processes or workspace layouts, where the term 'participatory ergonomics' has been used), contemporary definitions emphasise a design process:

> Safe design is about integrating hazard identification and risk assessment methods early in the design process, to eliminate or minimise risks of injury throughout the life of a product. This applies to buildings, structures, equipment

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[1] See *OHS BoK* 31.1 Risk for a discussion on these aspects of risk and risk management.

[2] See *OHS BoK* 28 Hazards Mechanical Plant and 29 Mobile Plant.

and vehicles. (SWA, 2018a)

Fundamental to safe design is the systematic involvement of decision makers and, ideally, end users, and the employment of hazard-analysis/risk-assessment methods for the designed product/system (ASCC, 2006). The process generates design options to eliminate hazards or minimise risks to those who make the product/system/structure, those who use or maintain it, and those who are at or in the vicinity of a workplace and may be exposed to or otherwise affected by it (Horberry, 2014). Safe design generally addresses control priorities at the peak of the hierarchy of control and at the earliest stages in the design time sequence. As a result, fewer barriers and defences may be required to compensate for deficiencies at later stages of the product/system lifecycle.

Safe design has been used in many industries, such as road transport (Horberry, Regan & Edquist, 2013), waste handling and incineration (De la Garza & Fadier, 2005), construction (Culvenor & Else, 2011; Pazell et al., 2016) and mining (Cooke & Horberry, 2011; Wester & Burgess-Limerick, 2015). There is often a regulatory or accreditation focus on reinforcing legal obligations; for example, the Office of the Federal Safety Commissioner Building and Construction OHS Accreditation Scheme. In the US, safe design began attracting the attention of researchers, designers and regulators in the mid-1990s (Howard, 2008) and, in Europe, safe design is central to directives relating to construction (design and management) and machinery safety (see, for example, European Commission, 2006).

Key principles underpinning the overall safe design process, as synthesised by Horberry (2014, p. 294), are to:

- employ a participatory design process, including actively involving equipment manufacturers, operators / end users and maintainers
- identify persons with control, such as business decision makers, designers or equipment purchasers
- explicitly consider the full product lifecycle – from concept to design, from manufacture to use, through to dismantling and disposal
- apply systematic risk-management processes, including hazard identification, risk assessment and risk control
- initiate effective information transfer, including design documentation via risk registers or similar (ASCC, 2006; Horberry, Sarno, Cooke & Joy, 2009; Schulte, Rinehart, Okun, Geraci & Heidel, 2008).

Although difficult to quantify, it has been estimated that the purchase and use of inherently safe plant and equipment would result in a saving of 5-10% of their cost “through reductions in inventories of hazardous materials, reduced need for protective equipment and the reduced costs of testing and maintaining the equipment” (ASCC, 2006, p. 7). Similarly, in some high-hazard industries, proof of safe design is increasingly a requirement for equipment procurement (Burgess-Limerick et al., 2012) or for a manufacturer to even enter the market (Hale, Kirwan & Kjellén, 2007). This is also the case for design in the process

industries, in particular by means of the application of the HAZard and OPerability study (HAZOP), Failure Mode Effects Analysis (FMEA) and other techniques used during the design phase, or as part of a formalised management of (design) change process. Considerable costs can be associated with unsafe design; for example, retrofitting, workers' compensation, environmental clean-up and public liability (ASCC, 2006). If safety is incorporated at the design stage, such costs can be avoided as it is often easier and cheaper to make safety improvements early in the product lifecycle.

However, there are challenges. Regarding user-centred design and control in high-hazard work domains, Horberry (2014, p. 296) stated:

> …a 'paradox' here is that although ergonomics should be involved early and regularly in the design/control process, the certainty of the effects of design changes on safety of the actual equipment or system of work being used is often not fully revealed until it is operational and the exact context of the working environment and work tasks are known (Hendrick, 2003).

Once a work system is operational it may be too late for the design to be substantially changed; remedial control may be required. Although consequences cannot always be reasonably predicted at the design stage (Hale et al., 2007), "where accidents have occurred there is the need for a 'learning loop' for designers to appropriately modify future designs and to evaluate the success of the precise safe design process used" (Horberry, 2014, p. 296).

3 Historical perspective

Although modern efforts to design for safety can be traced to the 1800s, it was the 1970s before a distinct design focus on worker health and safety emerged (Schulte et al., 2008). The safe design approach formalises terms and considers the full lifecycle of the equipment or system in a wider context (Horberry, 2014), encompassing:

> The practice of anticipating and "designing out" potential occupational health and safety hazards and risks associated with new work processes, structures, equipment, or tools, and organizing work, such that it takes into consideration the construction, maintenance, decommissioning, and disposal/recycling of waste material, and recognizing the business and social benefits of doing so (Schulte et al., 2008, p. 115).

The application of ergonomics/human factors and user-centred safe design principles to minimise safety and health risks throughout a system's lifecycle can be considered as a subset of the broader field of human systems integration (HSI) (Booher, 2003), which also considers aspects such as crewing, personnel and training. Formal HSI implementation programs have been established for many years within the US Department of Defense and

UK Ministry of Defence, and more recently in civilian agencies such as NASA, the US Federal Aviation Administration and the European Organisation for the Safety of Air Navigation. In these agencies, program managers are required to develop and implement an HSI plan, and extensive guidance and advisory documentation is provided (Burgess-Limerick, Cotea & Pietrzak, 2010; Burgess-Limerick, Cotea, Pietrzak & Fleming, 2011). Based on a review of practice in the implementation of HSI across defence and civilian industries, it was concluded that:

> …investments in HSI implementation will have a positive, and probably large, return on investment in terms of:
>
> - reduced probability of adverse safety and health outcomes
> - reduced probability of program failure
> - improved equipment effectiveness
> - reduced overall costs (Burgess-Limerick et al., 2011, pp. 59-60).

3.1 Safe design methodologies

Until recently, there has been little effort to standardise methodologies of safe design (Gambatese, 2008). Although not formally standardised, a useful model for safe design (SWA, 2018a) is shown in Figure 1.

In 2011 the American National Standards Institute published *ANSI/ASSE Z590.3 Prevention through design: Guidelines for addressing occupational hazards and risks in design and redesign processes*. This initiative, coordinated by the US National Institute for Occupational Safety and Health (NIOSH), provided an overall conceptual framework for safe design (ANSI, 2011).

In addition to long-established risk-management processes such as HAZard and Operability (HAZOP), a variety of tools are available to specifically promote safe design and support more systematic consideration of hazards and risks; however, some of these do not have an explicit user-centred focus (Horberry, 2014). Three such tools that are more user-centred than most are the designer misconception checklist (DMC), the construction hazard assessment implication review (CHAIR) and failure mode effects analysis (FMEA).

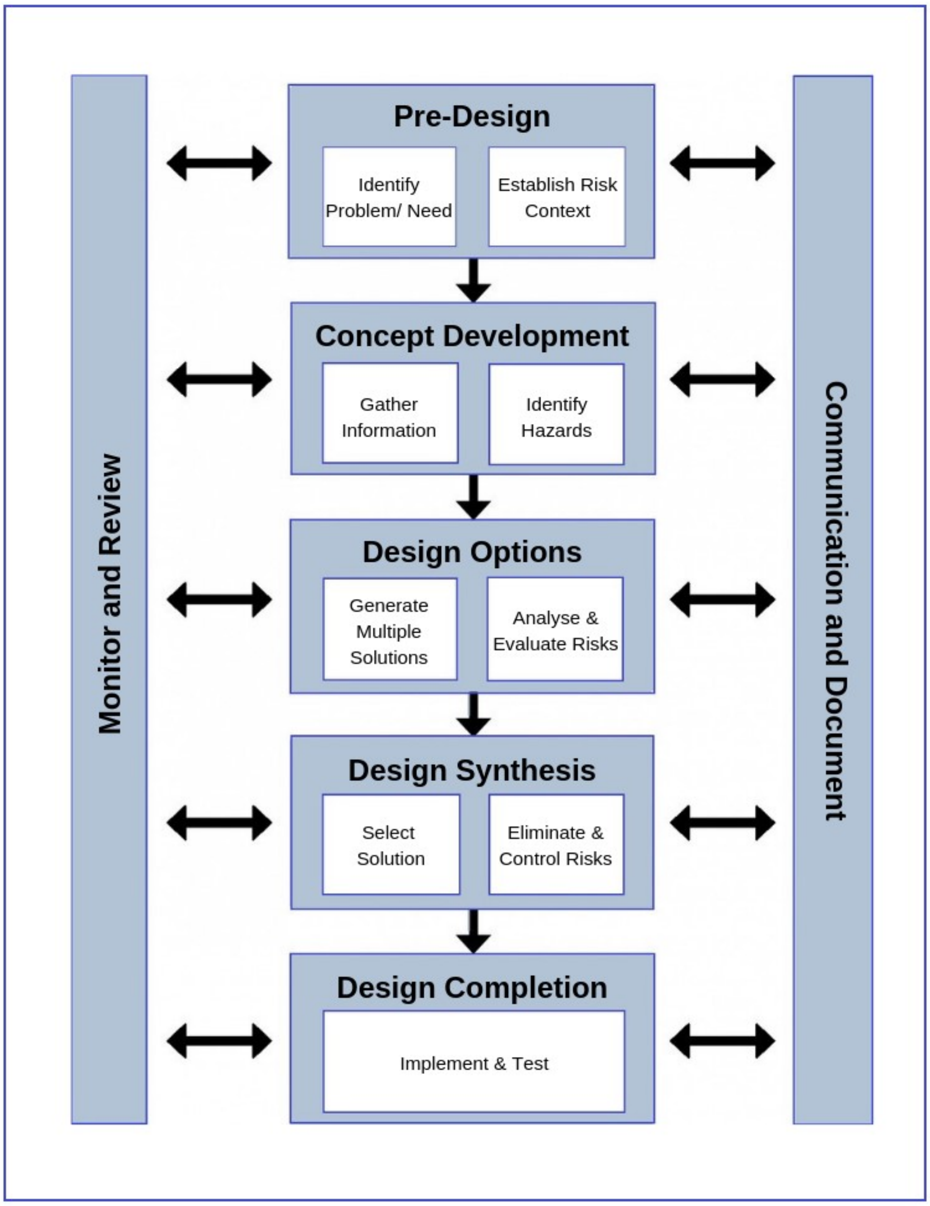

Figure 1: A model for safe design (SWA, 2018a)

3.1.1 Designer misconception checklist (DMC)

As a result of research conducted for the UK Health and Safety Executive, the DMC was developed to assist designers test products for design misconceptions (Busby, 2003). To characterise these misconceptions, it was hypothesised that safe design could be improved through examining accident reports and identifying the types of accident-contributing misconceptions that may have been present in the engineered systems. The analysis resulted in categorising about 30 main misconceptions that designers seemed to suffer, and which would compel their designed product to contain hazards; these include “the

misconceptions of designers about operators, operators' intentions and the operating environment…and the misconceptions of operators about the design, its rationale and boundaries of safe operation" (Busby, 2003, p. vii). An example of a designer misconception is "the belief that operators will sustain high attention levels – whereas attention is degraded in a variety of conditions" (Busby, 2003, p. 6).

3.1.2 Construction hazard assessment implication review (CHAIR)

CHAIR, a tool used in the construction industry, provides a discussion framework stimulated by guidewords "to review the conceptual design and identify the significant construction, maintenance, repair and demolition safety risks associated with a project" (WorkCover NSW, 2001, p. 10). Two sets of guidewords – *generic* and *overview* – are used to trigger thinking about hazards. Generic guidewords used for each design element are size, position/location, movement/direction, energy, egress/access, heights/depths, maintenance/repair, poor ergonomics, load/force and timing; and overview guidewords used for the whole design concept are environmental conditions, toxicity, environmental impact, inspection/testing, documentation, quality control, external safety interfaces, commission/start-up/shut down, safety equipment, natural hazards, demolition, construction equipment fire/explosion, utilities and services, and maintenance. The user systematically works through the guidewords one by one (not unlike a HAZOP) (WorkCover NSW, 2001).

3.1.3 Failure mode effects analysis (FMEA)

FMEA is a technique used to systematically identify and assess vulnerabilities in a system through the proactive identification of ways in which a system could fail (failure modes) and the potential outcomes of those failures (effects). Developed by the US Department of Defense in the middle of the 20th century, the technique was used in organisations such as NASA during the 1960s (Gilchrist, 1992). Since then, the methodology has evolved from a purely engineering focus (looking at technical component failures) to encompass examination of system and process vulnerabilities that might arise due to human error. As a systematic approach to identify and prevent product and process problems before they occur, FMEA has been identified as a key methodology for enhancing quality and safety in, for example, healthcare (Dhillon, 2003; Senders, 2004).

3.2 Integrating a user-centred perspective into safe design

Although safety in design is an increasingly influential aspiration, the effective integration of user-centred knowledge and techniques into safe design processes is a relatively new topic of discussion that has yet to be extensively researched (Fadier & De la Garza, 2006; Fadier, 2008; Horberry, 2014). The key message for generalist OHS professionals is that applying a participatory-ergonomics approach to safe design processes can help create more user-

centred equipment, systems and processes for end users (Pazell et al., 2016; Horberry, Burgess-Limerick & Steiner, 2018).

While the traditional focus of user-centred design has been on issues of usability, in safety-critical industries the concept of error-tolerant design has become increasingly important. This design philosophy accepts that human error is inevitable, and attempts to build into systems and processes enhanced ability for operators to detect and mitigate any errors that may occur, prior to safety being compromised (Kontogiannis, 2011). This approach focuses on error prediction and ensuring that errors are observable by the operator, and can be rectified easily.

A user-centred approach to safe design requires an understanding of the attitudes, abilities, limitations, motivations and expectations of users relevant to all components of the work system across its entire lifecycle (De la Garza & Fadier, 2005). As outlined by Horberry (2014), 'users' include those who build/modify the equipment, those who use it and those who maintain it (that is, not just end users). Such an understanding can be achieved by:

- Involving operators in the device/system designs, evaluations and modifications (proactively, by anticipating future situations of use) (De la Garza & Fadier, 2005; Horberry et al., 2009) by tapping into their ideas, experiences and requirements (Nael, 2011)
- Systematically analysing the tasks to be performed and their associated risks (Horberry et al., 2010; Boy & Bradshaw, 2006)
- Identifying how tasks are actually performed and how this deviates from the design-stage predicted performance (Fadier, 2008); this includes operation in non-routine situations or where parts of the system are non-operational (Hale et al., 2007)
- Investigating incidents – near misses and accidents – to obtain feedback on system performance and identify deficiencies in design and control (Rechnitzer, 2001; Hale et al., 2007)
- Using human factors information to develop appropriate technologies and usable interfaces to reduce the likelihood of human error (Boy & Bradshaw, 2006).

4 A user-centred safe design process

Section 3 outlined the need to obtain end-user input to ensure that designs and controls are user-centred. It was noted that the 2011 ANSI standard outlines a conceptual framework for safe design; methods aligned with this standard are now required. This section presents a user-centred safe design tool that, while it was created for equipment used in mining, is applicable in a variety of occupational domains (Horberry et al., 2009). The tool, which is aligned with the ANSI standard and incorporates risk-assessment and participatory-ergonomics processes, was developed and employed to achieve safer designs and design

processes for new equipment, and thus minimise the need for post-deployment site-based controls. Its application demonstrates the importance of obtaining end-user input to reveal design deficiencies and to identify effective user-centred controls. Part of the content of this section has been published previously in Horberry (2014) and Horberry et al. (2018).

4.1 SiDE – a user-centred safe design tool

Because the design of mining equipment is still technology-centred rather than user-centred (Horberry et al., 2010), most mining equipment requires considerable human intervention for maintenance and operation. Building on an existing process called the Operability and Maintainability Analysis Technique (OMAT) (Horberry et al., 2009) and general safe design processes (such as depicted in Figure 1), the Safety in Design Ergonomics (SiDE) tool was developed to help produce mining equipment that would ensure the safety and wellbeing of all operators and maintainers (Horberry, 2014). SiDE is a task-based, design and control process for human element risks; the purpose is to help identify, understand and provide solutions to risks users face when operating and maintaining equipment.

SiDE can be employed as a basis for new equipment purchase, to examine site-specific risks related to new equipment, to investigate equipment-related incidents, and to address residual risks during equipment operation or modification phases (Burgess-Limerick et al., 2012). Such site use also allows emergent interactions between the equipment and other aspects of the organisational system to be examined after the equipment has been deployed. Firmly within the industry risk-management approach (rather than being solution prescriptive), SiDE is intended to help designers and end users identify, understand and provide solutions to the risks people face when operating and maintaining equipment, specifically through user-centred/participatory-ergonomics processes (Haines, Wilson, Vink & Koningsveld, 2002).

Currently, most equipment-design processes in manufacturing for mining and similar industries rely heavily on failure mode and effects analysis (FMEA), which typically is used to understand the mechanical/electrical failure modes of discreet components or systems (ASCC, 2006). The SiDE tool focuses specifically on human interaction with equipment and is more easily incorporated in a structured design process. Use of both FMEA and SiDE can facilitate identification of relevant mechanical and human aspects (Horberry et al., 2010). This is especially important in the minerals industry, where designers may be unable to visit mine sites to see equipment in use (Horberry & Cooke, 2012; Hale et al., 2007).

4.2 SiDE methodology

The SiDE tool is a task-oriented risk-assessment process that focuses on operational or maintenance risks related to equipment design by means of a participatory-design process.

Following Hale et al. (2007), it is based on the assumption that acquiring knowledge about actual use and conditions of use is of vital importance to safe design and control. It usually involves seven steps (Figure 2), which are described below. Typically, Steps 1-4 are conducted in joint designer/end-user workshops.

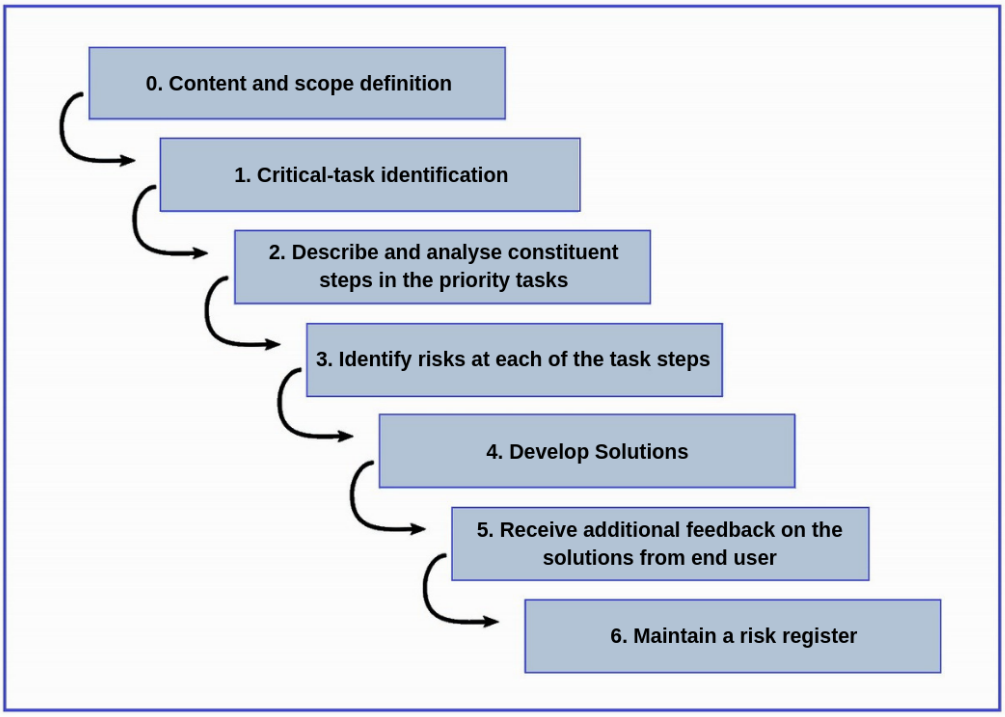

Figure 2: The SiDE process (Horberry, 2014, p. 300)

Perhaps most importantly, *Step 0* involves defining the context and scope of the analysis. The equipment-related problem or need (e.g. development of new equipment) is identified and the context for the SiDE process (including location and time available) is established. Several days may be required for this joint designer/end-user workshop (Cooke & Horberry, 2011).

Step 1 involves identification of critical tasks. From a full list of operations and maintenance tasks performed using the equipment (or likely to be performed in the case of a new design), critical tasks are prioritised. Consideration is given to safety criteria such as hazards identified (e.g. energy), incidents, previous risk assessments and near misses. Ideally, all tasks are analysed; however, time restrictions may limit the focus to tasks representing highest-priority risk.

Step 2 involves description and analysis of the constituent steps in the priority tasks identified in Step 1. In effect this is a hierarchical task analysis with characterisation of

each task step. Possible deviations, shortcuts or ‘hidden’ tasks are identified and noted. Videos of tasks being completed are often valuable task-analysis aids (Cooke & Horberry, 2011).

Step 3 involves identification of risks associated with each of the sub-tasks revealed in Step 2. Using risk-assessment matrices (e.g. 5-point severity and likelihood scales frequently used in the minerals industry), risks are identified and any controls currently employed (e.g. guard rails for working at height tasks) are noted. The task-based nature of the risk assessment helps to reduce the variance in risk perceptions of workshop attendees; however, as with other participatory/risk-assessment methods, different views remain a potential source of bias. Use of the hierarchy of control may help reduce this bias; for example, by focusing on hazard-eliminating controls rather than administrative controls.[3]

Step 4 involves development of user-centred solutions for the risks identified in Step 3. Again, time restrictions may limit the focus to highest-priority risks. Emphasis is on development of design solutions towards the top of the hierarchy of control that ideally aim to eliminate hazards.

Step 5 involves eliciting feedback on the Step 4 solutions from end users (and potential end users in the case of new designs). Incorporation of feedback may result in further development of solutions, which in turn are presented to end users for feedback.

Finally, ***Step 6*** involves maintenance of a risk register to keep track of the whole process. This includes documentation of who is responsible for which design aspects, and by when. This information may be especially useful for end users (and their managers) in developing controls for any remaining equipment-related risks when the equipment has been purchased and deployed.

4.3 SiDE outcomes

Although presentation of detailed results from the SiDE mining industry example is outside the scope of this chapter, successful trials have been reported by Cooke and Horberry (2011) and Horberry, Burgess-Limerick, Cooke and Steiner (2016) for mining equipment issues such as equipment access and egress (e.g. the design of safe and effective handposts to access a bulldozer’s cabin), and safe design for maintenance tasks (e.g. moving air filters to locations where maintenance personnel did not need to reach for them or hold awkward postures during filter changing). The improvements obtained in equipment design demonstrated that operator-centred design and control are possible in the traditionally conservative mining industry. The compatibility of the process with the 2011

[3] See *OHS BoK* 34.1 Prevention and mitigation.

ANSI standard, and the use of domain-specific language and working methods (Horberry & Cooke, 2012) have ensured the successful uptake of SiDE in the mining industry.

5 Other examples of user-centred safe design applications

5.1 Safe design procurement

In section 1, a possible role for generalist OHS professionals in the development of procurement processes that include safe and user-centred design considerations was identified. In addition to prevention of work-related deaths and injuries, procurement processes infused with safe design principles can benefit from “improved productivity, reduced costs, better prediction and management of production and operational costs over the lifecycle of the project [and] innovation in design and construction” (WorkSafe Victoria, 2017, p. 2).

Wong (2013) created a model for safe design procurement for SafeWork South Australia. Initial deliberations included considering the interactions of designers with other subject matter experts likely to be involved in work design projects. For example, in designing a building or structure, the architect/building designer consults complementary design experts in structural integrity, geotechnical, interior design, lifts and HVAC (heating, ventilation and air-conditioning). In the design process, the designers involved may therefore include those in process engineering, instrumentation and controls, software engineering and system programming, materials and exhaust ventilation, and occupational hygiene. The OHS professional may have a role to play in the design team in assessing the appropriateness of the design as it may impact on a workplace or be part of the work environment. The design function may be further complicated by the tendering or out-sourcing the project management of the design functions. (C. S. Wong, personal communication, 2014). Wong’s (2013) model considers three scenarios for the Australian environment and how safe design can be embedded in the process (Figure 3).

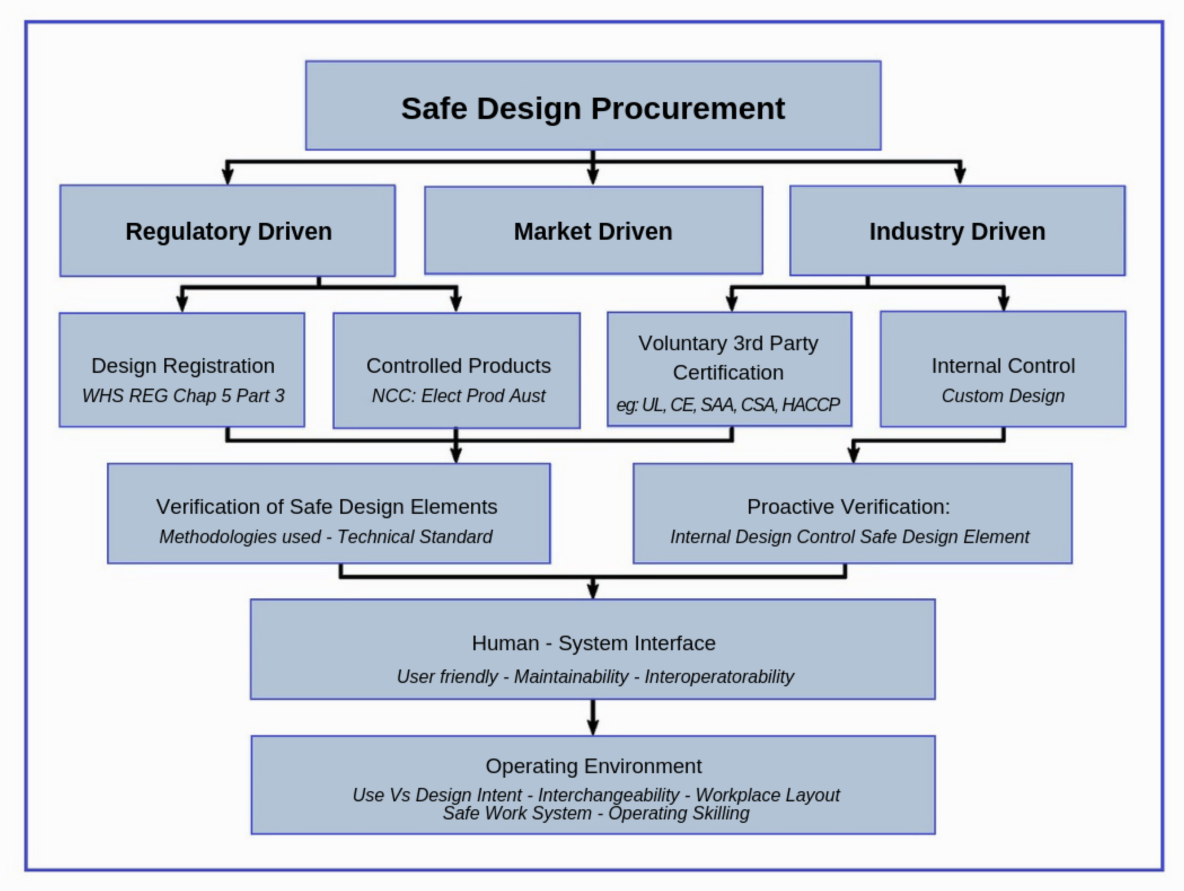

Figure 3: A model for safe design procurement (Wong, 2013)

These three scenarios – of regulator-, market- and industry-driven procurement of safe design – are explained below.

Regulatory driven: Certain designed products (building, plant, structure, material or substance and systems of work) of a high-risk nature may require design and plant registration. It is recommended that the OHS professional check relevant state/territory OHS legislation for specific requirements.

Market driven: The designed product has to meet certain industry and safety design standards, usually based on a voluntary third-party certification system as one of the criteria for entry into the relevant markets. The designer or OHS professional involved in the safe design procurement should perform some form of due diligence check on what is available in the open market.

Industry driven: The designed product is usually custom designed and/or part of a generic series, perhaps modified (by the original designer or other designers) from off-the-shelf products for a specific application. This latter approach is common in the Australian business environment where the market may be too small for individuality. The OHS professional has a vital role in influencing the safe design outcome,

notwithstanding that cost is always the other balancing/opposing factor in the decision making-process.

It should be noted that international designs and innovations can have a strong influence on procurement in Australia. Industries such as defence, off-shore oil and gas, aerospace and rail infrastructure are prime procurers of new sophisticated technology that may be associated initially with a development project and over time become part of 'business as usual' within Australian industry. An aerospace example is the acquisition of Airbus A380 by Qantas and the subsequent impact on local suppliers for new aerospace technology support, such as the manufacture of composite material components.

While there have not been any formal evaluations of Wong's (2013) approach, two mining expansion projects on safety in design were influenced by this best practice procurement model. As the result of the safe design reviews, the design approach of one of these projects was revisited to overcome identified hazards (C. S. Wong, personal communication, 2014).

5.2 Manual-task risk management

Typical programs of participatory ergonomics acknowledge that not all manual tasks are hazardous, and that managing manual-task risk requires, firstly, identifying hazardous manual tasks (Burgess-Limerick et al., 2007). Secondly, the degree and source of risk associated with the tasks must be assessed, with consideration given to the direct risk factors of exertion, postures, repetitive movements required to perform the task, the duration of exposure and other environmental characteristics. If risks cannot practicably be eliminated, then design controls must be implemented to reduce them as far as reasonably practicable. Administrative controls also may be required to manage the residual risks; for example, considering task variation to minimise injuries arising from repetitive actions. Successful management of manual-task risk requires participation at all stages of the process by the people who perform the tasks (Burgess-Limerick, 2018). Training in manual-task risk assessment and control is required to ensure this participation is successful.

Research activity relevant to manual-task risk assessment has highlighted the importance of:

- Securing management commitment to the entire process
- Employing participatory development processes to ensure ownership of the control measure
- Providing training in manual-task risk assessment using relatively simple semi-quantitative tools
- Integrating risk-assessment outcomes into site safety management systems

- Engaging a site champion to drive the process and facilitate communication among all involved
- Documenting process outcomes (successes and failures) in a format that facilitates sharing across the organisation.

Work in this area has included the development of a cloud-based online database that documents all hazardous manual tasks along with all risk assessments, control measures and residual risks (Horberry, Burgess-Limerick & Fuller, 2013). Such participatory approaches also have relevance for organisational issues such as job design.

6 Designer duties, legislation and standards

6.1 Australian legislation

Designers have obligations under the national *Model Work Health and Safety Act* (SWA, 2016) and *Model Work Health and Safety Regulations* (SWA, 2019). In this context, 'design' includes the design, redesign or modification of the design of structures, plant, substances, workplaces, processes and systems. Design outputs can include "any hard copy or electronic drawing, design detail, design instruction, scope of works document or specification relating to the structure" (SWA, 2018b, p. 5).

Under the national model Act, a 'designer' is a person conducting a business or undertaking (PCBU) whose profession, trade or business involves them in designing plant, substances and/or structures (SWA, 2016, s. 22). Designers include design professionals such as architects, building designers, engineers, industrial designers, chemists, building surveyors, interior designers, landscape architects, town planners and designers of plant systems such as software and electrical systems. A PCBU who alters or modifies a design without consulting the original or subsequent designer will assume the duties of a designer. The model Act requires a PCBU to provide a healthy and safe workplace; more specifically, the PCBU involved in the design of plant, substances or structures "must ensure, so far as is reasonably practicable, that the plant, substance or structure is designed to be without risks to the health and safety of persons" who may be exposed at the workplace or in the vicinity of the workplace (SWA, 2016, s. 22). Duties include the requirement to carry out "any calculations, analysis, testing or examination that may be necessary" as well as the provision of "adequate information to each person who is provided with the design" (SWA, 2016, s. 22).

These general duty requirements of designers are addressed more specifically in the national model Regulations (SWA, 2019). The plant regulations address specific design requirements related to guarding, operational controls, provisions for maintenance and

emergency stop controls as well as the requirement to provide information to enable the plant to be manufactured, installed, commissioned, used, dismantled and disposed of in accordance with the design (SWA, 2019, ss. 187-192). These duties are summarised in the *Code of practice: Safe design of structures* (SWA, 2018b) and *Guide for importing and supplying safe plant* (SWA, 2014).

Design processes can involve a range of people making financial, commercial, specialist or technical decisions in relation to the design (e.g. clients, architects, project managers and engineers). The model Act requires that, where more than one person has a duty for the same matter, each person retains responsibility for their duty and must discharge it to the extent to which the person has the capacity to influence or control the design. Thus, where there are a number of designers involved with plant, substances or structures during their lifecycle each designer has a duty and all must consult and cooperate with each other to control the risks. For example, a client may need to consult and cooperate with a designer to modify a design to address a health and safety risk identified in a manufacturing or construction phase. A person making changes to the design of plant, substances or structure takes on the responsibilities of a designer and must consider the potential impact of the changes on work health and safety (SWA, 2018b, p. 2).[4]

6.2 International standards

A number of international standards relate directly to user-centred control, safe design and participatory ergonomics. The most important of these is *ISO 9241-210:2010 Ergonomics of human-system interaction.* ISO 9241 is a multi-part international standard that provides guidance on a range of ergonomic issues from software design to workplace and environmental design. The standard includes specifications for appropriate design and guidance as to effective practices to ensure usability (ISO, 2010).

Generally, a designer can use any technical standards or a combination of standards and engineering principles relevant to their design requirements that will deliver a healthy and safe design. It should be noted that standards are not necessarily best practice, nor is following them necessarily sufficient for safe design.

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[4] For more information about the Australian legislation, see *OHS BoK* 8.1 OHS Law and Regulation in Australia and 8.2 Work Health and Safety Law in Australia.

7 Implications for OHS practice

A key component of the generalist OHS professional's role in fostering an organisational safety culture is ensuring that when purchases, upgrades or modifications of plant, equipment or structures are considered, key stakeholders participate in discussions about safe design. A participatory approach is necessary to obtain end-user input in design and to effectively identify, assess and control risks throughout the full design lifecycle. Several processes and tools can facilitate user-centred safe design, but the OHS professional must recognise when to seek the expertise of subject matter specialists such as ergonomists.

Although largely the province of engineering, operational safety requires a collaborative process that integrates technical standards, collective operational experience and engineering principles with underpinning health and safety management principles. It is at this juncture that the generalist OHS professional has a role in ensuring that the user-centred safe design process (among other things) is systematically managed and embedded in the broader organisational management systems. Generalist OHS professionals may be required to assist in safe design and to implement a systematic control process. A user-centred safe design process (such as SiDE) provides a structure for eliminating hazards or, if this is not reasonable or practicable, minimising the risks to health and safety. Two key messages are that regular worker consultation is vital, and that using a structured process to undertake this consultation is extremely beneficial.[5]

8 Summary

There has been growing recognition of the contribution of design to workplace health and safety. Safe design provisions are now explicit within OHS legislation and the need to perform a sufficiently robust process is a common requirement within, for example, contractual instruments for major construction projects and capital expenditure programs within industry. Furthermore, the Australian national and state governments have recognised the importance of safe design and are applying it to improve OHS outcomes in many industry sectors (e.g. the Office of Federal Safety Commissioner Building and Construction OHS Accreditation Scheme for contractors performing construction work funded by the Australian Government).

Human factors aspects (including human error) continue to contribute to (as opposed to cause) health and safety incidents. A user-centred approach during the design phase is

[5] See *OHS BoK* 34.3 Health and Safety in Design for a detailed review of the role of the OHS professional in influencing safe design.

critical to understanding key interfaces between workers, systems of work and plant (including control systems), and how these human factors deficiencies can be controlled in the context of a broader risk-management strategy. User-centred considerations can, and should, be well integrated into design and control processes. This chapter described how the use of a task-based risk-assessment method, such as SiDE in the mining industry, can result in the design of improved equipment and work systems to ensure effective user-centred control.

Fundamental to the safety of plant/equipment, workplaces or systems is the quality of the basic design rather than the addition of any special safety features. That is, design should seek to eliminate hazards rather than devise measures to control it. This philosophy is engrained within the principles of the hierarchy of control. The design phase is critical to building and sustaining maximum resistance to health and safety risk. Hazard elimination and application of the hierarchy of control is optimally achieved during the design/re-design phase. The implementation of safe design principles should demonstrate an overarching commitment to inherently safer design.

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